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Conceptualization of Industry 4.0 and its implications for Engineering Education

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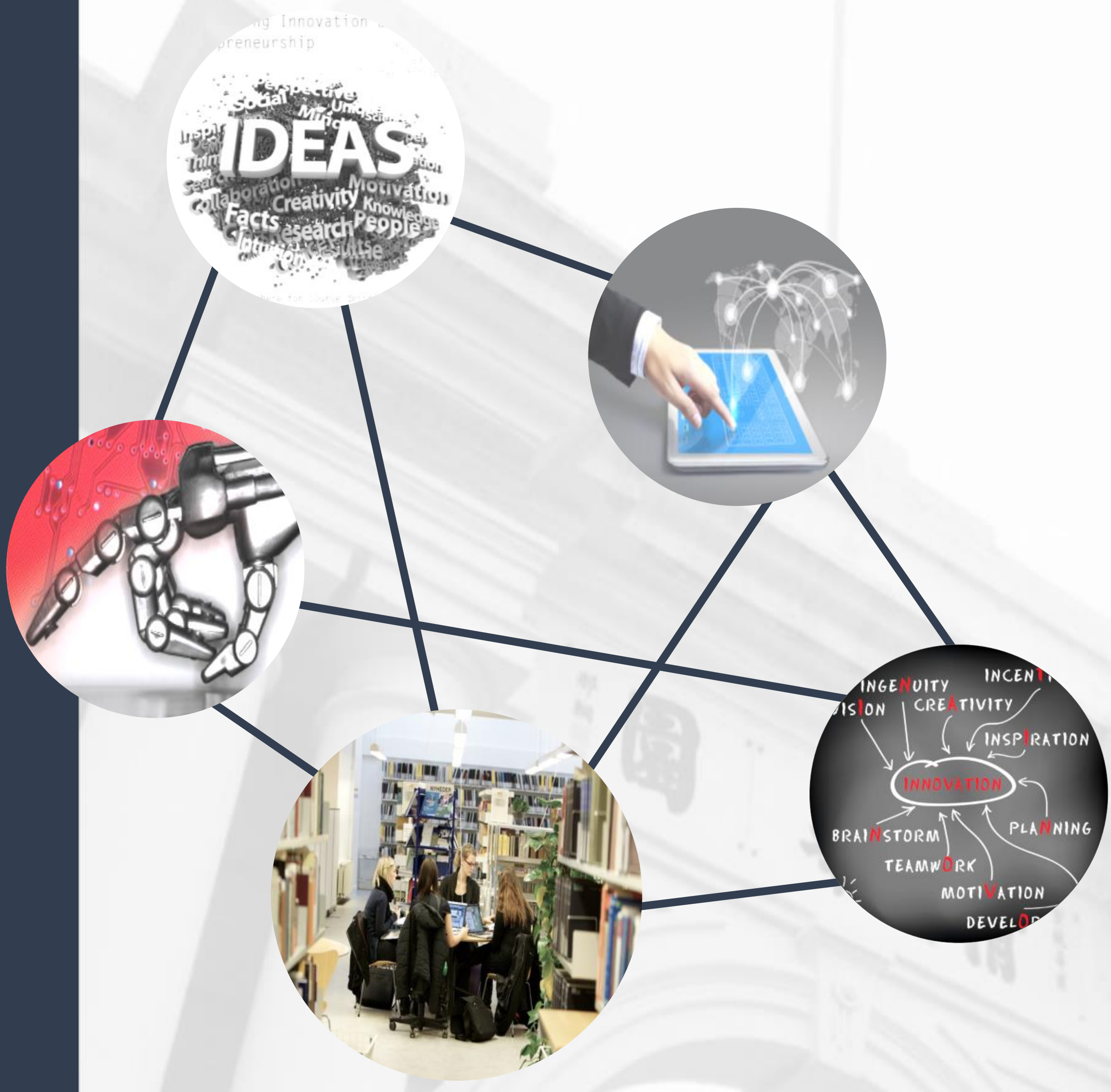

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Foreword

Innovation, PBL and competences in Engineering Education

"Education is not the learning of facts, but the training of the mind to think"

— Albert Einstein

Today's students will perform in a technology-based society and contribute to a global economy. Technologies, like automation, Internet of Things (IoT), artificial intelligence (AI), come with promise of transforming deeply the work places and creating new business models. In addition, the sustainability crises threatening the future of planet earth and human society. These trends posed new challenges to engineering education and on how engineers are being educated where competencies built during academic years might have to be continuously re-built and adapted. Addressing these challenges call for competences such as self-directed learning, teamwork, communication, critical thinking and interdisciplinary knowledge. Consequently, it is needed to re-think the education environments, the curricula constructions, learning outcomes and experiences capable of preparing the future generations to change and transform the world by acting and learning within and from it.

Having this in mind and Albert Einstein vision represented by the above quote, the 7th International Research Symposium on PBL (IRSPBL' 2018) theme is *Innovation, PBL and competences in Engineering Education* and the International Centre for Engineering Education (ICEE), under the auspices of UNESCO, Tsinghua University (China), hosts it. The overall goal is to reflect on how PBL can educate future generations with competences and skills needed to address the trends and challenges posed to higher education, especially to engineering education. The symposium is organized around several activities such as workshops, keynotes, panel sessions and paper presentations with the aim to promote discussion and active learning in all levels of education, particularly in engineering education. Similar to other editions, this seventh edition constitutes a meeting place researchers, practitioners, educational managers and industrial partners contributing to the PBL landscape.

The IRSPBL has collected 59 contributions from 23 different countries, all compiled in this book. The contributions cover a number of relevant PBL topics such as assessment, learning outcomes, students' engagement, management of change, curriculum and course design, PBL models, PBL application, ICT, professional development. This book not only represents some of the newest results from research on PBL but also best practices capable to inspire others practitioners to innovate their teaching and learning activities.

We hope that you will find the book useful and inspirational for your further work.

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Changed perspectives on engineering competence in the transition from engineering education to work

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Abstract

Employability has been on the political as well as the research agenda for a long time. International research on engineering education has identified issues in the transition from engineering education to work. Engineering education designers therefore have to increase the alignment between engineering education and professional practice and be in the frontline to prepare students for future trajectories of technological innovation. The purpose of this paper is to study the changes in perspectives on engineering competence in the transition from engineering education to work.

In Denmark, the research project PROCEED-2-Work was established as a longitudinal study with the purpose of identifying possible gaps in the transition from engineering education to work. The purpose of this article is to present comparative data on the respondents' perspectives on engineering when students are just about to graduate and after 10 months in work. The study is limited to a Danish context and it should also be taken into consideration that the cohort is to be considered as being in transition, as they only have 10 months of working experience.

The key results are that the students just about to graduate feel ready in terms of their academic and societal competences and less prepared related to career and work competences. After 10 months of working experience, the priority of these factors are inverted, with academic and societal competences less prioritised than career and work competences. The respondents point out that project work and internships have been especially significant factors in preparing for and the learning of employable competences.

However, students change perspective on engineering competences after just 10 months at work, which questions the alignment between current engineering curricula content and employability. The paper ends with a discussion of the potential of problem based learning to increase the employability of engineering students.

Keywords: Employability, transition, engineering competences, problem based learning

Type of contribution: Research paper.

1 Introduction

International professional organisations such as the Royal Academy (Lamb et al., 2010; Spinks, Silburn, & Birchall, 2006), and the McKinsey Global Institute (Mourshed, Farell, & Barton, 2012) have identified gaps in skills learned in education and skills needed in the work place. Politically, the European Bologna process seeks to close the gap between education and work, and accreditation bodies like ABET and EUR-ACE have formulated skills relevant to the work environment (ABET, 1995, 2006; Bourgeois, 2002; Engineering Council UK, 2004; Engineers Australia, 2006; EU Commission, 2008).

After conducting a literature review on employability, Kolmos & Holgaard (2018, forthcoming) have noted that the conceptualisation of employability is, and maybe also should be, a contextual term dependent on who is defining it, and that it is often interpreted as a set of specific skills such as communication, project management, etc.

At the conceptual level, there is a trend towards more comprehensive definitions of employability. As an example, in 2003, Knight and Yorke (2003) define employability as: "*a set of achievements, understandings and personal attributes that make individuals more likely to gain employment and be successful in their chosen profession*" (Knight & Yorke, 2003, p. 5). Later, Yorke (2004) broadens this definition to: "*a set of achievements – skills, understanding and personal attributes – that makes graduates more likely to gain employment and be successful in their chosen occupation, which benefits themselves, the workforce, the community and the economy*" (Yorke, 2004, p. 3). Kolmos & Holgaard (2018, forthcoming) combine academic (Mode 1), market-driven (Mode 2) and community-oriented (Mode 3) knowledge modes and argue for a broad definition that also presents the employee as a citizen and a member of society who is able to make a sustainable living.

Based on interviews with 50 global thought leaders in engineering education as well as case studies, Graham (2018) corroborates that the future direction for engineering education sector moves towards socially-relavant and outward-facing engineering curricula, and elaborates that *"Such curricula emphasize students choice, multidisciplinary learning and societal impact, coupled with a breadth of students experiences outside the classroom, outside traditional engineering disciplies and across the world"* (Graham, 2018: ii).

Although this trend towards more comprehensive definitions can be seen on the conceptual level as well as emergent at leading engineering education institutions, it can be argued that the elements in the curriculum that should lead to the identification and acquisition of professional knowledge could be characterised more as ritual than actual fulfilment of the needs of the work environment (Dahlgren, Hult, Dahlgren, af Segerstad, & Johansson, 2006).

Thus, there is a need for research on the requirements of the work environment compared to how ready engineering graduates perceive themselves to be in meeting work related challenges. This will form a basis for engineering education, which is co-constructed by different actors each with their own perspective on engineering. Engineering education designers must plan for the needs of tomorrow and be able to cope with the various demands of today.

2 Research design

In Denmark, the research project PROCEED-2-Work, was established as a longitudinal study with the purpose of identifying possible gaps in the transition from engineering education to work life. The 2010 cohort of enrolled engineering students have been surveyed four times, most recently, in 2015, on their expectations of work and, in 2016, on their experiences from work (Kolmos & Bylov, 2016; Kolmos & Koretke, 2017a, 2017b).

The purpose of this paper is to present comparative data on the respondents' readiness for work in 2015 and the respondents experience after 10 months in work, in order to investigate what changes occurred in their perspective of key-engineering competences in the transition from engineering education to work.

The methodology applied in the PROCEED-2-Work study is survey data. To analyse key-engineering competences, we have included items from the Academic Pathways Studies of People Learning Engineering Survey (APPLES), prepared by the Center for the Advancement of Engineering Education in the US (Atman et al., 2010). The results of the survey presented in this paper are based on frequency analysis.

The study is limited to a Danish context, and it should also be taken into consideration that the cohort is to be considered as being *in* transition, as they have only 10 months of working experience. These conditions will be taken into account in the following, where an increased focus on process competence during the transition to work and a high impact from project work on employability is argued for and discussed.

3 Work experience increases the focus on process competences

In 2015, when the cohort of engineering students was just about to finish their education, they were asked to prioritise different types of competences by stating what they considered important for being a successful engineer. In 2016, after about 10 month of work experience, the now graduated engineers were asked the very same question. The results are presented in Table 1.

Table 1: Different competences prioritised according to their perceived importance for becoming a successful engineer. The percentages signify the respondents who have answered that the items have decisive importance. 2015: N=979 and 2016: N=344-348

	2015		2016	
	%			%
Critical thinking	62.3%	1	1	53.8%
Teamwork	52.4%	4	**2**	**52.5%**
Communication	40.5%	5	**3**	**52.3%**
Finding new solutions	56.7%	3	4	50.7%
Self-confidence	28.4%	7	**5**	**46.2%**
Maths and science applied to solve real life problems	59.3%	2	**6**	**41.3%**
Science	34%	6	**7**	**19.3%**
Speak to a larger audience	18.9%	10	8	17.6%
Business talent	8.9%	13	9	14.3%
Leadership	13%	12	10	13.3%
Math	27%	8	**11**	**12.6%**
Social responsibility	14.9	11	12	7.5
Environmental impact	20.7	9	13	7.2

Overall, we can see a decline in the assigned importance of academic competences, as the ability to apply math and science to solve real life problems, as well as scientific and math skills, is considerable lower priority after entering working life. Even business talent and leadership, which were the lowest rated in 2015, are now perceived as more important than math skills. The same decline in relative importance is characteristic for competences related to sustainability.

On the other hand, there is a stable or increased focus on process competences. Whereas the ability to work in teams still received a high degree of attention, it seems that the importance of the ability to work independently and make use of communicative skills have surprised the engineers when coming into the workplace.

In the 2015 study, the engineers were further asked to assess the level of competence they have reached within different areas. The areas and the results are presented in Table 2, together with the ratings from the engineers in 2016 in order to compare the relative rating of the different competences.

Table 2: Perceived achievement of high level of competence (2015: N=953-958) related to the experienced importance of the competence in work (2016: N=344-348).

	2015 Competences obtained to high degree (%)	2015 Competences obtained to high degree (Rating 1-13)		2016 Importance assessed as decisive (Rating 1-13)
Critical thinking	60%	2		1
Teamwork	68.7%	1		2
Communication	31.9%	**8**	**>**	**3**
Finding new solutions	57.3%	4		4
Self-confidence	30.1%	**9**	**>**	**5**
Maths and science applied to solve real life problems	49.1%	5		6
Science	58.6%	**3**	**<**	**7**
Speak to a larger audience	33.1%	7		8
Business talent	7.7%	**13**	**>**	**9**
Leadership	14.8%	11		10
Math	46.1%	**6**	**<**	**11**
Social responsibility	12.5%	12		12
Environmental impact	21.5%	**10**	**<**	**13**

The differences in rating illustrated in Table 2 show that the relative knowledge gain in terms of communicative abilities, self-confidence and business talent is rated considerably lower than the relative level of importance assigned to the competences in a work place environment. This supports the increased emphasis on process competences compared to more technical skills.

Yet again, the conclusion is corroborated when the sense of preparedness of engineering students in 2015 is related to the assessment of importance of specific competences. There is a considerable discrepancy between the readiness engineering students feel when entering work life in terms of communicative abilities (going up) and applied science (going down).

4 Project work and internships as bridges to employability

Looking back on their education track, the engineers in work are asked to consider the extent to which different types of educational activities have provided them with a higher understanding of the work environment. The result is presented in figure 3.

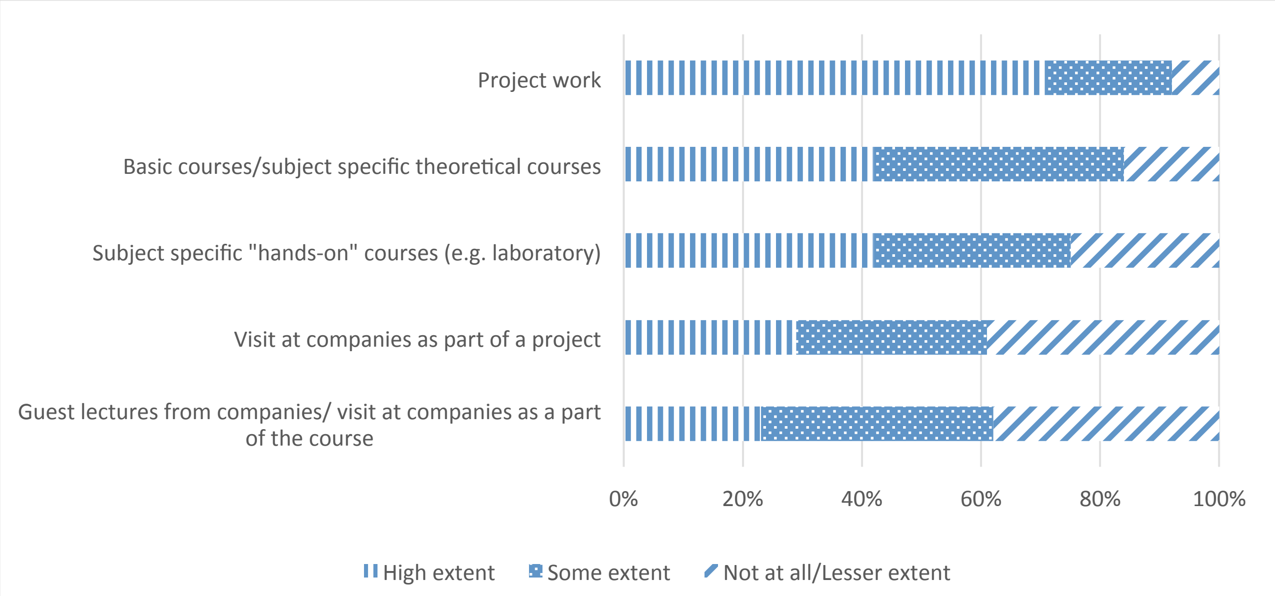

Figure 2: 2016: Educational activities and their contribution to making engineers understand their current work situation. N= 324-351.

About 2 out of 3 engineers suggest that project work has, to a high extent, contributed to their understanding of real world engineering. It is remarkable that project work has a higher impact than courses, as all engineering educational programmes have courses as a part of the curriculum, whereas not all engineering students have necessarily experienced extensive project work.

The attention paid to company interaction is minor compared to project work – but, yet again, it is also not common in general to have it as an extensive part of the engineering curriculum in Denmark. The 2015 study nevertheless showed that students who have been in company internships feel more prepared in relation to more generic competencies such as communication and design, business awareness, as well as the societal context and environmental impacts, and less prepared in relation to science, data analysis and the conducting of experiments (Kolmos & Holgaard, 2018 forthcoming). Thereby, students who have been on internships are more aligned with the higher focus on process competences, which have been detected in the transition to the work environment.

With this knowledge of the educational activities that had actually fostered abilities relevant for the current work environment, the engineers were asked to assess which kinds of educational activities they would like to have in order to make them even more capable of meeting the demands posed in an engineering workplace. The engineers were asked to choose five educational activities that could have increased their readiness among different types of educational activities. The top five when accumulating 346 answers from engineers were:

1. More practical assignments and tools for practice (> 50%)
2. More specific cases as a part of education (> 45%)
3. Better possibilities for internships during education (> 40%)
4. More problem-based education (> 35%)
5. More business-related education (> 30%)

Finally, it can be noted that project work was the educational activity that already had the highest impact in relation to the work environment – more than 1 out of 5 called for an even greater amount of project work in their education.

5 Discussion

The key findings presented above are that students before graduation feel prepared in academic and societal competences and less prepared in career and work competences. After 10 months in work, the priority of the factors have been inverted, so that academic and societal competences have declined in importance compared to the career and work competences. In the following, this identified gap will be discussed from the more traditional framework of employability and a more elaborated framework, including the societal perspective. Furthermore, project work and internships will be discussed as means for directing engineering education towards a higher degree of employability.

5.1 The identified gap between Mode 1 and Mode 2 knowledge

The identified gap between competences in the technical area compared to competences related to vocation and organisation relates to the traditional analytical distinction between academic Mode 1 knowledge and market-driven Mode 2 knowledge. Furthermore, studies indicate that higher education provokes a kind of instrumental turn in what students think matters in engineering work, and a general lack of attention to more contextual factors, including business awareness (Kolmos & Holgaard 2017, forthcoming). This corresponds with another Danish study, where employers expressed the wish that graduates had a greater understanding of business models, project management and communication (Kolmos & Holgaard, 2010).

This is, however, far from just a Danish phenomenon. Yorke (2004) reports that UK graduates across five different subject areas (biology, business, computing, design and history) found that academic staff gave subject knowledge the highest priority, while business awareness and practical workplace experience scored the lowest on a long list of factors. Furthermore, Nilsson (2010) produced a study, based on qualitative interviews with 20 recently graduated engineers, which found that they perceive engineering programmes to be too focused on academic disciplines and to miss out on elements of learning related to employability.

It can be argued that universities have a responsibility to provide engineering students with academic bildung (general education) when they are in higher education, whereas the work context will provide a more natural environment for developing skills in the areas of vocation and organisation. It can also be argued that the transition to work might be overwhelming in the first year, which can cause overemphasis on skills related to vocation and organisation. Nevertheless, taking into consideration the expressed importance of self-confidence in work practice, as well as the fact that 1 out of 4 of the Danish engineers studied actually had project management as a primary work function during the first year and that employers are in fact calling for more understanding of business models, project management and communication, it can also be argued that a change is needed in engineering education to embrace more interdisciplinary and generic competences.

5.2 The lack of focus on societal factors

In the broader conceptualisation of employability presented in this paper, engineering education moves beyond satisfying work place requirements. Jamison and colleagues (2014) have argued for a transformation of engineering education, which includes academic Mode 1 knowledge and market-driven Mode 2 knowledge (Gibbons et al, 1994), with a community orientation in an integrative Mode 3. As noted, Kolmos & Holgaard (2018, forthcoming) have furthermore proposed a comprehensive definition of employability that combines scientific and domain specific engineering skills with process competences (being transferable and generic in nature) and a concern for the business and societal context in which engineering work is embedded. However, the question remains who will be responsible for this move to a more integrative mode and which conceptual frameworks that will support this transformation of engineering education.

One of the conceptual frameworks that have been introduced to stress students responsibility as citizens and members of society is education for sustainability (ESD). The transformation of higher educational institutions to ESD is however relatively slow. In 2009, half way through the United Nations Decade for ESD, related actions had not yet influenced worldwide educational programmes in a significant way (Ferrer-Balas et al., 2010). This seems not to have changed significantly over a five-year period as Wals (2014) concluded that Higher Education Institutions were just at the beginning of making more systematic changes.This indicates a need for a “push” from outside, e.g. for employers to engage in a more comprehensive view of employability.

The response from Danish engineers during their first year of work does not, however, indicate sustainability to be high on the agenda. There can be multiple reasons for this, which can be brought to discussion and future research.

First of all, it will depend on the organisation of the company and the tradition of interdisciplinary work. Secondly, it will depend on the way the company addresses sustainability. If the company works, for example, according to a life cycle perspective and integrates sustainability in the design of their products, there will be a greater need for interdisciplinary work, bringing together environmental specialists, designers and engineers from other technical fields. A life cycle based environmental initiative affects all functions and departments of an enterprise (Remmen & Münster, 2003). If, on the other hand, the company takes a reactive approach to environmental concerns, documenting the environmental impacts of company processes, it might be that this function is rather isolated from the environmental department.

Another explanation could be that engineers would like to have a more product-centered or system view, as stressed by Shamieh (2011), of contextual factors. More than 1 out of 5 state that more inter-disciplinary knowledge would have provided them with a better understanding of their work environment, although the importance of sustainability seems to decline in the transition from engineering education to work. This implies that contextual competence based on what the work environment requires is more valued than knowledge that can be related to other engineering disciplines, e.g. environmental science. On the other hand, this perspective might contribute to, but will not assure, sustainably sound products for the future.

5.3 The call for project work and internships

Previous results from PROCEED-2-WORK show that students who have been in company internships feel more prepared in relation to more generic competencies such as communication and design, business awareness, as well as to address the societal context and environmental impacts, and less prepared in relation to science, data analysis and the conducting of experiments (Kolmos & Holgaard, 2018, forthcoming). This indicates a move to a more process-oriented and contextual employability perspective.

However, the most mentioned educational activity when engineers are asked to consider which activities had the greatest impact on their ability to understand their current work environment is project work. Even though project work has a high impact as it is, 1 out of 5 ask for more activities of this kind. Stiwne & Jungert (2010) support this by arguing that the best way to integrate employability into education is through company projects or co-curricular activities, which are often more open and problem-oriented compared to the traditional curriculum.

However, while this study shows a rather high focus on project work in Danish engineering education, and even though engineering institutions in Denmark are traditionally known for a problem-oriented focus – there is still potential for improvement based on a call for more practise related learning. There is a need for more case-based learning (show) and more hands-on activities (experience) to supplement the lecture based activities (listen) and analytical exercises (think). This calls for problem-based learning implies more emphasis on problems embedded within concrete and practical situations in a real-life engineering context.

6 Concluding remarks

Conclusions from this study indicate a gap between what engineering students perceive as important in education and in the work environment. Although a broader concept of employability, including academic bildung, citizenship and sustainability, can be argued for, there is still the risk of an overcrowded curricula. This study, however, questions the balance of the current curricula content from an employability perspective. The implications of a broad and strong employability focus will according to this study demand more emphasis on process competences, most notably communication, and agency to impact (and not just respond to) the future workplace to foster a more sustainable development of our societies.

The study furthermore points to the need to address the fact that newly graduated engineers, only in the very beginning of their career, are faced with the challenge of being project managers. This makes project management, not in an instrumental sense, but in a competence development perspective, an important area for further research. It is also striking that students are rather surprised by the importance of self-confidence in the work environment. This is a rather interesting result, which could be followed up with more research related to professional identity building.

Project work is praised as the educational activity which overall has the highest impact on preparedness for work. However, the interlinking of the work environment with concrete project situations requires more research – in other words, a project management course and projects designed by academics might not be enough to do the trick.

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Applying Design Based Research to New Work-Integrated PBL Model (The Iron Range Engineering Bell Program)

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Abstract

A new project-based model of engineering education is being developed to deliver an upper-division (final two years of four-year bachelor degree) experience. The experience is centred on students working directly in industry through engineering apprentice (cooperative education/internship) employment. Students will work in industry, completing projects, for the last two years of their education while being supported in their technical and professional development by professors, facilitators, and their peers through use of digital communication. This new model focuses on learning being more imbedded in professional practice, in contrast to the more traditional model of engineering, where the learning about the profession is done in the abstract of a classroom. The learning experience is designed to open doors for greater access to engineering education. Developed for community college graduates (entering students who have completed first two years of engineering bachelor requirement) in the United States, the program will serve a more ethnically and gender diverse student body. The innovative new model focuses on the development of transversal competences, a new set of teacher roles in PBL, industry-university collaboration, curricular design, continuous evaluation of practice, use of e-learning, and the students' learning processes. The program pilot starts July 2019. This paper will describe the new model, the design-based research method being used, report on the steps completed to date, introduce new sets of data on the new model, analyse the data, evaluate its impact, and result in the next iteration of design improvement. It will primarily focus on program development and the research approach for evaluation of the education model.

Keywords: Professional development, University-industry partnership, Practice-ready engineer, Work-integrated, Transversal skills

Type of contribution: research paper

1 Introduction

The past few decades have seen steady and frequent calls for changing and improving engineering education to meet the societal needs of today and the future (National Academy of Engineering, 2004; American Society for Engineering Education, 2015; Martin, Maytham, Case, & Fraser, 2005; Almi, Rahman, & Purusothaman, 2011; Hasse, Chen, Sheppard, Kolmos, and Mejlgaard, 2013). Emphasis is on the development of the whole engineer with an increased emphasis on the design and professional attributes and transversal skills, in addition to the traditional technical ability needed by engineers (Sheppard, Macatangay, Colby, & Sullivan, 2009). The new program focuses on developing more practice ready engineers through a student active learning experience centered on engineering practice (Lindsay & Morgan, 2016). Similar to how human-centered design is changing engineering practice to involve solutions based on the human perspective at all steps, the experience-centered engineering education of the new upper-division program will involve the student gaining engineering practice perspective at all steps.

The new program is the Iron Range Engineering "Bell Program" and is inspired by two models recently named as emerging engineering education world leaders in a report published by the Massachusetts Massachussets Institute of Technology (Graham, 2018). These models are the Iron Range Engineering (Johnson, 2016) and Charles Sturt University (Lindsay & Morgan, 2016) models in the U.S. and Australia respectively. Iron Range Engineering (IRE) is a project-based learning model that utilizes ill-structured, complex problems directly from industry (Ulseth, 2016) and Charles Sturt University (CSU) is a model that uses extensive cooperative education apprenticeships and on-line technical learning (Morgan & Lindsay, 2015). The Bell program draws its structure from CSU and its learning strategies from IRE. The Bell model is separate from the IRE model but being co-located under the same Iron Range Engineering administrative umbrella.

In October 2017, the Iron Range Engineering model was awarded the ABET Innovation award (ABET, 2018). The ABET Innovation Award recognizes vision and commitment that challenge the status quo in technical education. It honours individuals, organizations, or teams that are breaking new ground by developing and implementing innovation into their ABET-accredited programs. It is from this groundbreaking, award-winning model, that the new co-op model will be developed, being done so by the same development team.

The research of this educational innovation needs to be both formative, refining the model as it develops, and at the same time add to the theoretical body of knowledge on engineering education. Collins, Joseph & Bielaczyc (2004) proposed the design-based research approach of *progressive refinement* for developing a new curricular model. They described progressive refinement as when the "design is constantly revised based on experience, until all the bugs are worked out. Progressive refinement in the car industry was pioneered by the Japanese, who unlike American car manufacturers, would update their designs frequently, rather than waiting years for a model changeover to improve upon past designs". This type of design-based research (DBR) approach will provide the kind of rapid response that is needed and will include reflective practice approaches among the students involved, faculty, and the researchers (Brown, 1992). Design-based research (DBR) is recognized for its potential for developing an understanding of the organizational development and enhancing the professional practice (Andriessen, 2007; Romme, 2003; Van Aken, 2005) which are important parts of curricular development. This paper continues the study of the program development (Johnson & Ulseth, 2018) and focuses on the first evaluation of the new proposed model as part the DBR process. It specifically focuses on the evaluation by prospective students and a national group of community college faculty of the proposed model with the specific purpose of design improvement for the model in preparation for the inaugural group of juniors entering the program in 2019. Reflecting the DBR approach, the structure for this paper is adapted from the Collins, Joseph & Bielaczyc (2004) recommendation for reporting on design research work with a focus on the Goals and Elements of the Design, Implementation Setting, Current Research Phase, Outcomes Found, and Lessons Learned.

2 Goals and Elements of the Design

2.1 Goals of the new model

Creation of more effective engineering graduates - industries have long been dissatisfied with graduates of traditional engineering programs. This dissatisfaction stems from the inability of new graduates to navigate the professional world. At Iron Range Engineering, this deficit has been addressed by allocating substantial student time to both the application of technical knowledge in realistic settings and the practice of professional skills (Ulseth, 2016). The implementation of both the co-op experiences and the IRE strategies will provide the more fully developed and effective engineering graduate sought after by industry.

Diversification of the engineering profession – Especially in the United States, women, Hispanics, Black/African-Americans, and other minorities continue to be way underrepresented in the engineering profession as compared to their representation in society (NSB, 2018). Community college demographics, unlike traditional universities enrolling engineering students, are more aligned with societal representation in the United States (American Association of Community Colleges, 2018). The Bell model is being designed to enroll community college graduates in the upper-division (last half of bachelors) program. Thus, the goal is to have a more diverse student body and graduate pool entering the profession.

Adaptation of effective learning strategies created in the Iron Range Engineering model - In the 9 years of IRE operation, distinct models of learning for professional development, design, and self-directed were developed. These strategies include: highly developed model of reflection, professional responsibility curriculum, professional development plans, design and project management curriculum, technical development plans, seminar series, and an extensive communication curriculum. All of these curricular strategies are adaptable to the new model for effective engineering student development.

Very low net cost to the student - students will pay $11,000 USD per semester for five semesters (intensive training plus two years of co-op) for a total of $55,000. The student engineer will typically earn $20/hr for 24 months of co-op for a total of ~ $80,000 gross. Students who are able to live a college student existence during this timeframe will be able to graduate with near zero debt for the co-op portion of their education.

2.2 Elements of the design

The Bell program is the last 2.5 years of a 4.5 year bachelors of science and engineering degree. The first two years are completed at community colleges across the United States. Upon completing the entrance requirements into the program, the student will enroll for an on-site five-month intensive training experience (ITE). The ITE is followed by two one-year apprenticeships referred to as co-ops.

A cognitive apprenticeship (Collins, Seely Brown, and Holum, 1991) approach will be utilized to scaffold the individuals from their levels of competence at the entrance to the ITE to a prescribed level of competence upon completion of the ITE. Technical learning at the beginning of the ITE will be in a face-to-face on-the-ground mode with professors. As the ITE continues, the learning becomes more and more self-directed and more and more online until the end of the ITE where students are managing their own learning in an online course. Professors will facilitate technical learning throughout the 2.5 years. Learning coaches (facilitators) will guide students in their professional and design development throughout the ITE and the entire co-op experiences. The learning coaches will meet face-to-face via technology with the student engineers on a regular basis throughout the coop to provide guidance and support of the students' development.

Upon completion of the five-month intensive training experience period where they develop the high levels of self-directedness and professional responsibility necessary for success in a co-op placement, student engineers can either return to their home region or anywhere else in the country (or out) to complete a one-year co-op experience. After one year, they return to the home-base for one week of rigorous assessments, including the defence of student work, design capabilities, open-ended problem solving capabilities, professional acumen, and technical knowledge. Upon successful defense, they go back for a second year of co-op placement followed by another round of exams and presentations. Successful defense at this point results in the awarding of a bachelor's of science in engineering. Figure 1 portrays this model.

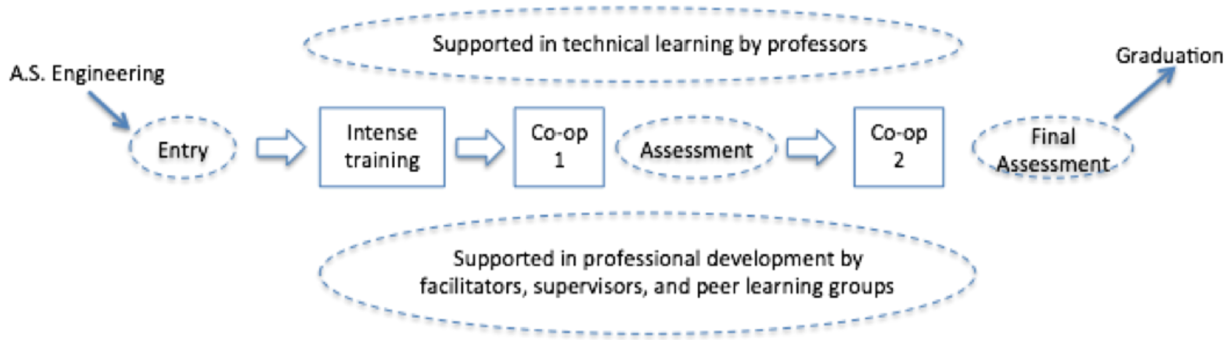

Figure 1. Graphic depiction of new model

This model utilizes unique strategies to integrate the development of the new engineer as a professional, technical, and creative person (Guerra, Ulseth, & Kolmos, (2017). The demand for engineering professionals is characterised by requirements of deep and solid interdisciplinary technical competences and communication and management skills. Changing engineering programmes (de Graaff & Kolmos, 2007) to meet these requirements can be addressed by different active learning approaches (Christie & de Graaff, 2017; Lima, Andersson, & Saalman, 2017). Several institutions of higher education have been addressing these requirements with project approaches to engineering education. Problem and Project-Based Learning approaches (Edström & Kolmos, 2014; Graaff & Kolmos, 2003; Helle, Tynjälä, & Olkinuora, 2006) have proven to be effective in making interdisciplinary connections between different subject matters, developing, in parallel, competences of project management, autonomy and communication (Lima, Dinis-Carvalho, Flores, & Hattum-Janssen, 2007).

Co-op education is a long established practice (Selingo, 2016) where students take a semester out of college to work as interns in engineering firms or industries. Students often find co-ops as the best part of their education, typically earn high wages while on co-op, very often more than $20 USD/hr, empowering students to graduate from college with less college debt. There are several engineering colleges in the United States that employ required co-op education (e.g. Kettering University, the University of Cincinnati, and Northeastern University).

In traditional co-ops, students receive only nominal credit (1-3) for the co-op experience and thus put off their graduation by a semester for each semester of co-op. In 2016, Charles Sturt University (CSU) in Bathurst, Australia began their co-op based engineering education model (Lindsay and Morgan, 2016). The Charles Sturt model does provide substantial learning during co-op as well as full credit towards graduation. The new model described above is an adaptation of the CSU model with influences from other co-op models. In summer 2016, the founders of the CSU model visited IRE to identify unique PBL attributes of the IRE model that could be adapted for CSU.

The technical, professional, and design learning that happens during the Bell Program co-ops is a departure from all other US co-op engineering models and is centered on PBL methodology. In order to align the Bell model with PBL, we have used the 7 elements of PBL (Du, de Graaff, and Kolmos, 2009). The objectives are PBL centric and interdisciplinary. The problems the coops will solve are open and ill-defined and will consist of a major part of the students' learning. Technical, on-line, courses will support the project and there will be external facilitation as well as formative evaluation. This learning is what enables the students to earn full credit towards graduation for successful co-op completion as compared to other US institutions where full credit towards graduation is not awarded. Further, it will be facilitated as projects with industry-working team members.

3 Settings where Implemented

The new model takes advantage of three educational experiences:

1. Community college education (anywhere in the country)
2. The Iron Range Engineering models of professional and self-directed development (ITE at IRE campus in northern Minnesota)
3. Co-operative engineering placement (anywhere in the country)

There are approximately 300 community colleges in the United States that offer associate degrees in engineering. The demographic of enrolled students at community colleges is considerably different than at universities. Community college students are more diverse ethnically, more gender diverse in the STEM fields, and are older, thus bringing more life experiences to their education. Among community college students, 51% are non-white, the average age is 28, and 36% are first generation college students (American Association of Community Colleges, 2018). Further, women earn 42% of the STEM degrees awarded at community colleges (National Science Foundation, 2017) .

The Iron Range Engineering (IRE) PBL program has developed unique and powerful models for creating professionally responsible, self-directed learners (Johnson 2016; Ulseth 2016). Over 10 published studies demonstrate the efficacy of these strategies and the advanced skill levels of IRE graduates (Guerra, Ulseth, & Kolmos, 2017). The strategies used at IRE serve as a cornerstone for the new program.

4 Current Research Phase

4.1 Methodology and method

When the design of the PBL program began in 2016 (Johnson & Ulseth, 2018), design-based research (DBR) was selected as the design and research methodology to guide the curricular development work. This work incorporates the four phases of DBR identified by Kolmos (2015): *design*; *implementation; data collection and analysis;* and *findings and conclusions*. The phases were adapted and combined with Andriessen's (2007) dual purpose of DBR model for this work as shown in Figure 2. The focus of the *program design* is *progressive refinement* through the problem statement; defining the design and learning objectives; planning (project management) of the curricular design, development of the curricular ideation and selection of a design for initial implementation; and ultimately a continuously reformed model with a curricular model improvement process. The focus of the *research design* is to establish the research questions; identify the learning theories applicable to the research work; design of the research work that influences the curricular implementation and improvement; and ultimately to disseminate what is learned and add to the body of knowledge on engineering education.

The research question for this phase of the program development is: "How do prospective stakeholders react to the prospect of the program and what input do they have to its development?" In the data collection section below, these reactions and inputs have been collected and analyzed. Improvements have been put in place and ideas are available to draw on for future iterations.

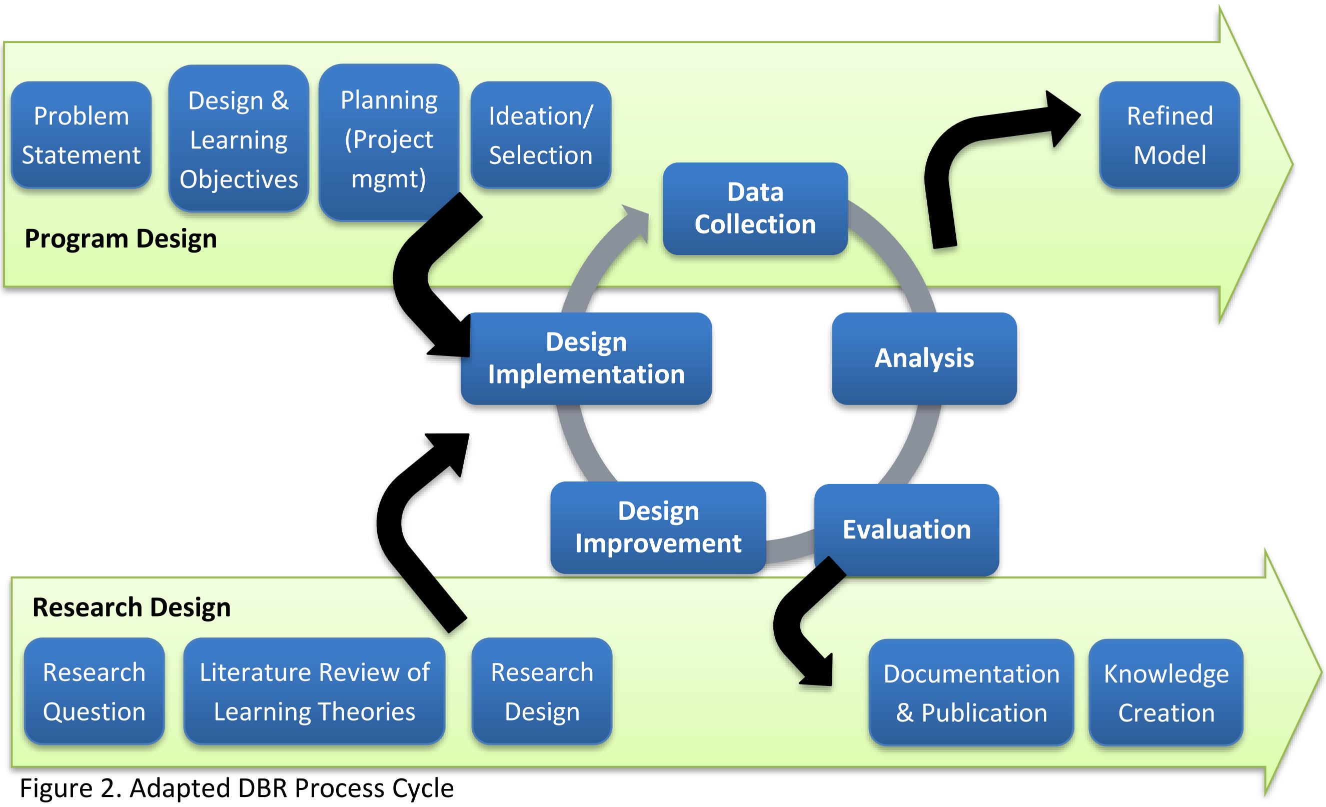

Figure 2. Adapted DBR Process Cycle

4.2 Data Collection

4.2.1 Faculty workshop January 2018

In January 2018, 30 faculty members from more than 20 community colleges (from which the initial students will likely come) were invited to workshop-based open discussion sessions about the intensive training and curriculum design. Their ideas, opinions and concerns were collected through poster presentations by small groups, paper feedback forms, and electronic feedback. The data was condensed and themes emerged.

First, prior to joining Bell Program, most students will experience a more traditional classroom setting. To ensure a smooth transition, the Bell program should provide an online orientation as a screening process to identify their motivation in remote learning. Some participants expressed support for a one-week orientation-type program for prospective students that would bring them to the Iron Range one year before matriculation to give them an in-person perspective on the Bell Program and provide a one-day project, active learning lab and online learning self-assessment. It could lessen some of the concerns about climate, distance, culture, and help the students to understand if the Bell Program is a good fit for their learning style and life plans after completing initial community college coursework. **Outcome: On-ground workshop and on-line orientation prior to enrolment would be of value to prospective students.**

Second, during the ITE, there must be a balance of technical learning and professionalism development. Each student will take a few competencies with a faculty to ensure a sense of community in a face-to-face setting. In terms of professionalism, students should complete a community-driven project to embrace inclusivity, diversity, ethics, learn from failures, as well as health and safety issues. Students will train to master job searching, resume writing, and interview skills, which help with co-op. Similarly, samples of student-written syllabi and best work could increase exposure, prepare students for the Bell Program, and more broadly help advance experiential learning as a pedagogical tool for engineering. **Outcome: Suggestions for ITE topics and strategies.**

Third, the method of assessment throughout the two-year co-op experience is vital to the progressive refinement of the program. In co-op periods, students should document their weekly learning progress via an e-portfolio submitted to on-site faculty who should also conduct short interview with their supervisor to confirm their performance. They are also encouraged to attend community webinars to share learning experiences. During their on-campus visit at the end of a semester, an assessment package will be assigned, including 8-hour open-ended problem solving exam, fundamental principles tests, and oral exams of their competencies. This multi-angle instantaneous assessment would help overcome the lack of communication in a traditional online education. **Outcome: Suggestions for learning/assessment strategies during co-op.**

Then, while reaching a consensus that the Bell Program is promising, owing to its unique PBL pedagogy, we have received more than 300 comments and questions regarding attracting prospective students and conveying the message to their local communities. One possible hurdle to market the program is the initial expensive tuition. While students eventually pay off loans by doing co-op, an estimation of financial stability should be explicit. Another common question is how to connect with local industry companies and search of available co-op opportunities. Some professional societies such as National Society of Black Engineers (NSBE), IEEE and Society of Women Engineers (SWE) have already established formal partnerships. These organizations could offer Bell Program students a first step in their professional career. **Outcomes: Need to have clear financial model for prospective students to understand. Need to have plan for connecting students to industry co-op partners.**

Finally, besides the interest from faculty, motivation of students ultimately dictates the success of Bell Program. Based on years of data on engineering students transferring to a university, community college faculty estimated that around 90 students would be interested in joining Bell Program as pioneers, provided they have a better understanding of the benefits of the program. **Outcome: 30 participating faculty members estimated 90 of their students per year would be interested in joining the new program.**

4.2.2 Student workshop May 2018

In response to the faculty workshop outcome advising an on-ground experience for prospective students, an on-site visit was developed and implemented. Students who wished to attend were identified through face-to-face or online interviews, with three questions being asked: (i) Benefits of joining the Bell Program; (ii) Anticipated accomplishments upon on-site visit; (iii) Types of engineer one would like to become. These questions were designed to help develop the program that better fits students' need.

More than two thirds of students' responses (N=30) for the first question listed hands-on skills and freedom of financial burden as the benefits. While the first benefit has been revealed with success through the sister program of Iron Range Engineering, the unique financial benefit to students could attract students, particularly in early phases as it pilots a new pedagogical model. To justify this attractiveness, we quantify the financial outcome for a hypothetical student. On the whole, the designated tuition for Bell Program is $55,000 USD (5 months of intensive training plus 4 semesters). Assuming an hourly rate of $20 and 160 hours of work per months, one could earn $40,000 for a single year of co-op. It not only compensates all the tuition cost, but also offers a net income of $25,000 upon graduation. **Outcome: potential students are attracted to the learning and financial aspects of the degree program**.

Regarding the incoming Bell Experience, most students would like to see the campus, facilities and community. Some also suggests a possible hands-on demo class. These requests can be addressed by existing IRE faculty. **Outcome: Suggested topics for Bell Experience.**

The response to the last question is rather diverse. Among 30 students, 12 are interested in Mechanical/Structural Engineering, 5 in Electrical Engineering, 7 in Chemical Engineering, 3 in Industrial/Aerospace Engineering and 3 are still unsure. Since the current IRE focuses mainly on ME and EE programs, the new Bell Program will consider to hire faculty and facilitators with wider scope of expertise. **Outcome: Diverse engineering interests of potential student body.**

The data from these three questions was available prior to the one-site visit held in mid-May 2018. Developers used the knowledge to create the workshop which gave students the opportunity to experience the unique attributes of the Iron Range Engineering model that will become part of the Bell program as well as to meet similarly minded students from across the U.S. Upon completion of the event, all participants (N=38) completed an on-line exit survey identifying the attributes of the model that they found most appealing as well potential areas of concern or barriers. The data was compiled and analyzed. Following are the top three themes from each area with direct student quotes supporting the themes.

Positive Themes:

1. Most of the students from the Bell Experience are beginning to understand the importance of the work experience before receiving their engineering degree.

   "I think this is a phenomenal and groundbreaking program in engineering schooling. So many schools just drill you on knowledge and it can be hard to see the true application of some concepts. Also, I think the cost is pretty reasonable for over 2 years of schooling, especially since the odds of getting a job increases drastically when you have experience from a coop."

2. This event gave every student an opportunity to experience what it would genuinely be like to be a student enrolled in the Bell program. It opened the student's eyes to some of the outcomes they would achieve by attending this program, and it allowed them to see if it was a good fit before making a decision to attend this program in the future.

   "…I've never met a more welcoming group of people who are genuinely interested in us as individuals AND as a group. The fact that the time was taken to break the ice and get all of us talking to each other is such an important factor that really made this experience so much more valuable, all while instilling strong ideas of project management, teamwork, and professional development. Thank you for this opportunity of a lifetime."

3. This event carried a lot of energy throughout, and many students were able to build confidence by working through them with other students from around the country. Many connections were made from the learning they were achieving at the Bell Experience to a working engineer.

   "I feel as though I am leaving this experience with a more optimistic outlook on the program and it's sound like it's more my style in the way that I'm not really a fan of sitting in a classroom and learning, I'd rather be out doing things and experiencing the field."

   Outcomes: Students are attracted to model of learning. Students are attracted to content proposed in Bell model. The idea of a scholarship is of high importance to incoming students.

Suggestions to pay attention to:

1. Many students look at their financial situation in a variety of different ways. There is something about a scholarship that students hold in high regard. Even if it was built into the overall cost of the tuition, scholarships should be offered for students who are looking to attend our program.

   "I have a scholarship in my community college and I am thinking about a university that I could apply for a new scholarship, but the Bell program has some advantages that interest me more, so I will evaluate my choice."

2. The cost of this program is interpreted in a variety of different ways. For some of the students, there is a common positive theme of the price because they are able to see the income while working as a large advantage. For others, the sticker shock of tuition sets a barrier that they can't see through. They use this, and this alone, to compare to their other university options.

   "The Bell Program seems to be an amazing option, but personally, my situation makes the cost of the program to be a great deal larger than my neighboring university."

3. This program is a stretch for some students who have their eyes set on other accredited universities in their area. Some students will need more comfort in knowing that their education and degree is just as valuable, if not more valuable, than other disciplinary degrees.

   "I feel like I am 90% sure I will apply to the program. The other 10% is holding be back because the program is fairly new, and I find it difficult to convince my family and friends that this is an accredited program. It's a leap of faith that I am still trying to warm up to."

Outcomes: The program needs to better describe and market the financial impacts of student expenses vs. revenues i.e. tuition vs. co-op salary. The newness and unique attributes are seen as barriers to some prospective students.

5 Outcomes Found

The outcomes for the two data collection events (faculty and student) were **bolded** in the previous sections and are listed in Figure 3 below. Analysis of these outcomes results in three emerging themes: 1) there is substantial interest in the model by prospective students. 2) The financial sustainability aspect of having students make money to offset tuition costs, while macroscopically attractive to students as a concept needs to be more clearly communicated microscopically for students to prevent it from being a barrier to enrolment. 3) Quality ideas for the ultimate design of the program in terms of processes and strategies were collected from participants in both workshops.

- 30 participating faculty members estimated 90 of their students per year would be interested in joining the new program. (student interest)
- Need to have clear financial model for prospective students to understand. (financial)
- Need to have plan for connecting students to industry co-op partners. (strategy/process)
- Suggestions for learning and assessment strategies during co-op. (strategy/process)
- On-ground workshop and on-line orientation prior to enrolment would be of value to prospective students. (strategy/process)
- Suggestions for ITE topics and strategies. (strategy/process)
- Potential students are attracted to the learning and financial aspects of the degree program. (student interest)
- Suggested topics for Bell Experience. (strategy/process)

- Diverse engineering interests of potential student body. (strategy/process)
- Students are attracted to model of learning and content proposed. (student interest)
- The idea of a scholarship is of high importance to incoming students. (financial)
- The program needs to better describe and market the financial impacts of student expenses vs. revenues i.e. tuition vs. co-op salary. (financial)
- The newness and unique attributes are seen as barriers to some prospective students. (strategy/process)

Figure 3. Outcomes summary.

6 Lessons Learned

The data collected and analyzed provides much potential for immediate and long-term progressive refinement of the Bell program model. The most immediate example is the outcome from the faculty workshop suggesting that an on-ground student experience could be useful to expose potential students to the model and give them a much better basis on which to decide to enrol. This suggestion, made in January 2018 was implemented immediately and delivered in May 2018. The prospective students then provided much more useful data through surveys explaining their needs and impressions.

Refinements identified as needing immediate action relate to the recruiting and marketing of the potential student body for the pilot cohort. Barriers exist and need to be addressed with regards to the explanation of the financial model for students as well as perceptions regarding the newness/uniqueness of the model.

Longer-term knowledge was gained regarding the learning strategies and program processes for implementation in the pilot cohort. In particular, topic suggestions for the ITE, communication with industry partners, diverse engineering interests of potential student body, and a wide variety of suggestions for assessments and learning strategies. All of this data will be taken into consideration in during autumn 2018 when the development team creates detailed implementation plans for the pilot cohort.

Perhaps the most telling lesson learned comes from the high levels of interest and enthusiasm from the faculty partners and the potential student body. This evidence clearly communicates that there is an appetite for a model of this type in engineering education in the U.S.

7 Conclusion

A new model of engineering education is being developed. A description of the model and its origin have been provided and grounded in the literature. The developers of the new model were also the developers of the established Iron Range Engineering model in 2009. Those experiences highlight the need for a structured process of progressive refinement during the start-up phase of this program. Design-based research has been adapted to serve as the structured process. A research question at this stage was posed and data collected. The results of the DBR implementation come from two data collection events, a workshop of faculty partners from community colleges across the U.S. and an experience for prospective students. Those events are described and the outcomes have been identified/analyzed. The outcomes have already resulted in a shift in the trajectory of the program development and will continue to do so into the future. The outcomes further justify the appetite for such a model by the potential students and faculty.

Future iterations of the DBR implementation will take place during the remainder of 2018 and the first half of 2019. Data collection events will include program analysis by an external advisory board and test implementations of the curricular strategies with current Iron Range Engineering students and the new enrolees in the Bell pilot.

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Research on the Ability Training Effect of Undergraduate's Innovation and Entrepreneurship Project

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Abstract

Innovation and entrepreneurship education is fundamentally an educational project. It is to train undergraduates to possess the pioneering consciousness, spirit and ability. The importance of innovation and entrepreneurship to society has been identified and discussed. Practice base is an important support for universities to carry out innovation and entrepreneurship education. In order to evaluate the effect of the undergraduate's innovation and entrepreneurship education, this paper combines the education and constructs a three-level index system for the self-evaluation of undergraduate's innovative ability, then forms a questionnaire. With the survey data, it explores the current situation of self-evaluation of undergraduate's innovative ability, analyzes the situation and shortcoming existing in the cultivation of undergraduate's innovative and entrepreneurial ability. Learning from PBL model, this paper puts forward reasonable advices and suggestions.

Keywords: Ability training, Undergraduate, Innovation and Entrepreneurship project, PBL model

Type of contribution: research paper.

1 Background

The innovation and entrepreneurship education was put forward by the United Nations Educational, scientific and Cultural Organization in 1989 for the international seminar on education in twenty-first Century. It is an educational model with the core of training the spirit and ability of innovation and entrepreneurship. It is an important measure to motivate the undergraduate's independent innovation and Entrepreneurship ability. Since the National Undergraduates' Innovation and Entrepreneurship Training Program has been carried out, the universities have responded positively. They broke the traditional education concept, cooperating with the government and enterprises, actively revising the training program, helping the students to accumulate their independent innovation and entrepreneurial ability in order to train the innovative and entrepreneurial type of social needs. Talent is the goal. According to the plan and local teaching resources, universities have adopted different models to cultivate undergraduate's innovative and entrepreneurial ability.

The first model is professional education model. It is to combine professional education with innovative and entrepreneurial education, set up the curriculum of innovative and entrepreneurial education as a required professional course for students, to supervise students' learning through credit setting, and to improve their importance to innovation and entrepreneurship education so as to achieve the goal of the education. **The second model** is practical education model. Innovation and entrepreneurship must be completed in practice. It is a practical course. Many universities' talent training plan sets innovation and entrepreneurship education in the practical education module, and combines practice education with innovation and entrepreneurship education. This just draws lessons from PBL model. **The third model** is employment education model. Employment education is an indispensable part of every university's professional training plan. Employment guidance is particularly important in the current situation of fierce competition and difficult employment.

The purpose of this paper is to evaluate the effect of the innovation and entrepreneurship projects of undergraduates by the sample data and to find the problems and shortcomings.

2 Review

Innovation can be defined simply as a "new idea, device or method"(Merriam-webster.com). However, innovation is often also viewed as the application of better solutions that meet new requirements, unarticulated needs, or existing market needs (Maranville, 1992). It also can be defined as something original and more effective and, as a consequence, new, that "breaks into" the market or society (Frankelius, 2009). The definition of Innovation ability is the ability to continuously provide new ideas, new theories new methods, and new inventions with economic value, social value, and ecological value in the fields of technology and various practical activities (360 Encyclopedia).

A group of scholars and research institutions made great efforts to study innovation and entrepreneurship education. Harkema & Schout (2008) introduced a learner-centred approach in innovation and entrepreneurship education, in which student is the driver of his learning process. Du et al. (2008) suggested the problem based learning (PBL) model should be actively explored and applied in university education. Huang & Ding (2010) established a mode of innovation and entrepreneurship education suitable for undergraduates in China. Yang & Alex (2014) believed that several contradictions existed in entrepreneurship education in China. For example, the discipline position of colleges' or universities' innovation and entrepreneurship education is illegibility and wildly, the course content system is not perfect, many lack professional teachers and other issues. Some scholars research the methods of innovation entrepreneurship education. Aljohani (2015) analyzed the importance of innovation and entrepreneurship in modern education and societies. The definition and content standards of innovation and entrepreneurship education were presented. Some scholars argued that advanced experience in running colleges and universities is an important way to promote the development of higher education. Chinese Association of Higher Education convoked the symposium of the innovation and entrepreneurship to gain a better view of innovation and entrepreneurship education in 2007. Wang (2015) proposed the systematic framework of the "university-wide" innovation and entrepreneurship education which was divided into four types and include: general-knowledge type, embedded type, professional type, and vocational type. Li & Ding (2016) researched an exploratory practice linking innovative entrepreneurship education teaching goal and methods. Cao & Shi (2016) emphasized on the update of innovation and entrepreneurship education ideas, to construct scientific and reasonable course system, to enhance infiltration and integration of professional education and to establish effective evaluation system of teaching quality.

Through consulting the literatures, this paper analyzes and defines the connotation of undergraduate's innovation and entrepreneurship ability, clarifies the evaluation dimension it, summarizes and collates similar indicators, determines evaluation indicators, and designs a measurement framework for undergraduate's innovation and entrepreneurship ability. Basing the definition of innovation and innovation ability, we think that to evaluate the innovation ability of undergraduate is a complex system. It should evaluate their progress of innovation. So this paper defines the innovation ability by three aspects:

project design, project implement and project cooperation. Then form a three-level indicator system. This is the basis of the evaluation research.

Table 1: The structure of innovation ability

Field	Ability
Project design	A. Ability to observe and identify problems
	B. Ability to collect and locate data information
	C. Ability to think and analyze problems
	D. Ability of construction and verification of research hypothesis
	E. Ability of design or develop research programme
	F. Ability of think systematically and critically
	G. Ability of assess programmes and make decisions
Project implement	A. Ability of document retrieval, reading, expression and writing
	B. Ability of implement and practice as planned
	C. Ability of innovate and explore
Project cooperation	A. Ability of communicate and verbal express
	B. Ability of collaboration with team members
	C. Ability of organization and management
	D. Ability of deal with risk and uncertainty
	E. Ability of time management
	F. Ability of resource management

3 Survey

3.1 Questionaire Design

With the three-level indicator system, we design a questionnaire and make an investigate research to find the real feelings of undergraduates about their innovation and entrepreneurship education.

The questionnaire is divided into two parts: Welcome degree and benefit degree. The welcome degree part is mainly about single choice questions, which mainly tests the respondent's views and attitudes on the undergraduate's innovation and entrepreneurship training program. The benefit degree part is mainly about scale problems, using the Likert scale, which is divided into 5 levels from low to high. The options from 1 to 5 mean different conforming degrees: Strongly conforming=5, conforming=4, Sometimes=3, disconforming=2, strongly disconforming=1. This part mainly measures the ability of different fields of respondents.

3.2 Questionnaire Survey

Using the online and offline survey methods, the undergraduates across the country were investigated through the questionnaire platform-Wen Juan Xing. The survey is mainly divided into two stages: pre-survey and formal survey. In the pre-survey stage, we collected 30 questionnaires from Shanxi University of Finance and Economics to test the rationality of the questionnaire. After revising, we used the new questionnaire to a formal survey. 85% effective information was considered to be a valid questionnaire. By completing the paper questionnaire and the electronic questionnaire, we received 242 questionnaires. Eliminated the questionnaires missing information more than 15%, or the questionnaire that was too arbitrary when the respondents filled in, and the choice information was obviously contradictory or convergent. Eventually, we received 198 effective questionnaires, with an effective rate of 81.82%.

3.3 Reliability and Validity Test

Validity usually refers to the validity and correctness of the questionnaire, that is, the degree to which the questionnaire can measure the characteristics it requires to measure. The validity of the questionnaire reflects the degree of systematic error control of the questionnaire. The structural validity test is performed in SPSS. KMO value is 0.957 >0.9, P<0.01, it means there are obvious structural and correlation relations between the original variables, and it has a very good structural validity.

Reliability refers to the degree of consistency of the results obtained when repeated measurements are made on the same thing, reflecting the stability and true degree of the characteristics to be measured. Generally speaking, internal consistency is used to indicate the level of reliability of the test. The reliability analysis was performed through SPSS. The results are shown in the table below. It can be seen from the table that the Cronbach's Alpha coefficient of the total questionnaire is 0.955, which indicates that the questionnaire has high reliability and reliability.

4 Result and Analysis

4.1 Sample

Table 2 shows the structure of sample, including gender, university, grade and whether participating an innovation project.

Table2: Structure of sample

Category	Indicator	N	Percentage (%)
Gender	male	72	36.4
	female	126	64.6
	total	198	100.0
University	985 project	38	19.2
	211 project	45	22.7
	neither	115	58.1
	total	198	100.0
Grade	freshman	11	5.6
	sophomore	50	25.3
	junior	97	49.0
	senior	40	20.1
	total	198	100.0
Major	economic	69	34.8
	management	27	13.6
	mathematic	9	4.5
	engineering	14	7.1
	Total	198	100.0

Whether participating an innovation and entrepreneurship projects	yes	96	48.5
	no	102	51.5
	total	198	100.0

4.2 Student's Attitude of Projects

4.2.1 Participated in Projects

In our sample, there are 96 undergraduates have participated the innovation and entrepreneurship projects. Table 3 shows their information deeply.

Table 3: 96 Samples Structure

Category	Indicator	N	Percentage（%）
Role	leader	31	32.3
	member	65	67.7
	total	96	100.0
Type	academic	41	42.7
	entrepreneurship	41	42.7
	investigation	14	14.6
	total	96	100.0
level	school-level	60	62.5
	province-level	24	25.0
	national level	12	12.5
	total	96	100.0
progress	ongoing	48	50.0
	closure	41	42.7
	give up	7	7.3
	total	96	100.0

From table 3, we can see that most of students have the experience of school-level projects. Comparing the participation rate with each class, the participation rates of most classes are less than 30% (see figure 1). It is not high.

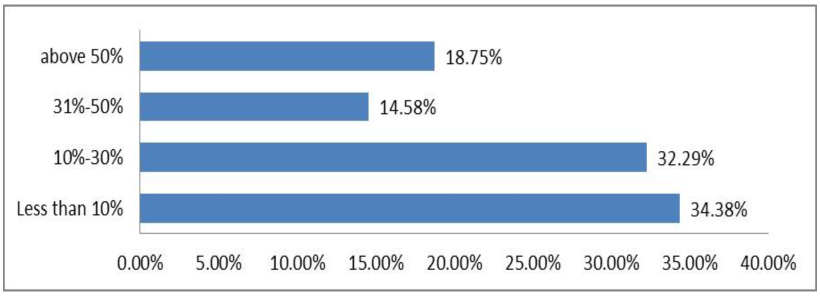

Figure1: Distribution of participation rate of classes

According to the survey data, 68.75 % of students feel that it need to expand the coverage of the project, 23.96% of students think that it should maintain the status quo. It can be seen that the majority of students tend to expand the coverage of the project among students.

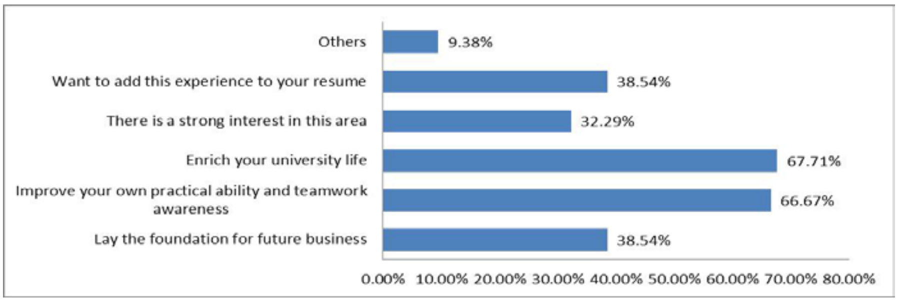

Figure 2： The effect of innovation projects distribution

According to the figure 2, 66.67% of students' participation motivation is to improving their practical skills and teamwork awareness and enriching their university life. 38.54% of students want to lay the foundation for entrepreneurship and to add such experience to the curriculum vitae is the same. In addition, 32.29% of students are for their interest. It shows that the reason of most students to participate in innovation and entrepreneurship training programs is to improve their relevant abilities and experiences.

Survey data shows that more than half of the students are willing to try to become project leaders. Among the students having experience of projects, 82.29% of students enjoy the experience in innovative and entrepreneurship projects. Most students like the scientific experience of innovative entrepreneurship training programs. The data shows that nearly 50% students think that the experience has much improvement to their innovation ability. 46.88% of students think that the improvement is general. 3.13% students think there is a little improvement to their innovation ability. In addition, only 17.71% of students do not like the experience.

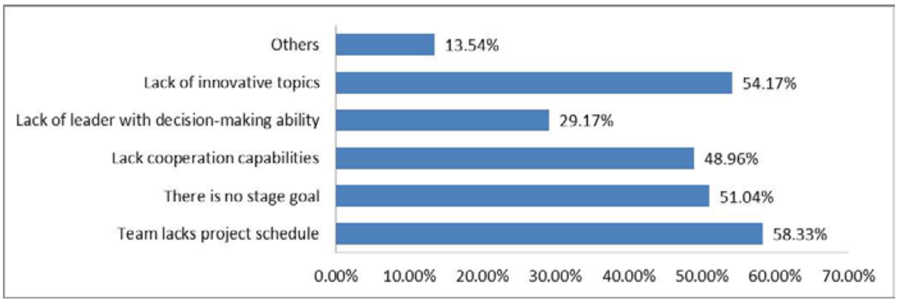

Figure 3： The difficult of project experience distribution

Figure 3 shows that during the participation, many difficulties appeared, such as lack arrangement of progress, no stage goals, poor communication among members, less innovation topic and so on. Nearly 50% of students choose these difficulties. 29.71% of students feel that lack a decision –making team leader. All these may be the main reason for students to enjoy or not enjoy the experience.

Think about future employment, study abroad and postgraduate guarantee, 63.54% of students think there is some assistance to future development. 18.75% believe that participation in the project would be of great help to future development, and 17.71% believe that participation in the project have no impact on future development. Most students accept the training programs.

4.2.2 Not Participated in Projects

In the sample, 102 students didn't participate in the innovation and entrepreneur projects. The main reasons are: It is difficult to find team members or form a team (64.14%); don't know how to choose a topic (57.07%); Lack of tutors (40%); Lack of expertise (40%); don't know when to apply (25.76%).

From these reasons, we can conclude that students lack initiative and less communication with teachers may be the most barriers for students.

Table 4： Sample distribution of students don't participate project

Category		No participation number	Total number	Percentage(%)
gender	male	31	72	43.06
	female	69	126	54.76
university	985 project	16	38	42.11
	211 project	18	45	40.00
	neither	66	115	57.39
grade	freshman	7	11	63.64
	sophomore	25	50	50.00
	junior	42	97	43.30
	senior	26	40	65.00

From table 4, we can see that boys are more willing to take the initiative in scientific research than girls. The students of the 985 project and 211 project universities are more proactive to participant projects. Junior students have high percentage to participant projects. So gender, environment and grade affect the willing of students to carry out innovation activities.

Sample data also shows that 65.66% of students worry about the study, time and energy. More than 50% of students worry about the tedious of defense and long cycle of projects. Nearly 36% of students worry about the found inspection. This shows that there is no project guidance in the early period, so students have too much concern about how to declare the projects.

4.3 Students' Self-evaluation of Innovation Ability

Project Design

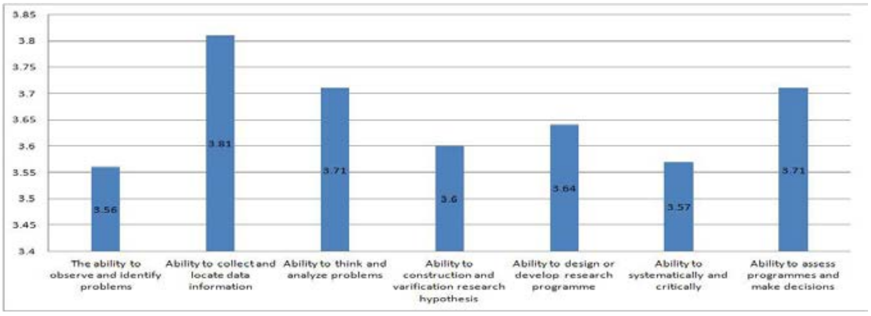

Figure 5： The average score distribution of project design

According to the score, we can sort the ability with the score from high to low in figure 5. The highest score is the ability to collect and locate data information； The lowest score is the ability to observe and identify problems. The whole average score of project design is 3.66.

Project Implement

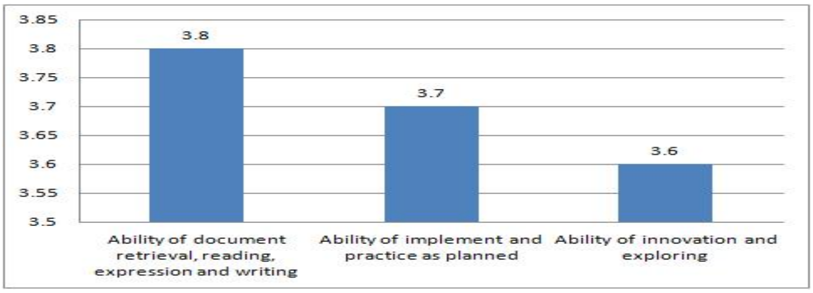

Figure 5: The average score distribution of project implement

According to the score, the highest score is the ability of document retrieval, reading, expression and writing; the lowest score is the ability of innovation and exploring. The whole average score of project implement is 3.70.

Project Cooperation

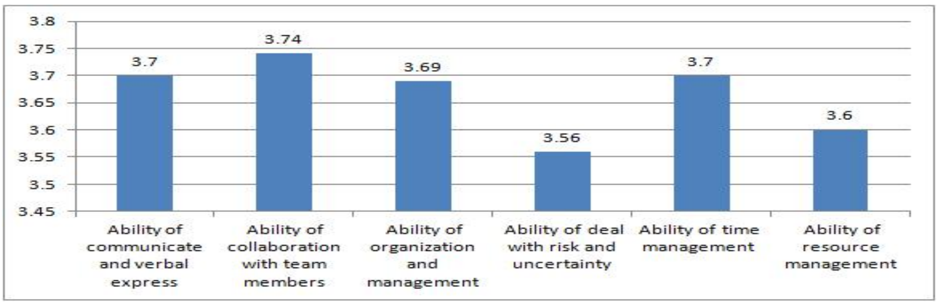

Figure 6: The average score distribution of project cooperation

According to the score, the highest score is the ability of collaboration with team members; the lowest score is the ability of deal with risk and uncertainty. The whole average score of project cooperation is 3.66.

Comparing the above three fields, we find that the score of project implement is bigger than the project cooperation field which equals to the project design field.

For the 96 students having the experience of projects, we can have some conclusion of different universities. The data shows that undergraduates' self-evaluation scores in 985 project universities are higher than others (see table 5).

Table 5: the average score of different universities

University	Project design	Project implement	Project cooperation	Total average
985 project	3.98	4.08	4.10	4.05
211 project	3.66	3.73	3.63	3.67
neither	3.55	3.57	3.49	3.54

5 Conclusion and Suggestion

5.1 conclusion

(1) The introduction and pro-training of the project can't satisfy the need of students and this will become the obstacle of students' participation. Most students would like to be leader of the team; they want to exercise themselves and realize their thoughts by projects.

(2) In the process of the project, students believe that innovation and entrepreneurship project can effectively improve their practical ability and teamwork awareness, enrich their life, and help to employment, go abroad, delivery to graduate student or university entrance examination and research is more obvious. But insufficient supports of university often lead students encounter the difficulties of lack of project schedule, milestones, communication, cooperation and innovative topics. So many students don't want to participate in the projects for they worry about many difficulties they can't resolve by themselves.

(3) Most students hope that there will be no transparent and unified process and evaluation criteria, reduce the personal preferences and preferences of the evaluation teachers, and pay more attention to the actual content rather than the form when the project is reviewed. The process of the project should be more clearly defined. Increase in financial support, etc.

5.2 Suggestion

The survey result shows that the innovation and entrepreneurship training activities can have a certain impact on the innovation and entrepreneurship ability of undergraduates, and have played a positive role in promoting the cultivation and improvement of undergraduate's innovation and entrepreneurship ability. But at the same time, students have many difficulties and problems in carrying out training activities. In order to do a good job in the training activities of undergraduate's innovation and entrepreneurship, the following suggestions are put forward.

(1) Set up a foundation course for innovation and entrepreneurship

Universities should do a top-level design, start from the source, include innovation and entrepreneurship courses in undergraduate teaching programs, and establish basic courses related to innovation and entrepreneurship in the next semester. Students should systematically studied the knowledge of innovation and entrepreneurship, study methods, research ideas, research content and technology routes, etc.

(2) Learn from PBL learning model

With the PBL model, we can set up PBL courses system for students to have chance to experience the process of innovation and entrepreneurship. Let them to expand the ability of innovative thinking, understand the national innovation mechanism, understand the innovation from a theoretical level, understand innovation, and have theoretical knowledge in order to better carry out innovative entrepreneurial activities. If the universities have difficulty in setting up a compulsory course, they can explore it from elective courses or explore that only by participating in innovative elective courses to apply innovation and entrepreneurship training programs, or set up innovation courses for those who have obtained innovation and entrepreneurship objects.

(3) Build a platform for innovation and entrepreneurship

In order to help students more chances to practice, universities should establish cooperation with some social forces, such as enterprises and institutions, to build practical training bases for undergraduates and build high-quality practice platforms. In terms of specific implementation, the universities can hire or invite successful entrepreneurs, to come to provide students with entrepreneurial guidance; universities and enterprises can strengthen scientific research cooperation to provide scientific research opportunities for undergraduates for more research funding. They can set up a undergraduate’s innovation and venture capital fund to encourage them to participate in various entrepreneurial plan competitions and innovation contests inside and outside the university.

Acknowledgement

Teaching reform project of Shanxi University of Finance and Economics: Research on the Evaluation System of the Ability Cultivation Effect of Undergraduates’ Innovation and Entrepreneurship Projects [2017204]

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Engineering 2030: Conceptualization of Industry 4.0 and its implications for Engineering Education

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Abstract

Industry 4.0 has the potential to significantly change the knowledge and skill-set requirements for professional engineers. There is a need to disclose and analyse the implications of Industry 4.0 for engineering education and how institutions will respond to it. Industry 4.0 will deeply transform the world and have a huge influence on future engineers' employability because they will have to perform and deal with an increasingly globalized, automatized, virtualized/digitalized, networked and flexible world. Industry 4.0 will create new business models, products and services. Indicators show that several engineering tasks might become transformed, less visible, and/or downright diminished as consequence of Industry 4.0. One example is the focus shift from traditional engineering methods to data-driven functions and cyber-physical systems. Whilst there are some prospects regarding the type of technologies, the role of training and continuing professional education upon implementing Industry 4.0, the qualification set from specific engineering disciplines and type of engineering education curriculum are not yet fully understood. Consequently, there is a need for institutions to be proactive and anticipate and adapt to Industry 4.0-derived needs for knowledge, skills and competences. Through a literature review, this paper addresses two questions. What kind of competences are needed for future engineers in context of Industry 4.0? What are the implications for engineering education?

Keywords: Engineering Education, Industry 4.0, Competences

Type of contribution: Review / conceptual paper

1 Introduction

Engineering, technology and innovation have been changing society for over 300 years. The term "Industry 4.0" refers to the early stages of industrialization and the industrial revolutions that have taken place (Drath and Horth, 2014). The concept, Industry 4.0, was first used at the Hannover Fair in 2011, where it was introduced in connection with a project initiated by the German government (Kagermann *et al.,* 2013). The Industry 4.0 technologies will transform the entire structure of world economy, society and human identities (Schwab, 2017). However, it is remarkable that Industry 4.0 has been proclaimed as the fourth industrial revolution before we have seen the full extent of implementation. The previous waves have only been identified as a quantum leap in industrialization in the historical perspective.

At the end of the 18th century, the industrialization process was initiated by a propagation of steam mechanization, which gradually replaced human-driven production, just like the steamship and railways opened new ways of organizing logistics over large geographical distances. During the second wave of industrialization, coal-based mechanization was replaced by electrification, which resulted in a push towards an intensified industrialization. The third wave of industrialization, also known as the Digital Revolution, started around the 1970s, where new advanced electronics and information technology characterized the development and automation of production processes. There is a prevailing consensus that we are now entering a new industrialization period, referred to as Industry 4.0 (figure 1). This fourth wave is a continuation of the previous wave; however, Industry 4.0 has been proclaimed as the fourth industrial revolution before we have seen the total extent of its implementation.

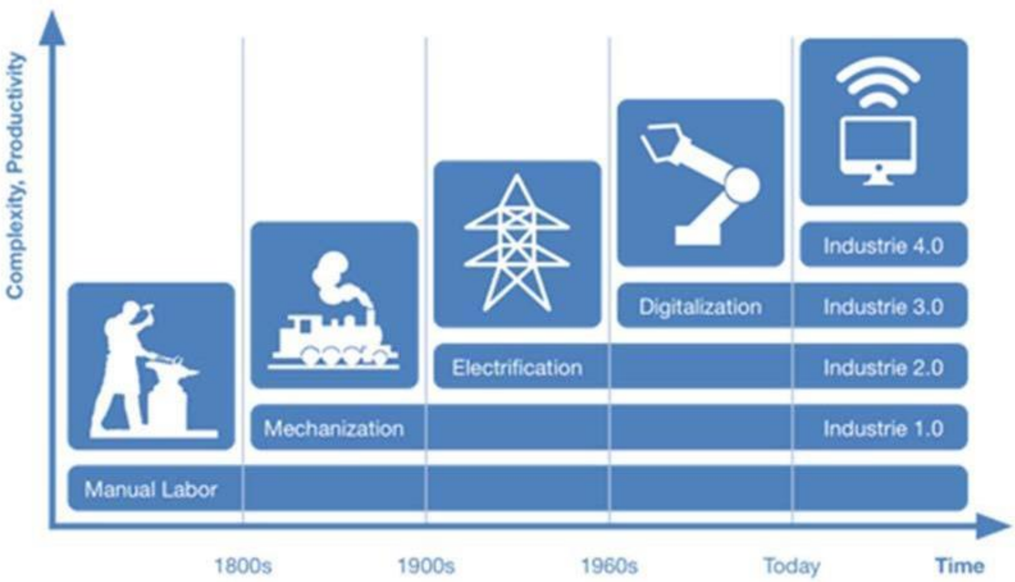

Figure 1: The four industrial revolutions according to Drath and Horch (2014).

Due to rapid technological development, engineering is an ever-evolving profession that shapes society as a whole and also shapes its own working environment. With Industry 4.0, future engineers will have to perform and deal with an increasingly globalized, automatized, virtualized/digitalized, networked and flexible world, where new business models, smart products, procedures and processes are continuously created (Motyl *et al.*, 2017). Furthermore, indicators provided by the Boston Consulting Group (BCG) show that several engineering tasks might become somewhat transformed, less visible, and/or downright diminished as consequence of Industry 4.0 (Lorenz *et al.*, 2015). In addition, the changes are also related to financial investments required for the acquisition and integration of new technologies in the work place and the availability of qualified staff on all organisational levels that can cope with the complexity of production systems (Dansk Vækstråd [Danish Growth Council] (2016). Therefore, training and continuing professional development will play an important role in the implementation of Industry 4.0.

In summary, Industry 4.0 will have a huge impact on the engineering profession and will change how engineering education institutions educate and prepare engineers for the future labour market. Whilst there are some prospects regarding the type of technologies and the role of training and continuing professional education needed when implementing Industry 4.0, the competences required from specific engineering disciplines and type of engineering education curriculum are not yet fully understood. However, curriculum changes in higher education involve complex processes and are typically slow, which makes engineering education reactive in educating and preparing engineers to address social and professional needs (National Academy of Engineering, 2005). Consequently, engineering education educators, researchers and institutions need to take a more proactive role and start to understand, anticipate and adapt the engineering education to Industry 4.0-derived needs for knowledge, skills and competences. In the relation to the aforementioned points, this conceptual paper proposes to answering the following questions:

What kind of competences are needed for future engineers in the context of Industry 4.0?
What are the implications for engineering education?

Through a literature review, the aim is to disclose and define the Industry 4.0 concept and further determine the implications for engineering education, specifically regarding the competences needed.

This paper is comprised of five parts. It starts with the Introduction in Section 1. This is followed by Section 2, which discusses the conceptualization of Industry 4.0. Section 3 discusses the new industrial revolution and new engineering qualifications. Section 4 covers the implications for an engineering education. The paper concludes with Section 5, which provides a synthesis of curriculum enrichment items as the basis for future research and meeting the needs of the engineering profession.

2 Conceptualizing Industry 4.0

Industry 4.0 is based on the use of cyber-physical systems (CPS), which can be defined as "*physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core*". In other words, this will transform the interactions with the physical world

(Rajkumar *et al.*, 2010). Zanero (2017, p. 15) refers to CPS as a "*the successful marriage of digital and physical systems to perform advanced automation and control tasks*". Cyber and physical resources are interconnected where "*embedded computers and communication networks govern physical actuators that operate in the outside world and receive inputs from sensors, creating a smart control loop capable of adaptation, autonomy and improved efficiency*". The Internet of Things (IoT) is another synonym for Industry 4.0 (Kortuem *et al.*, 2010), where basically "*the connection of physical things to the Internet makes it possible to access remote sensor data and to control the physical world from a distance*" (Kopetz, 2011). These are the core concepts for Industry 4.0 and indicate the type of technologies, products, services and processes it relies on, such as smart factories and smart products. A smart factory is capable of managing complexity, is less influenced by external factors and is capable of producing products more efficiently (Kagermann, Wahlster and Helbig, 2013). Figure 2 illustrates the relation between IoT and some of the processes of a smart factory, namely the exchange and integration of data from a distance through digital networked systems in the factory's processes and production.

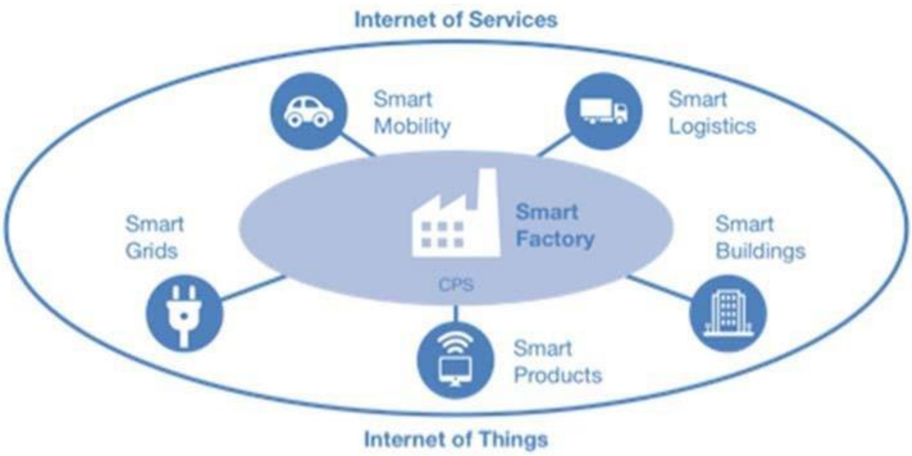

Figure 2: Smart factory and Internet of Things (Kagermann, Wahlster and Helbig, 2013).

In smart factories, people, machines and resources communicate with each other as naturally as in a social network. Similar to smart products, they know the details of how they were manufactured and how they are intended to be used. In order for smart factory to become a reality, the integration of automation technology and IT systems is needed. Kagermann *et al.* (2013) distinguished between horizontal and vertical integration. Horizontal integration refers to the integration of different IT systems used in the different stages of production and business planning processes involving the exchange of materials and information both within a company and between several companies. Vertical integration refers to the integration of the various IT systems at different hierarchical levels within the company (e.g. sensor, control, production management, manufacturing, execution and planning levels).

Besides automation and IT systems to transform a factory into a smart factory, other types of technologies are mentioned in the literature. For example, a report from the Boston Consulting Group (BCG) (Rüßmann *et al.*, 2015), described the nine technology trends presented in figure 3. The authors referred to these technologies as the building blocks of Industry 4.0.

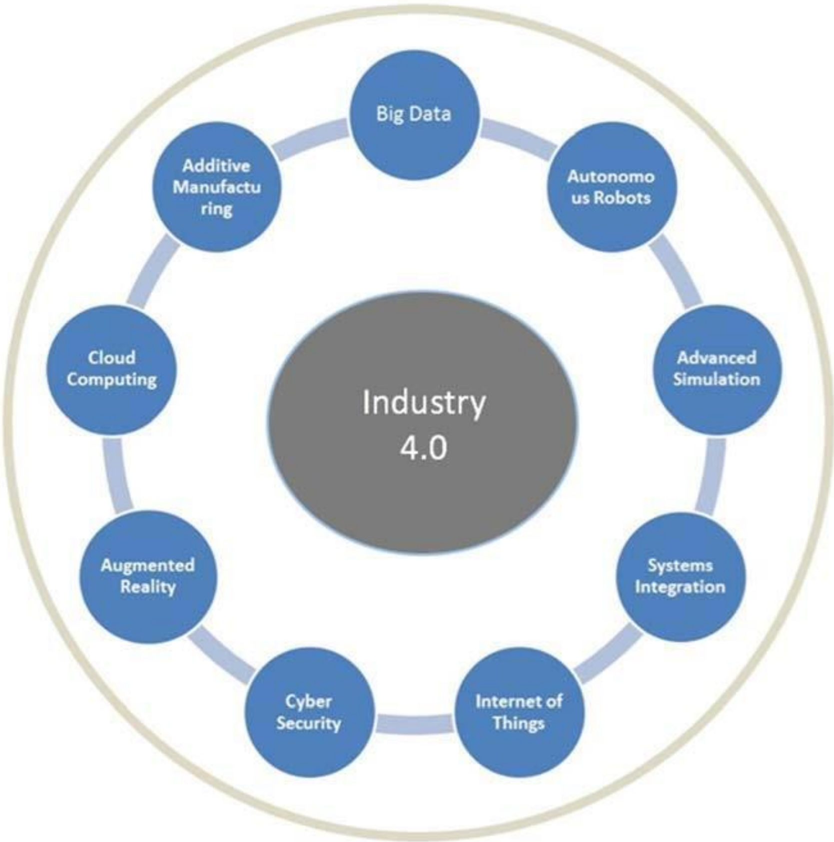

Figure 3: Nine fundamental technologies of Industry 4.0 (Rüßmann *et al.*, 2015).

Several of these nine technological advances are already in use in industry. However, with Industry 4.0, they will transform production into a fully integrated, automated and optimized production flow. They will increase the efficiency and change the production conditions and relations between suppliers, manufacturers and customers as well as between man and machine.

In summary, Industry 4.0 will bring deep changes into the engineering labour market. The fundamental core technologies provide opportunities to create new business models and a continuous technological innovation through use of IT, smart networked systems, smart products and services. Consequently, the traditional engineering disciplinary knowledge and competences, as well as the forms of education, may not be enough to fulfil Industry 4.0 requirements. Therefore, an understanding of the role of an engineering education and the type of qualification profiles needed for the employability of future engineers is needed. In the next section, the role of education, in general, for the implementation of industry 4.0 is discussed, along with an argument for kinds of competences needed for future engineers.

3 New industrial revolution, a new engineering qualification profile needed

According to Motyl and colleagues (2017, p. 1502), "*training and continuing professional education represent [other] fundamental key factor for achieving the Industry 4.0 objectives as they will significantly transform job and skills profiles of the workers*". Therefore, it is of outmost importance to understand what kind of competences are needed for Industry 4.0 not only to upskill and reskill the existing workforce, but also to provide a suitable initial education for today's engineering students.

The widespread expectations are that employees will increasingly focus on creative, innovative and communicative activities. For example, routine and monotonous activities will be taken over by machines (Pfeiffer, 2017). Similar to what was observed during the previous waves of industrialization, such technological progress will not diminish overall employment. Overall, the number of production workers fell, but new jobs emerged as well as the demand for new skills (Kagermann, Wahlster and Helbig, 2013). Undoubtedly, Industry 4.0 will deeply transform the workforce, and consequently some of the existing literature proposes frameworks (Erol *et al.*, 2016), groups of skills (Motyl *et al.*, 2017) and holistic models (Hecklau *et al.*, 2016) to formulate a catalogue of competences for human resource management.

Erol and colleagues (2016) proposed Erpenbeck's classification based on the typical roles in production to refer to competences needed to perform tasks required in an exemplary scenario of an assembly process on the automation and machine control level. The authors point to four groups of competences, namely personal competences, social competences, action competences and domain competences (Table 1).

Table 1: Competences required for Industry 4.0 according to Erol *et al.* (2016).

Competence group	Specific abilities, attitudes and skills
Personal Competences	Solution-oriented attitude Creativity Out-of-the-box thinking
Social Competences	Teamwork ability Consensus-finding ability, compromising Role taking, role-making ability

Action Competences	- Problem analysis and structuring, solution and development - Data analysis and interpretation - Method, tool selection and use
Domain Competences	- Application of, e.g. lean thinking and methods in manufacturing
Competence group	**Specific abilities, attitudes and skills**
	- Application conceptual modelling methods, e.g. data flow, material flow and process modelling - Application of information and communication technology (ICT) for material tracking and worker tracking

Personal competence can be understood as a person's ability to act in a reflective and autonomous way. Here, Erol *et al.* (2016) relied on a general trust in technology and personal flexibility in terms of working time, work content and workplace as a way of thinking. This is a prerequisite for flexible production that can respond quickly to market needs and environmental conditions. Social competences refer to the ability to interact in a social context. Full digital integration and automation of the entire manufacturing process (vertical and horizontal) will increase scope and complexity, which requires a mindset aimed at building and maintaining networks of experts in order to collaborate *ad hoc* and find appropriate solutions for complex problems. In this context, flexibility in problem solving and creativity are prerequisites as well. Action-related skills refer to the ability to take individual and socially designed ideas for/in action. Future employees need strong analytical skills and must be able to find domain-specific and practical solutions to problems without losing the overall goal. Domain-related competencies refer to abilities to understand and use domain knowledge for a job and/or specific task. When implementing Industry 4.0, employees must be able to assess whether subsystems work as expected and interact with systems through various interfaces. In this context, there is also need for digital skills at an upper level. In the case of disturbances, engineers must be able to analyse complex systems through specialized software. For engineers, a deep understanding of the relationships between the electrical, mechanical and computer components will be a vital ability to develop innovative products and processes (Erol *et al.*, 2016). The above competences groups present a landscape of competences, from generic competences, such as personal, social and action competences, to specific engineering knowledge and competences, such as the domain competences.

Motyl and colleagues (2017), using examples from mechanical engineering, proposed three groups of skills that are needed to cope with Industry 4.0 needs. They are: hard, soft and digital skills (Table 2).

Table 2: Group of skills according to Motyl *et al.* (2017).

Skills group	**Examples**

Hard Skills	Numerical and higher mathematical knowledge Problem solving Creativity and design skills
	Investigative and experimental skills Information processing Computer programming Knowledge of specific software tools
Soft Skills	Strong analytical thinking Communication Teamwork Leadership
Digital Skills	Basic digital literacy skills, such as use of digital applications and ability to carry out basic internet searches Digital skills for general workforce[1], such as specific use of IT applications for workplace, developed by IT specialists and processing information Digital skills for ICT professionals[1], such as skills linked to development of new digital technologies, products and services.

[1]Digital skills for general workforce includes basic digital literacy skills, while digital skills for ICT professionals includes all skills from basic digital skills and digital skills for general workplace.

Again, there is an emphasis on generic, or soft skills, in addition to digital skills. Whilst Erol *et al.* (2016) hinted at digital skills being domain specific, Motyl *et al.* (2017) explicitly referred to them as a third group of relevance competences. In a digitalized world, given the nature of core technologies of Industry 4.0 and great emphasis of ICT and use of smart networked systems, digital skills are emerging and assuming a greater importance. For example, see DigCom, The European Digital Competence Framework (European Commission, 2018a). This is a tool for citizens to improve their digital competences and it is a *reference for the development and strategic planning of digital competence initiatives both at European and Member State level*. DigCom 2.0 identifies the key components of digital competence in five areas, which are: information and data literacy, communication and collaboration, digital content creation, safety and problem-solving. Another example is the Skills for Industry (European Commission, 2018b), which states that "*disruptive technological change is changing the face of industry on a global scale. […] Skills are at the heart of industrial policy. Innovation comes from the creativity and skills of individuals. There is a global race for talent and our workforce needs to acquire high-level skills and continuously improve them to boost employability and fuel* *competitiveness and growth*". It claims there are increasing skills gaps and mismatches related to digital and high-tech key enabling technologies (KETs). It is necessary to introduce competence strategies and, for example, organize work in ways that promote learning. This will enable workplace and work-based learning and thus, work integrated learning. Enabling companies to retrain their workforce, education systems to close the IT skills gap and governments to strengthen their support will be crucial in realizing the promise of Industry 4.0 (Lorenz *et al.*, 2015).

Hecklau and colleagues (2016) proposed a holistic competence model. The model presents four categories of competences drawn from Industry 4.0 emerging challenges, such as economic, social, technical, environmental and political and legal.

Category	**Required Competencies**
Technical competences	• State-of-the-art knowledge • Technical skills • Process understanding • Media skills • Coding skills • Understanding IT security
Methodological competences	• Creativity • Entrepreneurial thinking • Problem solving • Conflict solving • Decision making • Analytical skills • Research skills • Efficiency orientation
Social competences	• Intercultural skills • Language skills • Communication skills • Networking skills • Ability to work in a team • Ability to be compromising and cooperative • Ability to transfer knowledge

	Leadership skills
Personal Competences	Flexibility
Category	**Required Competencies**
	Ambiguity tolerance Motivation to learn Ability to work under pressure Sustainable mindset Compliance

In summary, Industry 4.0 will deeply affect work places. There will be demands for a new qualification profile where transferable (also referred as soft and generic) and digital skills assume important roles along with disciplinary engineering competencies. The implementation of Industry 4.0 and the core technologies will transform tasks and jobs. Partnerships that enable a requalification of the existing work force, adequate preparation for future workers and provide lifelong support and continuous upskill and reskill of employees are needed. Even though the description above provides examples and an overview of needed competences, there is a need to further understand the competences that are used in different jobs and by different engineering areas of expertise in context of Industry 4.0 (see for example Erol *et al.*, 2016; Richert *et al.*, 2016; Benešová and Tupa, 2017; Motyl *et al.*, 2017). Undoubtedly, engineering educators and universities play an important role in facilitating the implementation of Industry 4.0 by adapting to its demands and providing suitable learning environments, programmes and training to educate future engineers.

4 Industry4.0 driven skills and competence requirements and the implications on engineering education

This conceptual paper aims to addresses two questions. What kind of competences are needed for future engineers in the context of Industry 4.0? What are the implications for engineering education?

It started by conceptualising Industry 4.0 through a literature review then continued with a specific interest in skills and competences in the context of Industry 4.0. The literature show that diverse skills and competences will be needed such as personal, social, action, soft, methodogical, hard, domain and technical. In terms of skills, they are often referred to as being ”soft” or ”hard”, which implies that engineering professional skills are categorised as being ”hard”. However, in the context of Industry 4.0, “Digital” skills are highlighted and explicitly categorised as indispensable at all levels in organisations. This is because the core element of Industry 4.0 is the full digitalization of production, which is only possible with an extremely skilled group of employees such that companies can gain the full benefits of digitalization. Therefore, companies require sufficient access to employees with strong digital skills (Dansk Vækstråd [Danish Growth Council] (2016). Soft skills, however, are also indispensable, and include language, communication and teamworking. The same applies when it comes to competences. The literature identifies categories and specific competences as being significant in relation to Industry 4.0. The competences can be divided into ”transferable” and “domain” competences. The transferable competences would include analytical, compromising, reflecting and conceptualizing. These are competences and attitudes that employees must process to be able to act in context of Industry 4.0. The domain competences will be related to the individual engineer’s professional occupation or discipline. Both generic and highly specialized domain competences will be needed depending on the specific tasks and size of the company. A small company might employ engineers with generic competences and through consultancies they could obtain the expertise needed (Wæhrens *et al*., 2018).

Even though the literature emphasises hard skills, e.g. digital and domain competences, as being essential for the realisation of Industry 4.0, the soft skills and transferable competences are put forward as being what makes it all come together! Without such skills and competences employees, will not be able to work efficiently in teams, communicate, analyse, interpreted and act in a flexible manner and thus continuously adapt to context and thereby reach the full potential of Industry 4.0 (Bonilla, 2018).

So a question remains, what are the implications of Industry 4.0 to engineering education? How can engineering education institutions adapt to Industry 4.0? It is certain that traditional teaching approaches are no longer sufficient to educate for the 21st century. Learning approaches must be able to develop engineering disciplinary knowledge, skills and competences. These would include the aforementioned domain competencies and hard skills and also the soft and digital skills. Undoubtedly, engineering educators need to revise their curriculum and implement learning approaches that create conditions for students to develop the competences needed for Industry 4.0. For example, the teams and settings where future engineers will have to collaborate is a challenge itself. Professional engineers will have to collaborate not only with experts from other professional fields and countries, but also with machines and in virtual spaces (Richert *et al.*, 2016).

The development of skills and competences, such as problem-solving, communication, creativity and innovation, flexibility and adaptability, collaboration and learn-to-learn, calls for active, student-centred and interdisciplinary pedagogies like Problem-Based Project Organized Learning (PBL) and the Conceive, Design, Implement and Operate (CDIO) initiative (Graaff and Kolmos, 2003; Crawley *et al.*, 2011; Edström and Kolmos, 2014; CDIO OFFICE, 2018). Curriculum change is a complex process and involves different types of resources and commitment. For example, institutions need to revise their vision, curriculum goals and structure, physical infrastructures and resource allocation. They must establish partnerships, namely with industry and other stakeholders, to create programmes for academic staff pedagogical development and role definition in addition to the re-formulation of learning outcomes, assessment methods, etc. However, several institutions are starting innovate their education practices and the way they look into engineering education (see for example (Graaff and Kolmos, 2007; Graham, 2016, 2018; Guerra, Ulseth and Kolmos, 2017).

Another cornerstone for the implementation of Industry 4.0 is continuing professional education. It is not only about how to educate the future engineers but also how to re-qualify the existing work force. Once more, close partnerships are needed to be established between universities and companies. The continuous requalification of employees is related to type of company and the competences required for continuous innovation and competitiveness (Sjoer *et al*., 2016). Consequently, the type of programmes and requalifications, and how they are delivered, might be on-demand and tailor-made to address the specific needs of companies and employees. As institutions of teaching, universities have the capacity to create such programmes; however, they might also require a revision of how continuing professional education is seen in universities and call for new forms of training (Nørgaard, 2016).

5 Conclusions and recommendations

In conclusion, engineering educators and institutions need to adapt to technological change and the changing needs for engineers and engineering education in order to educate and train tomorrow's engineers with sustainable qualification profiles. With the emerging concept of Industry 4.0, academia has a new paradigm that calls for new curriculum, content and learning approaches in order to foster the needed conditions to develop the competences required. Besides a revision of how tomorrow's engineers are educated, the role of continuing professional education is present in the implementation of Industry 4.0. Universities might assume a role in developing programmes in collaboration with companies that aim to better meet and match the requalification needs of the existing work force. This, however, opens new questions. From the above, it is clear that soft skills and transferable competences will be indispensable. In order to define specific hard skills and domain competences needed in context of Industry 4.0, a close and thorough collaboration between higher education and industry will be required.

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Innovation-oriented Transition of Learning Methods for Undergraduates and Postgraduates in Mechanical Engineering

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Abstract

The goal of training undergraduates and postgraduates in engineering education is to enable them to become outstanding engineers, but achieving this goal is not easy. The competence of engineering innovation should be trained as soon as students enter university, which conflicts with the fact that the traditional higher engineering education focuses on learning knowledge of each sole course, seldom involves the comprehensive use of various types of knowledge to solve practical engineering problems. For instance, the core courses in mechanical engineering include mechanical drawing, mechanism and machine theory, and basics of mechanical design. And these courses generally introduce the knowledge of drafting and commonly used mechanisms and parts, which hardly refer to the complex engineering design problems. In order to overcome the shortages of traditional learning methods to develop the competence of engineering innovation for undergraduates and postgraduates, the three dimensional model and the transition approach of learning methods are presented. The proposed approach consists of three transitions of learning modes, namely the transition from passive learning to active learning, the transition from subject learning to project learning, and the transition from definitive learning to tentative learning. Among them, the transition of the first two learning methods should be mastered by undergraduates, which will enable the undergraduates to become qualified engineers and outstanding engineers. And the third transition should be mastered by postgraduates and some undergraduates who are seeking excellence, which will enable them to become outstanding engineers. The teaching practice shows that, using the proposed transition approach, the students are competent to acquire excellent performance in innovation competitions of mechanical engineering. Many of these students achieve excellent results in the subsequent undergraduate study, and many students enter the postgraduate study.

Keywords: learning approach, engineering innovation, active learning, project learning, tentative learning

Type of contribution: research paper

1 Introduction

The competence of engineering innovation should be trained as soon as students enter university, which conflicts with the fact that the traditional higher engineering education focuses on learning knowledge of each sole course, seldom involves the comprehensive use of various types of knowledge to solve practical engineering problems. Hence, in the 1960s, a handful of education research institutions in the world proposed a novel learning concept, namely problem-based learning (PBL). After nearly 50 years of development, under the learning concept of PBL, various learning methods have been derived, such as project-based learning, team-based learning, self-directed learning, and contextual learning (Guerra *et al*., 2017; Kek & Huijser, 2017; O'Grady *et al*. 2012). In order to achieve PBL in the curriculum, the researchers proposed three strategies for curriculum setting. The first strategy is an add-on curriculum, which adds active learning and engineering cases into the classroom teaching (Shinde & Kolmos, 2011). The second is the integration strategy, which combines multiple courses to achieve project-based learning (Crawley *et al*., 2014; Edström & Kolmos, 2014; Dutson *et al*., 1997; Todd *et al*., 1995). The third is the rebuild strategy, which resets the curriculum system adapted to social development (Jamison *et al*., 2014; Kolmos *et al*., 2016).

Based on the learning concept of PBL, this paper presents a novel three dimensional model of learning methods and the corresponding eight styles of student training. In order to overcome the shortages of traditional learning methods to develop the competence of engineering innovation for undergraduates and postgraduates, the transition approach of learning methods is presented. The proposed approach consists of three transitions of learning modes, namely the transition from passive learning to active learning, the transition from subject learning to project learning, and the transition from definitive learning to tentative learning. According to the characteristics of the course content in different stages for undergraduates and postgraduates, the digital design, prototype design, and innovative design are used as tools to construct three approaches to transit the learning methods.

2 Learning Methods and Training Styles

The goal of training undergraduates and postgraduates in engineering education is to enable them to become outstanding engineers, but achieving this goal is not easy. This paper presents a novel model of learning methods and the corresponding eight styles of student training based on the three dimensions of passive learning and active learning, subject learning and project learning, and definitive learning and tentative learning, shown in Figure 1.

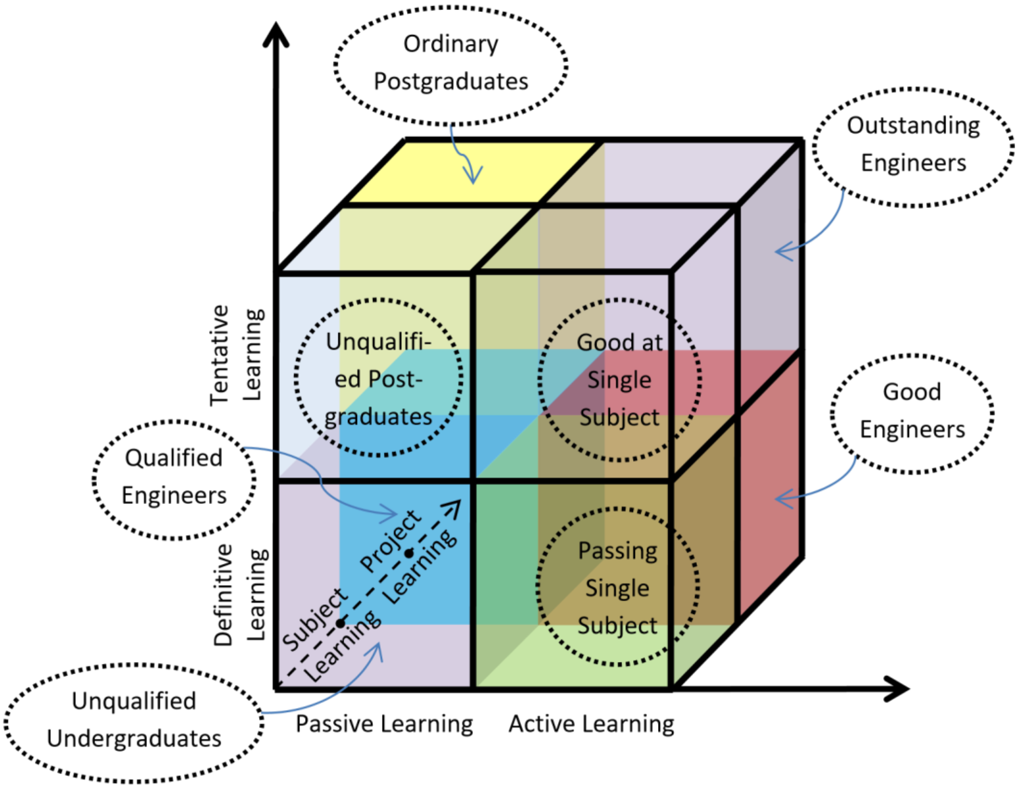

Figure 1: A three dimensional model of learning methods

It can be seen from Figure 1 that, achieving the goal of outstanding engineers in engineering education requires students to adopt active learning, project learning, and tentative learning methods. In contrast, if passive learning and subject learning methods are used, only unqualified undergraduates or postgraduates will be fostered. The three dimensions of learning methods and eight styles of student training are discussed in detail below.

2.1 Passive Learning and Active Learning

Passive learning means that students are guided step by step by the teacher, and the subjective initiative of students is poor, as shown in Figure 2. For undergraduates with definitive learning, if they only passively learn the classroom knowledge of each course, they will not eventually become a qualified engineer; if they can combine classroom knowledge of each subject to complete the project, they will become a qualified engineer. For postgraduates adopting tentative learning method, if they only passively study graduate courses, they will not become qualified postgraduates; if they can complete research projects under the supervision of their advisors, they can become ordinary but not excellent postgraduates.

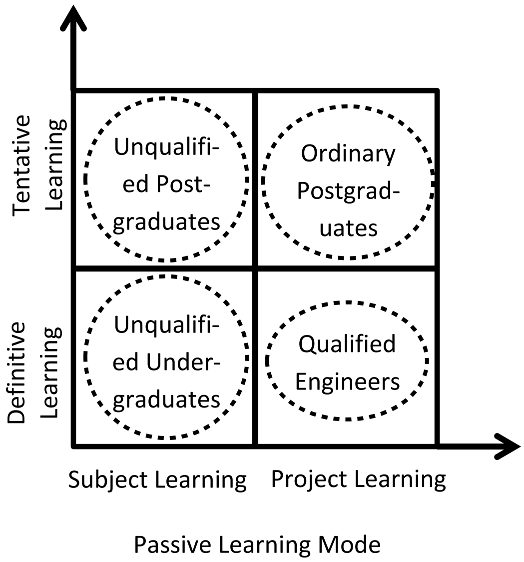

Figure 2: Passive learning projection from the 3D model of learning methods

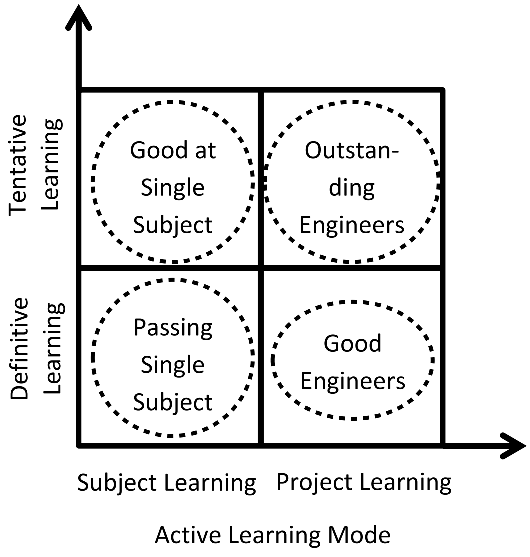

Figure 3: Active learning projection from the 3D model of learning methods

Active learning means that students are not only satisfied with the teacher's classroom teaching but also actively read the materials and hands-on practice, and students' subjective initiative is very strong, as shown in Figure 3. For undergraduates with definitive learning, if they are proactive in learning each course, they will be able to pass the course; if they can combine the knowledge of each subject to complete the project, they will become good engineers. For postgraduates adopting tentative learning method, if they actively study postgraduate courses, they will have excellent grades; if they can actively and scientifically complete research projects, they can be trained to become outstanding engineers.

For the transition of the learning methods, the transition from passive learning to active learning is the most basic change in learning methods for training to become an outstanding engineer.

2.2 Subject Learning and Project Learning

Subject learning means that students follow the curriculum and learn each course to obtain credits, as shown in Figure 4. For undergraduates with definitive learning, if they only passively learn the classroom knowledge of each course, they will not eventually become a qualified engineer; if they actively study each course, they can pass each single course. For postgraduates adopting tentative learning, if they only passively learn the classroom knowledge, they will not become qualified postgraduates; if they actively study postgraduate courses, they will have excellent grades.

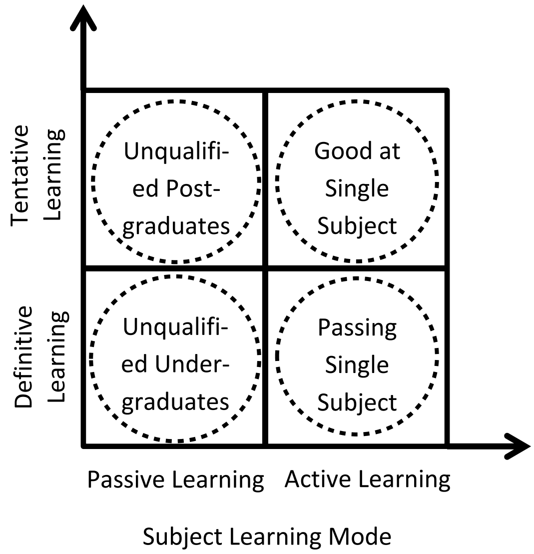

Figure 4: Subject learning projection from the 3D model of learning methods

Project learning refers to students' comprehensive application of various course knowledge and completion of engineering projects or research projects, as shown in Figure 5. For undergraduates with definitive learning, if they can complete the project under the supervision of the teacher, they can become qualified engineers; if they can actively and autonomously combine the knowledge of various courses to complete the project, they can become good engineers. For postgraduates adopting tentative learning, if they can complete research projects under the supervision of their mentors, they can become ordinary but not excellent postgraduates; if they can actively and scientifically complete research projects, they can be trained as outstanding engineers.

For the transition of the learning methods, the transition from subject learning to project learning is the most important change in learning methods for training to become an outstanding engineer.

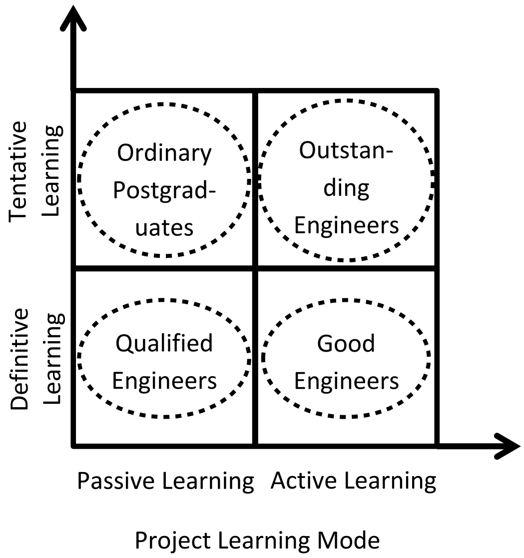

Figure 5: Project learning projection from the 3D model of learning methods

2.3 Definitive Learning and Tentative Learning

Definitive learning refers to students, especially undergraduates, learning books or the knowledge taught by teachers, as shown in Figure 6. For undergraduates who adopt passive learning methods, if they only learn the classroom knowledge of each course in isolation, they will not become qualified undergraduates; if they can complete the project under the supervision of teachers, they can become qualified engineers. For undergraduates who adopt active learning methods, if they actively study each course, they can pass each single course; if they can actively and autonomously combine the knowledge of various courses to complete the project, they can become good engineers.

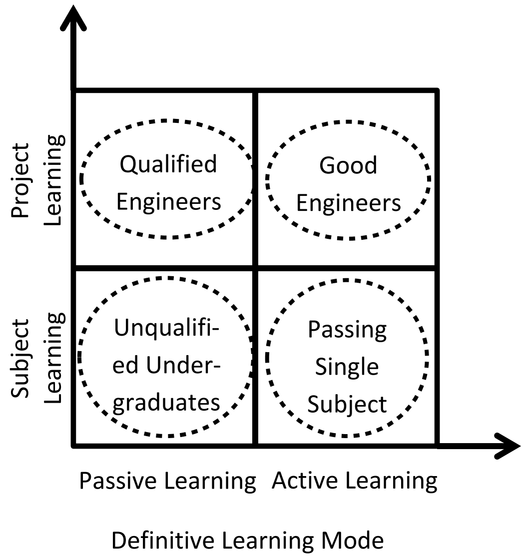

Figure 6: Definitive learning projection from the 3D model of learning methods

Tentative learning means that students, especially postgraduates, learn about knowledge beyond the classroom knowledge through exploratory experiments, as shown in Figure 7. For postgraduates who adopt passive learning methods, if they only learn the classroom knowledge of each course in isolation, they will not become qualified postgraduates; if they can complete the research project under the supervision of the tutor, they can become ordinary but not excellent graduate students. For postgraduates who adopt active learning methods, if they can proactively study postgraduate courses, they will have excellent grades; if they can actively and scientifically complete research projects, they can be trained to become outstanding engineers.

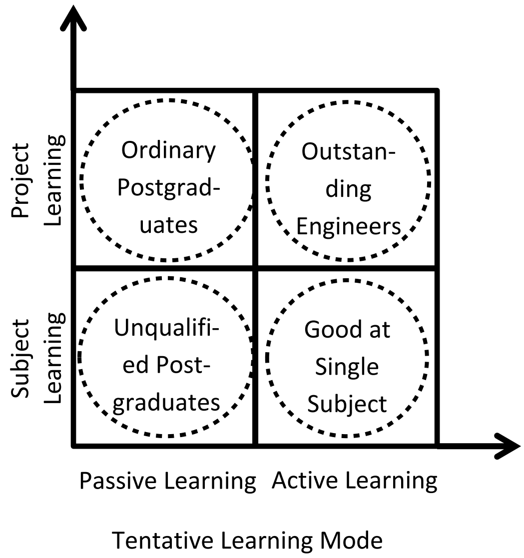

Figure 7: Tentative learning projection from the 3D model of learning methods

For the transition of the learning methods, the transition from definitive learning to tentative learning is the most difficult change in learning methods for training to become an outstanding engineer.

3 Approach to Transit Learning Methods

In order to cultivate outstanding engineers with creativity, the learning methods of both undergraduates and postgraduates need to be transited from passive learning, subject learning, and definitive learning to active learning, project learning, and tentative learning. According to the characteristics of the course content in different stages of learning, digital design, prototype design, and innovative design are used as tools to construct three approaches to transit the learning methods.

3.1 Digital Design as a Tool in Undergraduate Junior Grades

Digital design refers to the use of digital two dimensional software (such as AutoCAD and the engineering graphics module in three dimensional software), three dimensional software (such as SolidWorks, Inventor, Creo, NX, CATIA), and four dimensional software (such as the motion simulation module in three dimensional software, and the professional animation software CINEMA 4D) for 2D drawing, 3D modelling, and motion simulation of mechanical devices in the computer. The features of digital design include:

(1) Intuitive expression. In particular, the three dimensional model and the four dimensional motion simulation animation are very vivid and can stimulate the interest of undergraduates in the junior grades.

(2) Easy to modify. The digital design with the computer can be easily modified. It does not need to be redrawn or reprocessed like paper drawings, and is suitable for beginners in engineering education.

(3) Low cost. It only requires the use of software, no manufacturing costs, and is suitable for undergraduate junior students who lack financial support.

Therefore, digital design is very suitable for undergraduates in junior grades to transit from passive learning to active learning. If combined with the digital design competition for the relevant mechanical devices in the undergraduate stage, the learning method can be transited from subject learning to project learning. Some excellent undergraduates in junior grades can even achieve the transition from definitive learning to tentative learning. This is reflected in the outstanding achievements obtained by the lower grade undergraduates in the digital design competition for the mechanical devices. As shown in Figure 8, the Mars rover designed by freshman students to cross the obstacles won the first prize in the digital design competition in 2017. Obviously, the design of the Mars rover will not be involved in the first-year college books, so this belongs to the tentative learning method.

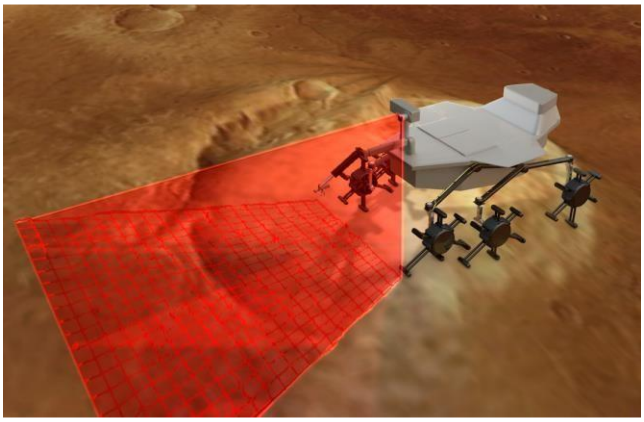

Figure 8: A Mars rover designed by freshman students to overcome obstacles

3.2 Prototype Design as a Tool in Undergraduate Senior Grades

The prototype design refers to the final production of the mechanical design process, including the scheme design, structural design, construction design, manufacturing, assembly, and commissioning stages. The features of prototype design include:

(1) Accumulated experience. Prototype design requires designers to have rich design experience and need to integrate the knowledge in multiple courses. In the design stage, the manufacturability, assembly, and controllability of mechanical devices must be taken into account. The requirement of design experience means that the prototype design is more suitable for undergraduate senior students than under-experienced junior students.

(2) Longer period. The prototype design cycle includes not only the design phase but also the manufacturing and assembly commissioning phases. Once problems are discovered during assembly or commissioning, it is likely that the prototype will need to be redesigned, so the entire prototype design cycle will be longer.

(3) Higher cost. The total cost involves the cost of parts and components, processing and manufacturing costs, and personnel costs for assembly and commissioning. Moreover, once the prototype needs to be modified, the cost becomes higher. Prototype design needs economic support.

Therefore, prototype design is very suitable for undergraduates in senior grades to transit from subject learning to project learning. If combined with the relevant mechanical device design competition in the undergraduate senior stage, this learning method will have a better effect. Some excellent senior undergraduates can even achieve the transition from definitive learning to tentative learning. This is reflected in the outstanding achievements obtained by senior undergraduates in the mechanical device design competition. As shown in Figure 9, it is a portable fruit picking device designed by undergraduates in senior grades to collect fruit on multiple branches at a time, which won the first prize in the mechanical device design competition in 2017. The design of the fruit picking device will not be involved in university textbooks, and this belongs to the tentative learning method.

Figure 9: Portable fruit picking device designed by undergraduates in senior grades

3.3 Innovative Design as a Tool for Postgraduates

Innovative design refers to a practical activity in which the scientific, creative, novel, and practical achievement is designed based on the full use of the designer's creativity, and the use of human existing scientific and technological achievements. The features of innovative design include:

(1) Novel concept. Innovative design requires designers to use creative ideas to analyse problems and be good at discovering new ways to solve complex problems that are difficult to solve with empirical knowledge.

(2) Unique technology. In order to meet requirements, the unique technology is applied to implement novel solutions in innovative designs. The uniqueness of technology can be expressed as advanced technology, or as adopting existing technology to dexterously solve practical problems.

(3) Practicality. Innovative design starts with demand analysis and aims at solving practical problems with design thinking. Innovative design is not only a novel scheme but also very practical.

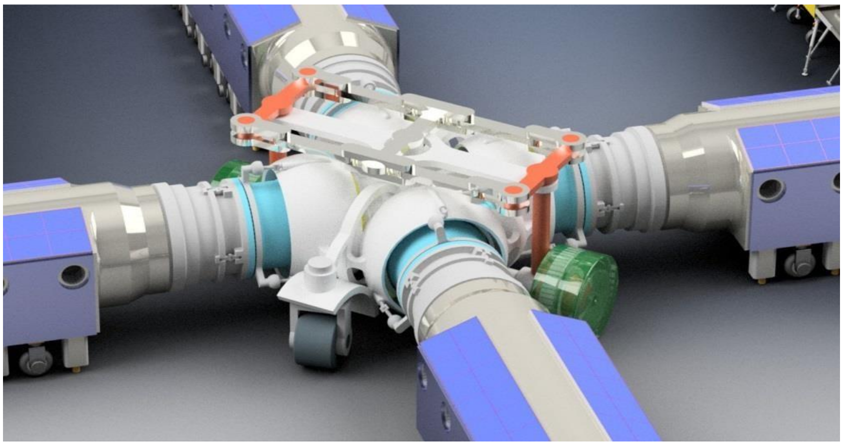

Figure 10: Movable cabins with a cross connection device between them for the human lunar base

Therefore, innovative design is very suitable for postgraduates to transit from definitive learning to tentative learning. If combined with the tutor's research project, the transition of the learning methods is better. As shown in Figure 10, the movable cabins with a cross connection device between them are designed by a postgraduate for the human lunar base. At present, no country has yet established a lunar base, so this belongs to the tentative learning method.

4 Conclusions

The goal of training undergraduates and postgraduates in engineering education is to enable them to become outstanding engineers, but achieving this goal is not easy. Based on the learning concept of PBL, this paper presents a novel three dimensional model of learning methods and the corresponding eight styles of student training. In order to overcome the shortages of traditional learning methods to develop the competence of engineering innovation for undergraduates and postgraduates, the transition approach of learning methods is presented. The proposed approach consists of three transitions of learning modes, namely the transition from passive learning to active learning, the transition from subject learning to project learning, and the transition from definitive learning to tentative learning. According to the characteristics of the course content in different stages for undergraduates and postgraduates, the digital design, prototype design, and innovative design are used as tools to construct three approaches to transit the learning methods. The teaching practice shows that, using the proposed transition approach, the students are competent to acquire excellent performance in innovation competitions of mechanical engineering. Many of these students achieve excellent results in the subsequent undergraduate study, and many students enter the postgraduate study.

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A Study of Challenge-based learning Based on Enhancing Innovative Ability

——An example from Tsinghua University

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Abstract

In challenge-based learning (CBL), innovation ability is the capacity that undergraduates use relevant knowledge, methods, and means to solve the challenging problems under the direction of their teachers, specifically including innovative consciousness, innovative quality, innovative thinking and innovative skills. On the basis of the overview of the background and current situation of CBL in Tsinghua University, this paper takes challenging tasks as its main line. From the three aspects of challenging task design, teaching organization for challenging tasks, and learning as well as practice to accomplish challenging tasks, this paper analyses the promoting effect of CBL on innovative ability. In the end, the researchers will evaluate and propose some opinions to perfect the current CBL in Tsinghua University.

Keywords: Challenge-based learning, Innovative ability cultivation, Challenging tasks

Type of contribution: Best practice paper

1 Introduction

1.1 The background of Challenge-based learning (CBL)

The emergence of CBL has special time condition and social background. It is not the product imagined by educational researchers or policymakers, but is caused by the interaction between the external demand of society and the change of the development of higher education itself. 21st Century is the century of innovation. The needs of society guide the development of education, especially higher education. Therefore, we should pay attention to the cultivation of students' innovative ability. On the one hand, the macro environment has put forward higher and higher requirements for college students' innovative ability. On the other hand, the enrolment expansion of Chinese universities has led to a relative decline in the overall level of Chinese university graduates. The increasing demand for society and the relative decline of the students' average level in higher education have narrowed the distance between each other, which forced the education researchers to find a good way to solve the problem. Under this background, in order to cultivate students' innovative ability and comprehensive ability, CBL teaching mode has arisen. According to problem-based or project-based learning (PBL), CBL is a kind of learning style which emphasizes the difficulty of problem and regards the cultivation of students' innovation ability as its main goal. The first CBL demonstration course of Tsinghua University was opened in 2012. Up to now, more than 80 related courses have been opened, and a pattern of multi department and multi professional coverage has been established. The CBL demonstration course of Tsinghua University has achieved certain teaching results and has been recognized by most of the students. The vigorous development of CBL requires managers to give better guidance. At the present stage, it is necessary to sum up experience from practice and to provide a reference for the future development of CBL from the perspective of academic research.

1.2 Research Method

Taking the course of CBL in Tsinghua University as the research object, this paper uses literature research, observation, interview and questionnaire survey. The four methods cooperate with each other, and questionnaire survey provides data support for this paper. The questionnaire takes the form of answering the questions on the network. 189 copies were collected, including 13 courses and 28 departments.

2 A related discussion of Challenge-based learning (CBL)

2.1 Concept definition

2.1.1 Challenge-based learning (CBL)

The challenge of CBL is mainly for students, that is, curriculum content, curriculum tasks and curriculum process are challenging. CBL’s keynote purpose is to enable students to fully stimulate their potential in the process of "pain and happiness" and enjoy themselves in the joy of success after overcoming difficulties [1]. CBL is the extension of PBL, and challenging tasks are its outstanding characteristics. The enhancement of College Students' innovative ability is CBL’s important effect and ultimate goal. This article defines the concept of CBL as follows:

CBL is an innovative teaching mode with students as its learning agent. Under the guidance of curriculum objectives and teachers, CBL is based on the challenging tasks which in the "zone of proximal development". Through the design of challenging tasks, the teaching organization for challenging tasks, and the learning as well as practice of challenging tasks, CBL can enable students to experience the joy of tackling difficulties and ultimately achieve the goal of improving the comprehensive and innovative qualities of the students.

2.1.2 Innovative ability

Since Burns and Storck put forward the concept of "innovation ability", which has the significance of economic management in 1961, this word has been widely used in many fields of discipline research. This paper chooses professor Jian Lin's definition of innovation ability:

Innovation ability refers to the ability of people to find new ideas or ways to solve problems on the basis of rich knowledge and open field of vision, and to produce new products, new technologies or new methods through creative practical activities. In particular, innovation ability should at least include the ability to discover new problems or new things, the ability to propose ideas or plans for a new problem, the ability to put ideas or plans into practice and achieve innovative results [2].

2.2 A comparison between CBL and PBL

PBL is the process that under the guidance of teachers, undergraduates will proactively identify, analyse and solve problems through a variety of research methods. It can help undergraduates to achieve their learning goals in knowledge learning, ability training and quality formation [3]. CBL is based on PBL. They have many similarities in concept definition and specific curriculum organization. It is helpful for us to further study CBL by analysing and comparing them.

Fundamentally, there is no essential difference between CBL and PBL. They are both encouraging undergraduates to explore scientific research tasks or problems in collaboration with each other. From the theoretical point of view, constructivism and Dewey's "learning by doing" thought are their theoretical sources. From the perspective of knowledge acquisition, CBL and PBL emphasize undergraduates in the form of group. Through the exploration and solution of the tasks from the real society, undergraduates can realize the understanding and reconstruction of the knowledge they have learned. From the perspective of curriculum core, scientific research tasks play a very important part in the course, and they are the core and backbone of the curriculum. From the students' point of view, CBL and PBL advocate that the undergraduates should be the centre, and how to achieve the goal of the course should be chosen by the students themselves. From the teacher's point of view, the two teaching models are opposed to monotonous lecture-style teaching, and teachers play a guiding role in the course.

Although there are many similarities between CBL and PBL, there are still some differences between them. The main difference is that the difficulty of curriculum task or problem is different. The tasks of PBL are to promote the undergraduates' understanding or application of the knowledge through the exploration, and there are no hard and fast demands on task difficulty. Instead of overemphasizing the difficulty of completing tasks, PBL focuses on stimulating students' interest in learning and exploring various aspects of their abilities. Compared with the PBL, CBL curriculum pays more attention to the challenges of the tasks, which must be difficult to implement or even teachers have never dabbled in solutions. The task of CBL courses are extremely difficult to accomplish by individual force, so they require cooperation between team members. Under the guidance of the teacher, students can break the mind-set and finally achieve the goal of the mission. From this point of view, CBL can be said to be an extension of PBL.

In addition, the application fields of CBL and PBL are different. According to the available data, PBL has a wide range of application, and many colleges or universities have accumulated a great deal of valuable experience for it. It is not only suitable for the teaching of specific subject areas, but also for interdisciplinary learning. CBL demonstration courses need to be screened in existing courses, and some courses that provide difficult tasks or many ways to solve professional frontier problems can play a prominent role in CBL. Therefore, it is the priority among priorities to clearly define how to select CBL courses and how to measure the challenges of the course.

3 Analysis of the factors of challenge-based learning (CBL)

CBL is a systematic educational model. In the study of the basic elements of teaching, Chinese academia has a variety of research results, mainly including three elements, four elements, five elements and so on. Based on the research results of Chinese academia and the related investigations of CBL courses, the researchers believe that challenging learning consists of four elements: teachers, students, challenging tasks and teaching resources., but the specific requirements of some elements are different.

3.1 Teachers

Teachers with rich theoretical knowledge as well as practical experience are the basis for the effective development of CBL, and the ability of teachers affect the realization of the teaching effect of CBL Demonstration Courses. Academic achievements have shown that teachers have a close influence on the creativity of the students. If the teacher has a great potential for innovation, the talented students can easily achieve excellent results [4]. CBL teachers need to have two abilities, that is, basic ability and curriculum ability. Basic ability is the basis for CBL, which includes a lofty sense of responsibility and great enthusiasm, extensive professional knowledge and profound academic foundation, excellent innovation ability and good communication ability between teachers and students. Curriculum ability helps to make full use of CBL effects, including outstanding classroom organization and teaching ability, rich challenging task experience, and adequate teaching resources.

Teachers in CBL courses need not only the theoretical knowledge of solid principles, technology, and related disciplines in the field but also the latest developments and future trends of the major. In addition, teachers should have the experience of solving practical problems and sharp judgment, mastering the progress of the students' task and providing the direction for the students to solve the task problem in time.

3.2 Students

No matter what type of CBL demonstration course, students are the main body of learning. Although there may be differences between the different demonstration courses, CBL has some consistency requirements for students. First of all, students need to have a strong desire for knowledge and a strong interest in exploring the unknown world. Secondly, a certain degree of independent innovation ability is one of the essential abilities of students who take part in CBL courses. Finally, students need to have independent learning and teamwork consciousness. In order to ensure the implementation of CBL and the realization of the teaching effect, students should have certain qualities, and prepare the four aspects of time, cognition, ability and knowledge.

Time preparation. It takes a lot of after-school time to complete every learning link of CBL. It is difficult to make progress in the various learning tasks of CBL without making full preparation on the time schedule. The "challenge" of CBL requires students to take time, to learn to spend time, and to improve their efficiency of time utilization. Therefore, the difficulties will be overcome and students can enjoy the joy of the success.

Cognitive preparation. Students who choose CBL courses need to make the following two preparations from cognition. First of all, students should have a clear understanding of the difficulties that will arise in the learning process. Students will encounter difficulties from many aspects in their learning process. Without expectation, it will be easy for them to generate fear and retreat psychology, so as to give up halfway. Secondly, students need to be enthusiastic about curriculum content and identify interest points. This interest can be an interest in the form of a CBL course, in a challenging task or from other aspects.

Ability preparation. CBL plays a positive role in promoting students' innovation ability, and their participation in CBL also needs to have some related consciousness or basic abilities. The first point is that students need to have a certain ability of self-learning and exploration, that is, autonomous learning. In CBL, students are free to grasp any knowledge and methods. The second point is that students need to have certain practical application ability. Challenging tasks come from the real society. CBL emphasizes the practical application of theoretical knowledge, which is also the inevitable requirement for the cultivation of innovative skills. The third point is that students need to have comprehensive abilities, including teamwork, communication, coordination, and oral expression. Not only should students be prepared to respond to a number of challenges in the team, but also should have the minimum capabilities required for the whole process of challenging projects, which are important components of innovation ability.

Knowledge preparation. The threshold requirements for professional knowledge are not exactly the same in different kinds of CBL courses. Students with interdisciplinary and diverse knowledge systems are more likely to play a greater role in CBL. First of all, students should consolidate the relevant knowledge of the major and master the methods of research. When a team meets theoretical problems, students should be able to provide solutions from a professional perspective. Secondly, students should be good at absorbing other professional knowledge, quickly find the corresponding points of relevant disciplines, and promote the reconstruction of their own knowledge system.

3.3 Challenging tasks

The challenging task is the core of CBL, distinguishing it from PBL evidently. First, the task of CBL is needed to be explored. As teaching model, CBL must be firmly based on the promotion of the subject of students' scientific research ability, relying on challenging tasks and allowing students to exercise scientific exploration ability in practice. Secondly, the task of CBL is extended. The challenging task is not to simply complete a single or static task, but to run through the course, and integrate the various elements such as scenario presupposition, knowledge acquisition, practical exploration, self-reflection, and future development as a whole. With the improvement of ability, challenging tasks are tackled step by step, and eventually, students finish seemingly impossible tasks at the end of the semester. Finally, the task of CBL is centred around core goals. Challenging tasks are the ways or means to achieve goals. They are not separated from other curriculum elements but should be carried out closely around learning objectives. The task is from simple to complex, from easy to difficult, and learning objectives are realized in the continuous completion of tasks.

3.4 Teaching resources

Teaching resources are the important support for the successful development of CBL. According to its characteristics, CBL resources can be divided into three categories: site resources, teacher resources, and information resources.

The first is the **site resources**. Teaching resources that meet the requirements are the guarantee of CBL. Generally, the CBL teaching sites can be divided into two parts: the ordinary classroom and the laboratory. The common classroom is the place where teachers teach daily lessons. According to the objectives and requirements of the course, special classrooms can be designed for CBL, such as mobile Desk chairs, perfect multimedia facilities, and more humanized classroom environment designed to stimulate the desire of students to discuss with each other. The laboratory is the place for students to fulfil their tasks. CBL needs to provide students with a certain amount of experimental equipment. The related laboratory is not necessarily reorganized, but it can make full use of the existing experimental conditions in the Department. How to maximize the function of the laboratory is an important problem to be solved by the teachers.

The second is **teacher resources**. Challenging learning often involves interdisciplinary knowledge. If the questions raised by the students are unfamiliar areas of the teacher, the teacher should be able to provide them with a timely method of contact with the experts who can help solve the problem. On the other hand, teachers can arrange different professional students as teaching assistants to meet the need for answering questions in the process of completing challenging tasks.

The third is **information resources**. The promotion of challenging tasks needs to be based on existing research and achievements. Searching and integrating information is a key skill for students to focus on training. CBL should provide a convenient way for students to find all kinds of information, including paper and electronic materials, involving various types of theoretical knowledge, operation process, and application practice etc.

4 The impact of challenging tasks on the promotion of innovation ability

As the core of CBL, the realization of many goals and abilities of CBL courses cannot be separated from challenging tasks. There is a question in the questionnaire of this study, which allows students to sort the factors of innovation ability from the point of importance. Average comprehensive score = (Σ frequency x weight) / number of people. The higher the score, the higher the ranking for this option is. According to the results, 189 students who participated in the survey believed that the most important factor in the cultivation of innovative ability is challenging tasks.

Table 1 Importance ranking of factors for cultivating undergraduates' innovative ability

Options	Average comprehensive score
Design and implementation of challenging tasks	5.05
Autonomous Learning of the task team	4.14
The teacher's words and deeds	3.23
Study and discussion of innovative cases	3.1
Curriculum evaluation system with innovative and incentive	2.95
A relaxed and enjoyable course atmosphere	1.97

This paper will take challenging tasks as the main line, starting with the three stages of challenging task design, teaching organization for challenging tasks, learning as well as practice to accomplish challenging tasks, and analysing the role of challenging tasks in the process of innovation ability training.

4.1 Design of challenging task

Interest is the foundation and source of innovation. An interest in what we do will motivate individuals to strive for better results. Innovation is often born in the process of continuous pursuit of excellence. The key factor to create actively is arousing students' interest in learning, and challenging tasks will bear this important mission. In CBL, part of the task is not completely copied because there are no ready-made samples. In order to achieve the desired goal, students must get rid of their dependence. Another part of the task may have related results, but the requirements for challenging tasks are not simple replicas of existing one. If students want to obtain excellent curriculum evaluation, new results must be made better than existing results. Instead of copying the idea of the existing research results, this requires students to create a new approach, and to design the exploration activities independently. In the initial stage of the task design, the students will unknowingly accept the standard training of innovation ability.

In CBL, teachers should prepare challenging tasks and design relevant frameworks to achieve a balance of challenge, goal and interest. The challenging task design method can be divided into three types: teacher design leading, student design leading as well as teacher and student design together.

Table 2 Comparison of three design types for challenging tasks

Type	Example	Evaluation
Teacher design leading	The teachers arrange the subject directly.	It can better grasp the difficulty of challenging tasks and the combination of challenging tasks and curriculum goals, but it has a certain impact on students' characteristics and their autonomy.
Student design leading	The students choose projects independently and the teachers check them	It can better combine the characteristics of teams and students, but it is easy to make the difficulty of challenging tasks differently.

Continued Table 2 Comparison of three design types for challenging tasks

Type	Example	Evaluation
Teacher and student design together	The teachers provide the scope of the topic, and the students choose it independently	A good combination of the two characteristics and advantages of teacher design leading and student design leading.

On the one hand, the design of challenging tasks should not be decided completely by the teachers. The way which teachers assign challenging tasks directly will have a negative impact on the students' sense of classroom input. On the other hand, teachers should not be completely out of touch with the design of challenging tasks. Moderate control helps them to ensure consistency of difficulty and scientificity of design. Challenging tasks should not be static, and they should be constantly adjusted and optimized, so as to maintain novelty, advancement, scientificity, as well as foresight. At the beginning of the semester, teachers should communicate with the students in the proper way to master their ability, learning level as well as interest in time, which can give teachers the suggestions to change the teaching mode, the form of the course and the arrangement of the tasks. At the end of the semester, teachers can find out the shortcoming of curriculum from feedback from students, and further, optimize the design of challenging tasks. In addition, teachers should also pay attention to the development of this major, make challenging tasks in the forefront of the field, further stimulate students' desire for innovation, and prepare for the effective development of innovative practice.

4.2 Teaching organization for challenging tasks

If the design of challenging tasks provides a source for the cultivation of innovative consciousness, then the teaching organization of challenging tasks provides an important channel for the improvement of innovation quality and the training of innovative thinking. On the one hand, the teaching organization of CBL can help students acquire knowledge as well as create knowledge, and promote the development of challenging tasks. On the other hand, the teaching organization of CBL will help create a good atmosphere for innovation as well as development and lay the foundation for the cultivation of students' innovative ability. The group cooperative learning can effectively mobilize the students' enthusiasm as well as initiative, which can help them get rid of the excessive dependence on teachers, surpass the authoritative thinking set, meanwhile, can also pay more attention to the individual, meet the students' interest in learning, give full play to their individual advantages and implement effective individualized learning. In CBL, the teaching organization of the curriculum is carried out around challenging tasks. The content of the teaching is to serve the students in the mastery of learning methods. The form of teaching is conducive to the training of students' innovative ability. To carry out teaching organizations around challenging tasks, we should pay special attention to the following questions.

The first point is to deal with the relationship between challenging tasks and basic theoretical learning. CBL is a kind of teaching mode, which uses "challenge" to drive "learning", and learning is one of its goals. CBL is inseparable from the links of basic theoretical learning, and the completion of challenging tasks is also inseparable from the foundation laid down by the theoretical study. There are two misunderstandings to be avoided in challenging learning. The first mistake is that the teacher completely arranges the class time to teach the content of courses, so there is no essential difference between CBL and traditional courses. Another mistake is that the teacher completely arranges the class time for students to complete challenging tasks. As we all know, one of the challenges of CBL is that a large amount of complicated curriculum tasks, requiring a great deal of knowledge, will pose a challenge to undergraduates' psychological endurance. The profound knowledge contained in some challenging tasks requires teachers to give an analysis to help students understand and digest them. Otherwise, the lack of this basic knowledge will make the challenging tasks unable to advance, reduce the students' enthusiasm for learning, and eventually hinder the use of innovative thinking and the output of innovative results. In the course of CBL, it is necessary to complete challenging tasks as well as learn basic theories, and dynamic adjustment is made according to students' learning progress. In the early stage, teachers should focus on basic theoretical study, lay a solid foundation for students and enhance students' self-confidence. In the later stage, the course is inclined to the practice of challenging tasks, giving students the opportunity to demonstrate, oral expression, and to put forward critical views on the results of other teams. Finally, the students' creative and innovative skills are fully exercised.

The second point is to deal with the relationship between teachers and students in theoretical teaching. In order to improve the ability of innovation, we must first change the state of the students' passive acceptance in the course. In maintaining the equality of the teacher-student relationship in CBL, the role of the teaching organization is more important. In consciousness, teachers should change their authoritative thinking and inspire, support, guide as well as encourage students' learning activities while communicating with them on an equal basis. In the atmosphere, teachers should provide students with a democratic, relaxed and free atmosphere, so that students can always maintain a positive psychological state of exploration and stimulate their interest in learning. In the teaching style, teachers should be flexible and diverse, so that the classroom will be more unique, artistic and novelty, which will have a positive impact on students' learning effect.

4.3 Learning as well as practice to accomplish challenging tasks

CBL emphasizes the combination of theory and practice, which in favour of producing new ideas or results in the process of integration. Whether the design of the challenging task or the teaching organization lays the foundation for the innovative achievements, and the transformation of innovative thinking into innovative results cannot be separated from practical activities.

Learning as well as practice is first reflected in team learning for the completion of challenging tasks. Students have full autonomy to form learning groups and communicate their queries in the course of learning. The study group can not only answer questions, check vacancy or holes, improve the overall knowledge level of the team members, and make some puzzling questions of the individual be dealt with effectively, but also can make the students create new ideas after collision and distillation.

Learning as well as practice can also be reflected in practical activities to accomplish challenging tasks. Innovative skills need to be learned in practice, and only by continuous use and practice can we improve their familiarity with it. In addition, innovative skills have the characteristics of stability, that is, once they are cultured, they can be maintained for a long time, and they will be further upgraded and optimized in the future practice.

One of the main objectives of CBL is to help students master innovative skills, which requires specific practical training. In view of the challenging tasks, teachers provide students with innovative practice platform such as scientific research laboratory, software database, and innovation practice base, so that students can use knowledge to solve problems and improve their innovation ability.

5 The future development of CBL in Tsinghua University

5.1 General situation of the CBL demonstration course in Tsinghua University

Since the first CBL demonstration course was launched in 2012, the construction of relevant courses in Tsinghua University has been steadily advancing. In addition to the professional compulsory courses that have to be selected, many non-mandatory selective CBL demonstration courses also provide students with free choice space. Many students choose CBL demonstration courses mainly because they are interested in the form of the curriculum or believe that the curriculum can exercise their ability. Taking interest as the key element of selecting courses is more suitable for CBL theory, reflecting the advantages of this kind of teaching mode. After several years of development, the CBL demonstration course of Tsinghua University has achieved certain positive results. It has achieved the expected effect of the school administrators, and there are three points from the overall level.

The first point is to change the traditional lecturing teaching mode and promote the combination of theory and practice. In the exploration of the cultivation of innovative talents, the CBL demonstration course of Tsinghua University first enriches the course link, and transforms the single teacher's teaching into a richer form, including ordinary teaching, classroom discussion, completion of challenging tasks and reports. The integration of challenging tasks, in particular, enriches the content of the curriculum, inspires the students' potential and the desire to overcome the difficulties, and gives them the opportunity to apply the knowledge they have learned to the actual problems. Innovation comes not only from thought but also from practice. Their interaction promotes innovation capability.

The second point is to activate the curriculum atmosphere and break the thinking set in free discussion. Limiting creative thinking is stereotyped thinking pattern. In order to create innovative ability, we first need to learn to think independently and form our own judgments as well as opinions. There are two ways to break the thinking set in CBL. The first method is the challenging task that students need to explore independently. Students are not subject to stereotyped constraints without existing templates. Another method is active curriculum atmosphere and classroom discussion. CBL not only encourages students to speak freely but also requires them to fully express their distinctive opinions. The presentation of ideas or questions is not only in the daily teaching of teachers but also in the on-site report of students' challenging tasks.

The third point is to cultivate students' interests and attract their all-around participation. One of the directions for the reform of the CBL in Tsinghua University is to set up a student's main position in the course. While imparting the basic knowledge, it allows the students to choose the challenging task that is consistent with their interests. On the premise of making up the research group according to the individual's will, the students are free to choose the theory, method, and way of solving the problem, so long as they can achieve the training goals of the challenging task, all the links are held by themselves. The autonomy of curriculum not only increases students' sense of responsibility and self-management but also creates favourable conditions for their interest and hobbies development.

5.2 Suggestions for promoting the development of CBL

According to the existing achievements, the next stage of the work of Tsinghua University should focus on updating concepts and building systems. In order to better regulate the development of CBL, school administrators can set up a special steering group to guide the construction and promotion of relevant courses. First of all, the school administrators should formulate a sustainable financial support policy, set up a multiparty channel to raise funds, and provide students with a more diverse choice of tasks under the premise of the actual course of the curriculum. Secondly, the school administrators should formulate a scientific CBL system, follow up the latest situation of all kinds of Demonstration Courses, and put forward the optimization opinions on the course that the difficulty of challenging tasks is not up to the standard or the reform does not meet the requirements. Thirdly, the school administrators should give more support to CBL teachers. School administrators can provide more learning opportunities for teachers to enhance their CBL teaching skills, and jointly develop courses to better serve students. Fourth, the school administrators should optimize existing professional training programs. They should organize the teachers of various departments to study the feasibility of adjusting the students' training program, and bring the CBL into the courses that the students need to choose. Students can choose the corresponding CBL courses according to their interests. Considering that students need to devote a lot of time and energy to challenging tasks, the number of students' elective courses and curriculum credits are also required to be dynamically adjusted in the optimization of training programs. In addition, schools may consider setting up some CBL lectures or other transitional courses to enable students to understand the norms as well as requirements of the CBL teaching mode and reduce the conflict of these kinds of courses.

6 A summary of the full paper

The CBL demonstration course is put forward by the school teaching affairs office in the context of the party and the state vigorously advocating the training of innovative talents and combining with the actual situation of Tsinghua University. CBL is based on PBL and includes four elements: teachers, students, challenging tasks and teaching resources. The challenging task is the core of CBL. It promotes the cultivation of students' innovative ability through three aspects of challenging task design, teaching organization for challenging tasks, and learning as well as practice to accomplish challenging tasks. The development of CBL in Tsinghua University has achieved certain achievements. In the future, we need to pay attention to the construction of concepts and systems and promote the joint participation of teachers as well as students in the practice of CBL.

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On the mechanics curriculum for innovative engineering[1]

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Abstract

In the 21st century, innovation was regarded as the core of the sustainable development of China. Cultivation of top-notch talents for technological innovation is not only the famous "Tsien Hsuesen's Question", but also a critical issue of China in the new century. Mechanics, as the foundation of engineering science, should play a key role in exploration the answer to Tsien's Question. In accordance with this mission, the Tsien Excellence in Engineering Program (TEEP) was set up by Tsinghua University in 2009, aiming at cultivating talented students in engineering. TEEP is also part of the Tsinghua Xuetang Program and the National Top-notch Talent Development Program. As the principal professor of TEEP, we first demonstrated three basic points of view: Mechanics has the "gene" of both quantification and technological innovation; the former has been developed well in the past, while the latter has been relatively poorly developed; the imbalance in the developments may have been the reason responsible for the difficulties that mechanics has encountered in the past 30 years and have significantly limited engineering innovation. Then, based on a brief introduction of the curriculum of TEEP and the cases of its implementation, we show how such a "Learning Through Research" curriculum can significantly reduce the total learning time cost, strengthen the fundamental knowledge of science, and foster the students' strong interests in academic research and technological innovation. The TEEP curriculum has been warmly welcomed by students and teachers alike from many disciplines.

Keywords: engineering foundation, mechanics gene, learning through research, curriculum

Type of Contribution: Best practice paper

1 Introduction

The background of this paper is the pain of the country as coined by "Tsien Hsuesen's Question": "China is not fully developed yet. One important reason is that no university develops proper education model for cultivating talents for scientific research or technological inventions. This is a big problem."

Since the new Millennium, emerging technologies such as the Internet and artificial intelligence have accelerated the process of bringing human beings closer to a "singularity" that has never been confronted: Human intelligence has been surpassed by Non-human beings. A dramatic change in education, i.e., from knowledge transfer to creative ability cultivation, is expected and the speed and the scope of this transition are far more than expected. Therefore, to find the answer of Tsien's question quickly becomes one of the most urgent national strategic challenges.

The structure of this paper is as follows: Section I describes the core characteristics of mechanics; section II

[1] This article is a concise version of Ref. [1] and is translated by L.P. Xu and C.Q. Chen.

presents the new curriculum of mechanics for innovative engineering, with a discussion of the history of its past, present and future development; in Section III we introduces the innovative educational concept, curriculum, practical cases of Tsien Excellence in Engineering (TEEP) program, and the thoughts on how to construct a future-oriented technological innovation curriculum under the background of engineering; perspectives and discussions on the development of future technological innovation and mechanics are given in Section Ⅳ.

2 The "genes" of mechanics

What are the essential characteristics and "genes" of mechanics? Newton's "Mathematical Principles of Natural Philosophy," published in 1687, marked that mechanics has become the first quantitative science. From then on, the study of the relationship between the motion, the force, etc., and the quantification of materials has become a basic feature of mechanics. In the following two centuries, mechanics and its scientific methodologies and mathematical methods dominated the development of science. Lagrange-Hamilton mechanics, electrodynamics, thermodynamics, relativity, quantum mechanics, etc., have laid down the basis of today's entire physical science.

Newton is the founder of modern science and the inventor of calculus. The quantitative characteristics of mechanics have made it inseparable and complementary to mathematics for a long time. This phenomenon continued until the middle of the 20th century. For example, Cauchy was one of the greatest mathematicians of the nineteenth century and one of the founders of applied mechanics. Another example was the Department of Mathematics and Mechanics of Peking University established in 1952 and the Department of Mathematics and Engineering Mechanics of Tsinghua University established in 1958, where Mechanics and Mathematics did not separate until the “Cultural Revolution”. Along the quantification direction, mechanics has also promoted the development of many branches of mathematics.

The industrial revolution in the 18th century has decisively promoted engineering and technology from qualitative to quantitative. The basic equations of elasticity and fluid mechanics established in the first half of the 19th century by Navy, Cauchy, Poisson, Stokes, among others made it possible to model the deformation and flow of solids and fluids. Since then, mechanics has evolved into the current applied mechanics system, the basis of engineering sciences.

The aforementioned history of mechanics shows that it is the foundation of engineering science and has the characteristics of science, mathematics, and engineering. Due to this characteristic, mechanics plays a unique quantification role in engineering (or technical science). The mathematical attribute brings the quantitative "gene" of mechanics, and the scientific attribute endows the innovation "Gene". In the past century, one of the representative developments of the quantitative gene is the finite element method, while the representative of technology innovation gene is the aerospace technology and industry.

3 Curriculum of mechanics in engineering schools

In the major engineering schools at Tsinghua University (i.e., School of Civil Engineering, School of Architecture, School of Mechanical Engineering, School of Aerospace Engineering, School of Environment and School of Materials Science), theoretical mechanics, mechanics of materials (or a combination of the two as engineering mechanics) and fluid mechanics are deemed as compulsory courses. Compulsory mechanics courses in most engineering schools of Chinese universities are similar. Although not listed as the core courses, mechanics in information science and engineering, biomedical engineering, etc., are also very important.

The questions are what the factors that prompted the engineering schools to choose the above-mentioned mechanics courses are and how these factors are different today and what the fundamental changes are that may occur in the coming decades.

3.1 Historical factors

Before the advance in computers in the 1950s and the development of computational mechanics methods such as the finite-element method in the 1960s, there were very few problems in elasticity or fluid mechanics could be solved. Pioneers like Prandtl and von Karman developed boundary layer theory and singular perturbation theory which were adopted to solve a large class of problems in fluid mechanics and many most critical problems in aerospace engineering at that time. von Karman was widely recognized as one of the most important aerospace scientist and engineer of the twentieth century and is the first winner of the U.S. National Medal of Science (1962). In response to the large number of engineers' needs, Timoshenko has published a number of textbooks on mechanics of materials, structural mechanics, theory of elasticity, elastic stability theory, vibration in plates and shells since the 1930s. These textbooks have been translated into multiple languages and published in various countries around the world, and have become the mainstream framework of the curriculum of engineering mechanics in China and has continued to serve the role in the near future.

Mechanics of materials is usually limited to "one-dimensional" solids such as beam and bar. The advantages are: (1) Such systems are very popular in civil engineering and mechanical engineering; (2) Usually, analytical solutions to the obtained differential equations can be obtained; (3) The analytical solutions, once available, are very powerful for the design of "one-dimensional" systems, not only at macroscopic scales, but also at small scales even down to 10 nanometers. For example, the atomic force microscope, based on the working mechanism of the deformation of beam, can have a sub-nanometer (10-10 m) spatial resolution and the force resolution of pico-newton (10- 12N). Another example is that the beam resonance theory is the core of many sensors having wide applications in Internet of things, automatic driving, and micro- electromechanical systems, etc. The aforementioned advantages of mechanics of materials make it still being an essential course in engineering programs.

In order to investigate the mechanics problems of two-dimensional or three- dimensional bodies in various applications such as aerospace engineering, ship- building, civil engineering, chemical engineering, one has to resort to theory of elasticity. In order to tract these problems, one needs mathematical methods in the physical sciences, theory of partial differential equations, asymptotic methods (perturbation theory, variational methods, etc.), and even functional analysis. That means, students need to spend many more hours learning various mathematical tools other than just calculus. Furthermore, the problems in elasticity that can be analytically solved are extremely limited. Such a low input-output ratio is unacceptable to most engineering students and engineers.

With the above reasons, it is not difficult to understand the following phenomena: (1) most engineering departments arrange a concise course on elasticity; (2) experts in mechanics often become applied mathematicians; (3) a considerable proportion of top researchers in engineering are also experts in mechanics.

In addition to the quantification gene, mechanics should have had the gene of technological innovation.

Although it is common there were some top researchers in applied mechanics who turned to be the founder of new engineering disciplines. Among them, the outstanding representatives are von Karman and Tsien Hsuesen in the aerospace field, and Fung Yuan-Cheng in the field of biomechanics. In addition, Tsien Hsuesen made significant contributions to physical mechanics and theory of systems engineering.

3.2 Today's factors and the difficulties of mechanics

The most influential changes in modern applied mechanics were the rapid development of computers in the 1950s, and the emergence of various computational methods for mechanics (e.g., the finite element method and computational fluid dynamics). With the advances in the numerical methods, it became increasingly feasible to track complex mechanics problems. Moreover, a number of powerful and user-friendly commercial software have been developed to implement the numerical methods. As a result, have enablenon-mechanics experts to apply these methods conveniently, traditional mechanics training seems to be no longer necessary. This led directly to the aforementioned close down of the mechanics departments in Chinese and American universities.

3.3 Trends in the coming decades

Most engineering departments correspond to a specific industrial field. This correspondence on the one hand determines the current practicality of an engineering discipline, and on the other it also determines its relative transitory nature. In contrast, without a single industry background, the core mission of applied mechanics is to quantitatively study the movement of matter, the relationship between motion and force, implying that mechanics will inevitably continue to play a fundamental role in engineering in the foreseeable future. Therefore, it is expected to continue to play a crucial role in the birth (innovation) and maturity (quantification) of new engineering disciplines. In this sense, mechanics researchers are both unfortunate - difficult to play a major role in mature industries - and lucky -with relatively long-term vitality.

In the 21st century, the exponential growth of human knowledge has become even more obvious. The impact of the information, biotechnology, and nanotechnology has become ubiquitous. The development of technology such as internet, big data, artificial intelligence, robotics, etc., has brought unprecedented opportunities and challenges to our society, economy, and education. Where will mechanics go in this new context? Can we keep its momentum of development by strengthening our role as the foundation of engineering sciences? Or will it disappear quickly or be assimilated in different specific engineering subjects? How should engineering mechanics and the mechanics curriculum be reconstructed to meet the increasingly urgent needs of China and the world for the cultivation of technological innovation and innovative talents?

4 TEEP, a pilot program for Innovative Engineering education

Tsinghua University initiated the Tsien Excellence in Engineering Program (TEEP) in 2009, aiming at answering, at least partially, the above-mentioned questions.

4.1 Vision and Mission of TEEP

TEEP is positioned as the foundation of engineering. Its core mission is to explore how to cultivate innovative talents who are interested in changing the world through technology and try to answer Tsien’s Question.

Headed by Prof. Quanshui Zheng, the principal scientists of the TEEP program, a team of dozens of researchers and staffs from eight engineering schools and departments of Tsinghua University, works together to build an open and interdisciplinary system to help students develop technical innovation capability and leadership.

From a practical point of view, survey of the graduates in the past 5 years shows that that TEEP, as an elite engineering program, has already been widely recognized. For example, the most graduates continued their higher degree study ,with roughly one- third in mechanics, the others in other specific engineering disciplines such as aerospace engineering, mechanical engineering, civil engineering, materials science and engineering, information technology, biomedical engineering etc.

4.2 TEEP's curriculum and students' "T-shape" knowledge system

The total credit requirement of TEEP (2016 edition) is 148, which is divided into three categories: the challenging honor courses (70 credits), basic structural courses (no less than 50 credits), and general courses (sports, English, etc., a total of 28 credits). In the curriculum, the 18 challenging courses are divided into 6 sub-categories: mathematics, natural sciences, engineering foundation, professional and research, humanities, integrated learning, respectively. These 18 courses are all highly challenging and well arranged in the first three years of study. To guarantee their learning effect, students can take no more than three of these challenging courses every semester. This curriculum, enforced since 2016 at TEEP, was chosen as the only pilot undergraduate honor degree program at Tsinghua University.

The basic philosophy of TEEP is student-centered. In this program, we encourage students to choose their possible career based on their interests and expertise, and to strengthen either the quantification gene or the innovation gene, or both. If one prefers the former, he or she will be recommended to take more applied mathematics, computational mathematics, and computational mechanics, otherwise he or she will be encouraged to further study quantum mechanics, solid physics, cell biology, etc. They are encouraged to dive deep into knowledge, build up their own passion, ability and self-confidence in creating new knowledge, and eventually find their own development path for future learning and innovation.

At present, the curriculum of mechanics and most other engineering majors in China offer very limited courses of chemistry and biology, and the physics courses are also relatively weak. In contrast, TEEP not only increase the ratio of these basic sciences, but also increases the request and challenging level. The purpose is to strengthen their capability on scientific thinking and original innovation invention.

Compared with the requests of more than 170 credits in most engineering majors at Tsinghua University, TEEP significantly reduce the total study hours and emphasizes on the quality and challenging level for the core courses. The question is, given TEEP students have more diverse professional development paths, one may worry that the decreasing the number of credits and shrinking the curriculum will undermine the chance for students to construct a comprehensive knowledge and skill structure. Our brief reply is that TEEP is not trying to provide one plan containing all courses to serve the students with diverse needs. In fact, the curriculum is highly modulated and personalized, so that different students can take different courses to build their unique "T-shape" knowledge and skill system.

4.3 Reform of TEEP's Core Mechanics Courses

Four courses, i.e., Introduction of Dynamics and Control System, Fundamentals of Solid Mechanics, Fluid Mechanics, and Thermodynamics and Statistical Physics, are taken as the essential core courses for most engineering schools at Tsinghua University. At TEEP, however, the courses are largely reformed.

The first question is: why do we choose these four courses? Classic Newtonian-Lagrangian-Hamiltonian mechanics focuses on the laws of force and motion of a rigid bodies. The feature of elastic mechanics, or solid mechanics in a more general sense, is deformable solids, which is caused by the interactions between solid atoms/molecules that are dominated by chemical bonds. The interaction between atoms or molecules of object (gas or liquid) fluid mechanics is dominated by van der Waals forces, and its essential feature is large deformation. For the students to move from the understanding at university physics level to the level of complex material systems (such as concrete and mudslides) or complex behaviors (such as turbulence and tornadoes) that must be faced in engineering science, it is necessary to develop the concepts of deformation and their mathematical descriptions.

4.4 Learning through research and Personalized Professional Courses

To improve the personalized learning, TEEP cooperates with various engineering schools at Tsinghua University. In the first two years, after taking essential courses and doing basic research training (student research training, SRT), most TEEP students can determine their own interest and development path and identify their mentor when they put forward their ORIC (Open Research for Innovation Challenge) research program. Mentors can help students design personalized learning path and choose core professional courses accordingly.

Let's take Hu jiliang, a student of TEEP graduated in 2017, as an example. His summary of the 4 years of “Learning Through Research” process is as following:

- Freshman: Extensive understanding of solid mechanics, nanotechnology, and bioengineering, among many others. (Methods: Classes, visits to the laboratory, participation in the group meetings, and discussion with teachers).
- Sophomore: Deep dived into biophysics with a lot of time to hands-on research (2000 hours) and learned a lot of knowledge of biology and biological experimental techniques.
- Junior Years: Independently raised original research proposals and contacted several laboratories for research and discussion (Department of Mechanics, Department of Biomechanics, Center for Micro and Nano Mechanics, and Biosciences of Tsinghua University; Peking University; MIT) Led and Participated Multiple research projects, published many papers.
- Senior year: In-depth study of complex systems science, development and evolution. Communicated with researchers in different fields and help younger students solve problems in their study and share experiences with them.

Hu Jiliang is a example on personalized learning through research path in TEEP. In terms of research, he published 5 papers, one of which he is the first author published on PNAS.

5 Perspectives and Discussions

At present, the curriculum of mechanics of engineering schools in China did not have any essential reform from the system of half a century ago when computer and computer-based calculation methods started to appear. The essential mission and powerful vitality of applied mechanics lies in continuous creating of new engineering disciplines (such as what von Karman, **Tsien Hsuesen**, and Fung Yuan-Cheng have done), or helping the development of new engineering disciplines by improving their quantitative level, or helping solve complex and critical engineering and technical problems. These are the original advantages of applied mechanics as the unique and long-lasting foundation of engineering science.

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Students' experience with Dassault Systemes' ILICE platform for PBL

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Abstract

Students increasingly bring informal digital tools and practices into formal educational arenas. For collaboration and organisation of the problem-based project work at Aalborg University (AAU), students equivalently use tools that they know from everyday life and previous education, e.g. Facebook and Google Docs. These might be easy to use, but not necessarily the best tools to support the learning process and experience. The university currently does not provide a feasible alternative solution for digital support for project work. The primary virtual learning environment of the university is a learning management system mainly used for delivering course descriptions and resources, leaving the students on their own with respect to collaboration tools. This gap is remarkable, especially given the fact that AAU considers the Problem Based Learning (PBL) to be the core of the learning activities.

Dassault Systemes' ILICE platform is a project management platform made for PBL engineering education. This paper reports and discusses results from a pilot study of a student group using the ILICE framework to support their PBL work, for a large project corresponding to 50 % of the students' workload during the semester. ILICE is an acronym for Inspire, Learn, Create and Evaluate, which reflect macro-processes in industrial work, and the platform contains applications supporting these processes. In this work, we study the ILICE platform as a professional alternative to the students' current tools by analysing the students' use and experience of using the platform. On basis of the results, we define factors characterising the context, project and student group, and discuss how these influence whether using the platform is beneficial for the students or not. We discuss the potential of the ILICE platform and the demands and challenges of implementing an industrial framework in a PBL context, including how a PBL-project differ from an industrial project.

Keywords: Problem-based learning, ILICE, project management platform

Type of contribution: **research paper**

1 Introduction

More and more communication and exchange of information are happening online. The educational sector is no exception: Universities are making both administration, information and educational materials available online, and the students are used to search and access materials from a large amount of online resources, including not only traditional scientific literature, but also increasingly courses such as those offered as

Massive Open Online Courses - along with the many other formats of teaching materials available freely or for purchase. For universities, their main communication channel for educational resources is often Learning Management Systems (LMS) such as Moodle, Blackboard and Canvas, with market shares of 65%/12%/1% in Europe (e-Literate, 2016) and 19%/33%/20% in the US (Edutechnica, 2017).

However, these platforms are all focusing on supporting a classical university setting, where the students take a number of courses, which are again subdivided into a number of lectures. While there is some support for interaction between students with courses, for example in terms of workshops with peer feedback, chat functions, and discussion forums, there is little support for communication between student groups working in Problem Based Learning settings. Additional platforms focusing on peer assessments and peer gradings, such as Peergrade (https://www.peergrade.io/) and Teammates (http://teammatesv4.appspot.com) have some functionality but do not really support the project work in terms of e.g. project planning, project management, document sharing and version control, information sharing etc. As such, the students are often left on their own, and either end up using tools that they know from everyday life such as Google Docs/Drive, Facebook and Messenger (Rongbutsri, Khalid and Ryberg, 2011; Guerra, 2015; Sørensen, 2018) or tools that only do part of the job such as Github for sharing of code and code documentation.

In this study, we offered the students to use a professional collaboration platform widely used in industry, which facilitates all parts of the project work and at the same time contains a number of programs/tools used by engineering students e.g. for modelling and simulation. While the platform is developed for use in professional settings rather than for academic use, it provides an interesting setting for doing research on how the students use the platform, and how this again impacts their project work. In this study, we follow a group of six undergraduate students (3rd year), which are using the platform throughout the semester, and where the use is evaluated by conducting qualitative interviews during the semester. The use of the platform was supported by training and support, and we encouraged the students to test out as much functionality as possible. However, to get a realistic picture of the usage, the students were always free to also use other tools and methods as they would see fit their projects.

The main objective of the study was to determine if a platform as ILICE can support groups of students working in a PBL setting, and to determine which factors influence the use and usefulness of the platform. This also helps us to identify a number of points where the platform in the current setting does not really match the needs of the students.

The rest of the paper is organised as follows. Section 2 elaborates on the background for the study, specifically focusing on how PBL is conducted at Aalborg University and trends within European education as outlined in the Agenda for the Modernisation of Higher Education promoted by the European Commission, followed by Section 3, which introduces the ILICE framework. Section 4 presents the research methodology followed by the analysis in Section 5, and finally, Section 6 presents the conclusions and discussions.

2 Background

AAUs educational model is based on problem-based and project-oriented learning. It was developed and deployed across the entire university since the inauguration in 1974 (Kolmos, Fink and Krogh, 2004; Holgaard *et al.*, 2014). The students work with PBL every semester (3-4 months), typically in groups of 4-6 students, with an authentic and self-selected problem. The problem provides a framework for the students to formulate, analyse and solve their problem, and they work together to manage the project and write a joint report, which reflects the process from the problem formulation to the solution. The students go through different types of inquiry: Problem identification, problem formulation, theoretical and methodological inquiry, data collection, analysis and discussion. Every group is assigned a supervisor, which functions both as facilitator and professional support. In parallel with the project work, the students have project-supporting courses with relevant theories and methods. The students have a joint responsibility to plan and manage the work process including which supporting technologies to use. With this background in mind, AAU is currently investigating how digital tools can be used to support the students, especially with the PBL approach in mind, and how to find the optimal combination of virtual and physical learning spaces. This is in line with the challenges outlined in the EU Agenda on Education (European Commission, 2011), which mentions the need for improving the quality and relevance of higher education through e.g.:

- Exploiting the transformational benefits of ICTs and other new technologies to enrich teaching, improve learning experiences, and facilitate access through distance learning and virtual mobility.
- Stimulating the development of entrepreneurial, creative and innovation skills and promote innovation in higher education through more interactive learning environments.
- Increased mobility and cross-border cooperation.

All these points can be supported through the combination of PBL with relevant digital collaboration tools, especially if used in international and interdisciplinary settings.

This pilot study took place in the autumn semester 2017. We offered a project group from the study programme Electronics and IT to use Dassault Systemés ILICE framework for their project work. The group formation took place early September and the group had to hand-in their project report ultimo December. The group obtained access to the platform at the beginning of the project period and was introduced to the platform through a two-day workshop conducted by Dassault Systemé. After this workshop, the students had the possibility to ask for support, but it was still their own responsibility to plan and manage their project work and how or whether the platform could be a part of it.

3 The ILICE Framework

The platform, we have chosen to offer the students are Dassault Systemes' ILICE platform for PBL, which is part of the 3DEXPERIENCE platform (Dassault Systeme, 2018; Fouger, 2018). It is a virtual workplace consisting of five sections: INSPIRE, LEARN, INNOVATE, CREATE and EVALUATE. ILICE is an industrial framework, where the INSPIRE, INNOVATE and CREATE sections are three broad categories reflecting macro-processes in the industry, while the LEARN and EVALUATE sections are educational add-ons:

The INSPIRE section consists of a dashboard, where the students can collect different kinds of resources, including hyperlinks, videos, and RSS-feeds. INSPIRE intends to contextualise the problem, and help the student to determine and analyse their problem.

The LEARN section is for the collection of formal and informal learning resources.

In the CREATE section, the students can find an industry driven toolset. The tools reflect traditional activities for product and process engineering and include, among others, tools for 3D modelling.

The INNOVATE section is for communication, which enables collaboration, production of ideas and negotiation among a common solution of the problem.

The EVALUATE section intends to help educators and students to individually and collectively monitor their learning activities and performance indicators.

4 Method

This pilot study is based on three qualitative semi-structured group interviews and observations of the activities on the 3D experience platform during the project period. The interviews were distributed evenly over the period from the introductory workshop to the project hand-in, spanning approximately one month. All six members of the project group took part in the interviews, except for the first interview where one of the students was unable to attend. The duration was one hour for each interview.

Between the interviews, we observed the students' use of the platform. In this way, we followed the progression in the group's use of the platform and the rationale behind their use through different project phases. We were neither active or invisible participants on the 3D experience platform. We planned the time and location for the interview in the INNOVATE section and liked a few messages.

We used a semi-structured approach to the interview i.e. the scripting of the interview was structured by themes, but at the same time flexible and open to exploring interesting themes emerging in the interview situation (Kvale and Brinkmann, 2009). The creation of interview scripts was shaped by observations on the platform as well as previous interviews. After each interview, we transcribed the interview and did a qualitative coding to analysis the interview and identify relevant themes for the coming interviews.

5 Analysis – the ILICE framework from a student perspective

The intention of this project was to give students the possibility to use ILICE to support their project work and to evaluate their use and experience with this. As described in the following sections, the students have not fully utilised all features of the platform, and so their descriptions of the platform may be characterised as impressions rather than experiences. Their experience shows the complexity of the introduction of a new collaboration platform and the student rationales for choosing technology. It also shows how close the collaboration tools and collaboration practice are intertwined. After summarising the student use of each section of the platform, we look further into the student rationale behind their use or/and deselection of the platform, and the students' perspective on the potential of the ILICE platform.

5.1 The student use of the ILICE framework

In this section, we describe the student use of the ILICE framework, section by section, based on our observations and the three interviews.

INSPIRE: The project group did not use the INSPIRE section actively. Shortly after the workshop, the group shared a few videos and set up RSS-feeds with news from the company by which they collaborated. They saw this section as the most useful tool in the beginning of the project where they needed to figure out the scope of the project. When the group was introduced to ILICE, they already settled in on what they wanted to do with their project, which according to the students is why they did not find this section useful.

LEARN: In the LEARN section, the group had the lecture schedule from Moodle and the learn tab contained a collection of links to 3D experience tutorials. The group did not check the schedule in LEARN, though. Instead, they went directly to the Moodle platform for content descriptions and resources for the courses.

INNOVATE: The students have only used the communication thread in INNOVATE to a limited extent: They used it to share a few pictures of the testing process, besides the coordination of dates and choice of location for the interviews.

EVALUATE: Shortly after the introductory workshop, the group embarked on the construction of a time schedule; they divided the project period into phases and defined tasks with a deadline for each phase. The EVALUATE section contains a different view of the project planning: a time schedule, a Gantt diagram, and phase gate diagram. During the first half of the project period, the project group updated their time schedule about two times a week; they marked finished tasks and synthesised the time schedule with the blackboard. The time schedule worked as a reference point in relation to how far the group was in their process. At the first interview, the students explain that the time schedule contributed with a good overview and forced them to reflect on how different tasks are connected and to make more specific task descriptions of more specific deadlines than they have done in the previous project. One of the students describes that the time schedule brings 'a bit more perspective':

I think it forces us a bit more perspective because you have to know is this a subtask to something else or where in this project do this belong. So it forces us to sometime put it into like the bigger picture, like why are we doing exactly this, this because it is a part of this which is a part of this phase (Student 1 – first interview)

The group did register when a task was done, but did not add new tasks during the project period. As the project work intensified, the intervals between the students checking the time schedule became longer, and in the last period of the project, the students do not update the time schedule at all.

5.2 Competition from easy-to-use tools already familiar to the students

In many ways, the group had a well-working practice and already used many other digital tools with at least seemingly similar functionalities. Their rationale for deselection of some functions and gradually dropping other functions of the ILICE-platform relates to their established working practices and habits including the use of such other tools. In the following, we look further into the student work practice and their rationale for choosing technology to support their project work and for the limited use of the ILICE platform.

On a usual workday, the group members meet from 8 am to 4 pm to work on their project, only interrupted by lectures. The project group has a dedicated group room with their own key and "inhabited" with e.g. a coffee maker. The project group use the blackboard in the group room for planning by writing the ongoing tasks and the responsible group members on the blackboard. The groups often work in peers/subgroups with specific tasks listed on the blackboard. When a subgroup has finished their task, they either help the other subgroups or they begin a new task after coordination with the rest of the group. To digitally support the project work, the project group writes their project in ShareLatex, and store and share resources with Microsoft Onedrive. When the group has to communicate and they are not together, it happens through a common Facebook thread, mostly used for short informative messages, e.g. 'I am late' and for sharing links.

The limited use of the ILICE platform and the students' rationale behind the use relate to the established digital infrastructure as well as the physical study environment. According to the students, the main reason for the limited use of the LEARN and INNOVATE sections was that they had already tools for the purposes of resource sharing and communication. The students emphasize that Facebook is both the easiest and the quickest way to communicate when they are not together; everyone already uses Facebook and is notified on their phone if there are any updates. In a similar way, the students explain the use of Microsoft Onedrive (sharing and storage solution) and Moodle (LMS), which are both offered by the university, as the main reason for not using LEARN. In this way, in our particular setting, the ILICE compete with tools, with which the students already have an established practice and which they find easier and to use as well.

At the interviews, the students describe, that the group did not experience a strong need for the INNOVATE section and for communicating through the platform in general, because they were together in the same location throughout the main part of their study time. The students emphasize more than once, that if they were geographically distributed, they would have found the ILICE-platform more useful:

As people are working together without sitting together, it can be really helpful to get an overview. Because when we sit together, we don't really need that overview because it is easy to maintain because we are sitting together and can talk together. But if we couldn't do that then the platform would be a lot more useful (Student 3, first interview).

It is always easier to share it in person. So if it is not an option, then this could be used. If you are working in a group in separate rooms then maybe it could be kind of used maybe to summarise, but I think you'll need to be there face to face, because it is so much easier - especially if you can draw on a blackboard it makes it so much easier to communicate what you are talking about. Especially when you not always quite know what you are saying yourself, cause you don't quite understand it. (Student 1 about the INSPIRE section, third interview)

The students describe it as both more *convenient, quicker* and *easier* to communicate face-to-face than using ILICE or another digital tool. The blackboard work as a springboard for discussions and is also the group's primary tool for planning. Likewise, the students praise the blackboard for being quick and easy to use for planning, and for being suitable for both bigger tasks and smaller reminders. "*You just have to cast an eye over the laptop to the blackboard to get a quick overview",* Student 1 says.

Furthermore, the students find that the platform has a steep learning curve and points out more than once during the interviews that if the platform should be an integrated part of the project, the students have to know it beforehand. Finding the learning curve steep is also an essential part of the explanation of the limited use, and indicates that more support and facilitation is needed from the beginning.

Despite positive experiences by using the EVALUATE session for the time schedule, the project group gradually dropped to update or just to check the schedule. At the interview, the students give two main reasons for this: That they have to work on the project, and that they forgot:

*It (*the 3D experience platform*) is in the back of your head right now. We have something we need to work on our project right now. It is the most important thing, I guess.* (Student 1, second interview).

I think in the beginning we were open to try this new thing and try and implement it. And then as we got more and more stressed and had more work to do we kind of fall our old time schedule and way of doing things as *we were used to and then we kind of forgot to update the 3D-management platform* (Student 1, third interview)

By saying *they need to work on the project,* Student 1 indicates the use of the platform is taking time away from the project. By this indication and the student emphasizing what is quick and easy, the students' choice of technology seems like a cost-benefit analysis with the project report in mind, where the advantages of using a specific tool are compared with the resources and time needed to acquire the tool. Sørensen (2018) finds similar rationales among other AAU students and characterise the choice of technology as an outcome-focused and pragmatic approach. The students have the project report in focus, it is a question of 'what works', and time is an essential factor. This again relates to the learning objectives of the students, which describes what is eventually measured at the final exam.

5.3 Ad-hoc vs. structural approach to planning

The students describe that they find that the ILICE platform does not fit their way of working. This relates to the fact that there are specific features that they do not experience a need for (or only a minimal need) such as 3D modelling and the digital communication thread, and also to the work practices the ILICE platform promotes. The students describe that the ILICE platform promotes a structural approach with regular updating and more detailed long-term planning. Student 3 describes detailed planning as difficult, because of all the new things they have to learn through the project. He says:

I think, if we knew - when we started the project - exactly what we were going to do during the project when it would be easier to use the platform. It would be easier to schedule tasks and assign them […] When I was coming this morning, I was not exactly sure what direction to take on what I am doing […] And I think, project work for each semester it supposed to be something new, so we do not do what we learned last semester, but we use it to learn something new. And it forces us into a situation where we need to learn from each other […] The direction is due to change I think. (Student 3, second interview)

Student 3's description indicates an ad-hoc approach to planning. This appears a part of their learning strategy, a way to handle a project where the exact ending point is not known and where tools, theories and methods are new to them. This ad-hoc approach to planning manifests in the blackboard with the list of ongoing tasks. At the wall across the blackboard, the project group has a pinboard with sheets of paper divided into days, as a calendar for the primary deadlines, interview dates and supervisor meetings. The pinboard symbolizes the long-term planning in the group consisting of only a few deadlines.

5.4 ILICE potentials from a student perspective

The potential of the platform in other contexts was an essential part of each interview. As described in the section above, the students find that the platform (especially the INNOVATE section) will be very useful in a case, where the group is working remotely and has to collaborate on the distance. In general, the students suggest that the platform will be more relevant for larger groups, larger and more complex projects, multidisciplinary projects and collaboration across project groups. For each section of the ILICE platform, the students see many potentials in different contexts:

For the INSPIRE tab, the students suggest that it could be used for documentation for bigger groups and long-termed projects of what has been done and why. In continuation hereof, the students explain that they do not find that a lot of documentation is needed, partly because the evaluation of the process is not a prescribed part of the project (which was the case, at earlier semesters).

Even if the project group did not use the LEARN section, they see a potential for sharing and collecting resources across project groups and courses. However, this will require that more groups have to use both the platform and the 3D platform. They also see this section as useful within a group, as a hub for resources sorted by chapters. This could give an easier access to resources and be useful for the exam. They became aware of this potential in the third interview, but it requires a systematic approach from the beginning.

As previously written, the students find the INNOVATE useful for distributed collaboration and CREATE useful for working with 3D modelling. For the EVALUATE section, the students suggest that in addition to an overview for the students, it could give the supervisors a better view into the process of the group, adding that supervisor presence will motivate for use. In the ILICE framework, the EVALUATE section is supposed to be a tool for the supervisor to evaluate the project groups, but in this case, it was not possible to involve the supervisors. According to the students, the supervisor should not use it for evaluation, but for focusing the supervision. This demonstrates that the platform use also depends on the role of the supervisor.

5.5 Summary

The platform never became an integrated part of students' collaboration and project management. Student 2 describes the platform as a non-critical 'side-thing'. The platform-use has been an addition to their usual practice and way of working, instead of a part of a changing practice. The motives and rationales behind the limited use of the platform can shortly be summarised as a combination of not feeling the need for the specific functionalities and having other well-known tools to support them.

Recurring for the three interviews are the tension between the limited use of the platform in the project group and the many potentials the students point out the platform could have had in their project work or in other kinds of project work. The students' experience is that the platform did not fit their way of doing project work. It manifests in the gap between the structured approach and regular updates the 3D experience platform affords, on one hand, and the student ad-hoc approach to planning on the other.

Table 1 summarises different factors, which from a student perspective make the ILICE framework more or less useful. It is based on a combination of the student's conception of the settings in which the use of the platform will be most useful and relevant, and the observations by the authors of this paper. While the observations are interesting and useful, it is important to be aware that this is a pilot study in a single setting: The results might not generalise, and a larger and systematic study would be needed to verify each of the factors pointed out. Especially, it would be interesting to try out the platform in a setting where the integrated 3D tools would be used by the students. The study illustrates the complexity of introducing a new platform to support project work, how it interferes with existing practices, and how physical and other contextual factors influence its use. If we intend to change the practice of the students and make them learn an industrial framework, scaffolding and supervisor presence seems to be important factors. New ways of collaboration, which make the use of the platform 'more critical', new settings and requirements (e.g. a greater focus on the process in the project evaluation) could be beneficially incorporated.

Table 1: Factors which makes the ILICE framework more or less useful from a student perspective

	More useful	Less useful
Group size	Big	Small

Project size	Big	Small
Project complexity	High	Low
Multidisciplinarity	Multidisciplinary	Monodisciplinary
Geography	Geographically dispersed	Same location
Supervisor using the platform	Yes	No
Other tools	No	Yes
Process part of learning objectives	Yes	No
Scaffolding	Strong	Weak
Use of specific tools offered by platform	Significant use	Little/no use

6 Concluding discussion

According to Table 1, the 3D experience platform supports complex projects, large groups and collaboration across disciplines, place and time. This reflects the expectations and requirements existing at present and, in particular, on the students' future work on projects in the industry. Such projects are often characterised by openness, simultaneous projects running in parallel, temporary constellations of collaboration and collaboration across time, space and organisational boundaries. This is contrary to AAU PBL groups, who work on one project at the same location and is characterised by being a one-disciplinary and strong-tied group with a high degree of autonomy. The explanation for the tension between the student experience, that the platform did not fit their way of doing project work and all potentials of the platform, which the students point out, may be found in this gap.

To close the gap between the students' way of working and what the platform affords, we find two directions to go: Change the setting or change the platform. The platform calls for new settings, which may better reflect the industry with weak-tied multidisciplinary groups collaborating across boundaries. We would, therefore, encourage more experiments with new forms of PBL collaboration inspired by the above characteristics. At the same time, we find it important to maintain the strong-tied one-disciplinary groups in the same location and the learning environment it brings, and to study how we can best support this digitally. We suggest to move in both directions, so the students experience both strong-tied and weak-tied collaboration. This also leads to a reflection about the way PBL is conducted in our university, where students develop a "good practice" of collaboration and project management, which is refined throughout the study but not really challenged or disrupted: A stronger focus on trying out different tools and methods for collaboration during the studies, e.g. through explicit PBL learning goals, might add to their transversal competences. This is actually being explored in the project (https://www.pblfuture.aau.dk).

On a final note, the project has led us to realise how close collaboration methods and collaboration platforms are tied to each other: While the idea of offering the students a single platform to handle all aspects of their collaboration, this might very well dictate most aspects of how they work together: From how time plans are made and followed-up upon to how brainstorms are conducted. In an educational setting, where we encourage the students to experiment with different ways of collaboration throughout the studies, further research should be conducted on how to support this in the best possible way. This could also address how we motivate students to try out new methods and tools, even if the additional effort does not immediately pay off in terms of the projects/products to be handed in - for example by assessing also the competences related to the collaboration and project management processes.

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Facilitating process competencies with digital workspace

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Abstract

Nowadays, industries demand more process competencies to work online in virtual teams. The study focus on 3DEXPERIENCE™ platform and digital workspace to support project work in a PBL course of Automation of Manufacture Process. As long as online collaboration and projects management are facilitated, the students acquire process competencies. In the platform, students perform all the project group activities, including communication, ideation, scheduling and documentation, while using real engineering tools to finish the project. The course of the undergraduate curriculum of Mechatronic Engineering has six teachers and 22 students from the last semesters. The curriculum is blended in lectures and projects. Each group of five or six students has to develop a project taken from an industry real manufacturing process. This study shows the first implementation experience and lessons learned. The data were collected from open-ended questions and by tracking the group process into the online platform. The effectiveness of this strategy was assessed by using text analyses and achievements were compared with previous courses.

Keywords: Project-based learning, PBL, 3DEXPERIENCE, project management, e-learning, CSCL

Type of contribution: Research paper.

1 Introduction

The industry 4G demands expert engineers with skills to perform efficiently and competitively. There are professional organizations listing a number of skills to work (World Economic Forum, 2016). Industry has been changing in the ways of work, integrating online collaboration and cooperation to increase performance. The competencies needed include problems solving skills, collaboration, cooperation, innovation, communication and project management. The nature of industry 4G is to work collaboratively but independently, that is, an online work, using on cloud drives and apps remotely (Schwab, 2016), which foster interdisciplinary work.

Studies of Computer-supported Collaborative learning (CSCL) have found that online collaboration online is hard to achieve (Clarke et al., 2013; Lin & Tsai, 2016). Factors include lack of social interaction, believing it will happen automatically (Kreijns, Kirschner, & Jochems, 2003), lack of group strategies awareness (Miller & Hadwin, 2015), and poor socioemotional interactions (Rogat & Adams-Wiggins, 2015). Therefore, students transform traditional ways to manage projects into online approaches, adapting or acquire new skills (Järvelä & Hadwin, 2015), and enhancing face-to-face process competencies.

This study regarding PBL online collaboration aims to enhance process competencies in 3DEXPERIENCE™ platform or 3DS (Dassault Systèmes, 2018a). The 3DS was selected to meet two purposes: to support the project work enhancing collaboration while students use a real workplace engineering platform, and to have engineering apps to perform projects. Then, when students learn to use efficiently and with efficacy the 3DS, they are enhancing their process competences.

2 Process competencies

Process competencies refer to individual capabilities associated to project management that require communication, collaboration, cooperation and technical knowledge to perform subject areas. Process competencies are part of the subject area competencies linked to emotion and motivation, hence, involving behavioural changes, self-management, and self-evaluation (Kolmos & Kofoed, 2002, 2003).

Reflection in the experience is a way to acquire process competencies that students have to learn by doing. In PBL, students are required to reflect about the project process through a portfolio, while they develop process competencies (Kolmos & Kofoed, 2003). The facilitation support during the group-work, often done by face-to-face meetings, even when the role of the facilitator is supervision (Savin-Baden, 2003)

However, online educational resources demand alternative ways to facilitate students. First, group communication tends to be online, by social networks; secondly, the impersonal contact between students break real feeling, emotions and perceptions, and finally, the engineering has been varying to a more interdisciplinary and collaborative online work, providing advanced tools for project management.

Students use communication and the internet to develop project tasks. Social networks systems have been growing around the world: in 2017, more than 3 billion people used social media each month, with 90% connected in mobile devices, and proliferation of 11 new users per second (Kemp, 2018). As social individuals, it is expected that networking communication also increases in the project-work, and, in consequence, meetings face-to-face would be reduced.

The impersonal communication has a negative effect on learning. One of the core principles of PBL is based in Carls Rogers' idea of self-direct learning (SDL) (Kolmos & de Graaff, 2015). The idea of SDL strives for transformative learning involving personal aspects such a self-perception, self-awareness, self-consciousness, self-direction and self-reflection (Illeris, 2014). Those aspects need a positive relationship environment between the group members (Rogers, 1965). Lacking personal contact causes deficiencies in the group members personal perceptions, since online communication have effect in relationships and in the well-being (Kraut & Burke, 2015; Kreijns et al., 2003; Walther, 1992).

3 3DEXPERIENCE™ for PBL

Implementing 3DS demands support to facilitate project management. Since 3DS is a collaborative online platform, it has both social collaborative tools and engineering specific application software to work interdisciplinary projects and product development. It is technically called a PLM (Product Lifecycle Management) software. To simulate PBL, the 3DS uses a stage template called ILICE, acronym of *Inspire, Learn, Innovate, Create and Evaluate* (Dassault Systèmes, 2018b). Thus, the teacher setup courses and students access to learn and share ideas by using social collaboration. They also use engineering tools to share ideas into a community, questions, news, wikis, videos, requirements, designs and simulation.

Then, in the automatization course with ILICE, there were three static dashboards to students, I*nspire, Learn and Evaluate*, while two dynamics, *Innovate and Create*. For the first group, the teacher upload relevant information with documents, news and videos regarding the course to inform to the students. In *Innovate* there is a community, the course, where the students, teachers and anyone who is invited there can share ideas. Meanwhile in *Create*, students will use 3DS engineering apps for the project.

In a more structured application of the project work, 3DS uses and embedded software called ENOVIA. It is a complete application for the whole product lifecycle. Include tools for roles, resources, ideas evaluation, task assignation and evaluation. Ideas from ILICE can be promoted directly to ENOVIA, as project task assignation.

4 Methodology

The study is based on the students' experience with 3DS platform. The students were enrolled in a PBL course of Automation of Manufacture Process (AMP). The course belongs to in the Mechatronic Engineering program at Universidad Nacional de Colombia in the last semester, so the students are almost engineers. The course had 22 students, and all of them were enrolled in the platform to do a project in teams.

Since the AMP gathers knowledge and skills from the whole curriculum, it has six teacher from various subjects, i.e. robotics, control, automation, manufacture, programming, and design. The learning outcomes for the course include applying all those subjects in the project. In turn, just four teachers were team facilitators, but all of them were active course participants, including access to the 3DS platform, with some lectures or consulting to the students.

The students were grouped in four teams of 5-6 students to do four different projects linked to an automatic process in a real industry: painted coffins, broom manufacturing, filter packaging and plastic conversion. To run the project, students were requested to use the platform. To introduce 3DS, they were trained only two hours. It was planned that students learn more by doing activities on the platform, assisted by the Dassault learning material. Students spent 15 weeks to do the project.

During the project, just 15 students used the platform with some project activities. After project completion, a seven open question online survey was sent to participants in the platform (Table 1), and 13 surveys were collected. The aim of the questions is to collect students' reflections to facilitate future platform interventions.

Table 1 Open questions for the experiment

Open question
Do you think platform could be useful to manage academic projects? Explain
Do you think platform could help with collaboration for the project task?
Do you think platform fosters ideas generation and evaluation?
Did you find useful comments and ideas in the automation community at the platform?
Do you think platform is useful to communicate with your teammates for the project?
Do you think platform could be useful to learn directly from your peers?

5 Findings

5.1 3DEXPERIENCE usage

Figure 1 shows student participation in the community during the project. Participation was mainly by media (40,6%), questions (22,2%), ideas (11,6%), posts (8,9%), and questions (8,9%). Media included documents 54,8%, pictures (51,1%), drawings (2,7%) and 3D Models (1,4%) indicating high participation by sharing information. Drawings and models of specific project tasks are developed within the platform apps. Questions were about the use of the platform. Ideas were about the project main topic and issues during project progress. Posts comprise new question and themes.

The first part of the project-work included the project problem definition, team roles by task assignation and methodology. The second part is closer to problem solving by engineering procedures. It is coherent with the students participation in the platform at the beginning and middle, as shown in Figure 1. It also showed low participation at the end, because by that time, students do not use apps of the platform such as DELMIA and CATIA.

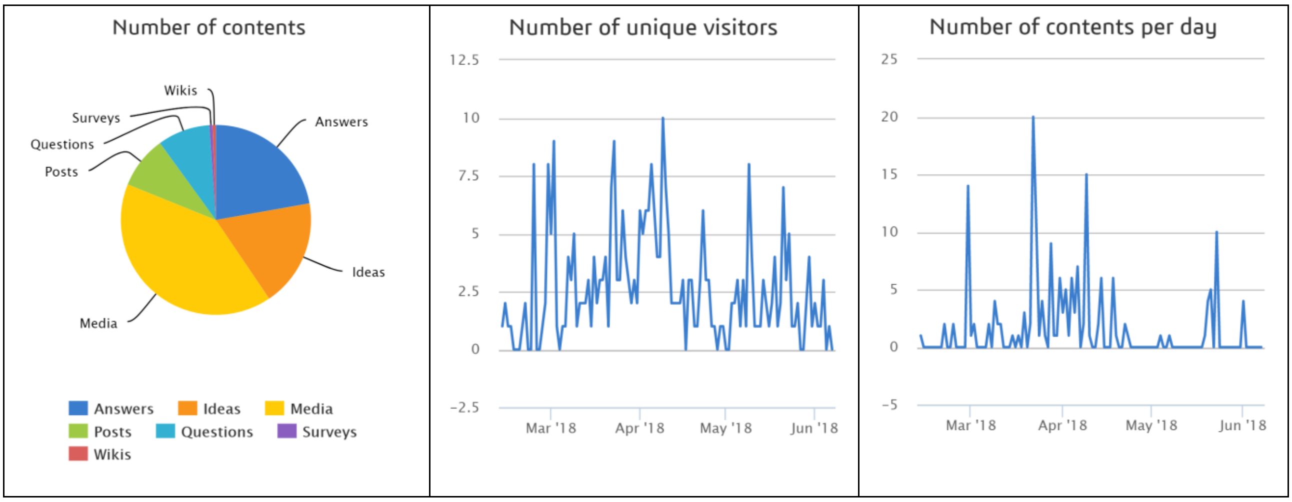

Figure 1 Statistics from the 3DExperience platform (3DS). Take from 3dSwym analytics in the platform environment

The participation in 3DS showed active working during the semester. Although students were active in the community, there are not previous studies or courses indicating rates to compare. However, participation was enough to notice low levels of procrastination during the project work, and to support students' comments in the study.

At the end of the project, students were stressed. In consequence, they preferred to use traditional software to resolve the project. Moreover, they used older DELMIA versions, other than available in the platform, because the apps' environment and menus looked different.

5.2 3DEXPERIENCE prospective to enhance process competences

The study considers a group of students working in a project in 3DS. From ILICE they were stimulated to idea generation, course content, training videos, sharing information. They also begin to use ENOVIA for project management.

Students were concerned about lack of platform training to become users. It was a general issue because they just had two hours of training. Although they learned platform utilities by themselves, it was not sufficient.

Project management

Regarding project management students used ENOVIA along with the Innovate dashboard from the ILICE framework. It was expected that the whole project process have more realistic meaning for the students. The process started with a project formulation by sharing ideas in the community, followed of idea selection, and finally promoting it to an ENOVIA task. However, the researcher realised that the students had never used tools for project management. Consequently, they did not have fundamental concepts to work in this way. Hence, an additional training of ENOVIA was made. This was also confirmed with the students' perceptions about 3DS advantages to project management and their requests for more training before use. Some perceptions were:

> *"It is a tool with a lot of potential to manage a project, but really we need a better teaching to face this platform" (Student 07, original in Spanish).*
>
> *"It allows to advance in projects, being aware of the progress of the tasks assigned to my colleagues" (Student 08, original in Spanish).*

In the platform, some students were also aware that 3DS has potential to increase performance in the project work. It implicates changing its traditional way to do projects:

> *"When having the ability to use the platform, it is possible to do a lot of things in one place, and I have the that it can work faster, which invites me to work in the platform (Student 10, original in Spanish).*

After showing them ENOVIA, they were afraid about the many tools to learn, thus they preferred to use other well-known tools. According to the following comment, it was true but to a certain extent due to the lack of good attitude to learn.

> "The platform worked to create project schedule, however its large number of functions makes its use something complicated that discourages the desire to continue working on this platform to organize the project, since there are other programs that can be downloaded to the cell phone, the computer and be synchronized in several devices…" *(Student 09, original in Spanish)*

Online collaboration

There was online collaboration at the beginning and middle of the project, but it decreased at the end. Students were encourage to online participation by upload there a short presentation in the ILICE Innovate framework. It was satisfactory because students had the opportunity to share ideas and received peer comments. According to the Figure 1, there was also active participation in these two stages. However, students prefer to use their traditional ways to do it, with well-known tools, perceived as efficient by them.

> *"…Although the platform is for that, since it is not a tool used in the past, nobody wants to learn a new tool, and it is preferred to continue with those that are known and worked. Although aspects such as the percentages of contribution in the project can be used to*

evaluate the commitment of each one within the team". (Student 13, original in Spanish)

Fostering idea generation and usefulness

Idea generation need to be fostered by the facilitator participation. Since the students tend to follow instructions, they look for facilitator's comments more than from their partners.

> *"Through forums and questions with the facilitator, more specific concepts, can be stablished and then develop better ideas in the process" (Student 11, original in Spanish).*

Students prefer traditional face-to-face meetings for sharing ideas. Despite the students often communicate by social networks, they are not comfortable when doing it in a more structured way online. For example:

> *It could be, but it is something virtual more for remote work of a project. Instead when you see the groupmates continuously, it is easier to do it personally, but you end up using other more intuitive tools. (Student 12, original in Spanish).*

Communication

Since the 3DS has many tools that are slow to load due to internet connection, students prefer to use traditional social media to communicate and collaborate. Most of its communications were by text messages as observed directly in the course. Additionally, to share documents, they preferred traditional on-cloud drives. This also happened because some team members refused to use 3DS.

> *"If the whole collaboration of whole group members were achieved on the platform, perhaps it would help in the collaborative activities. First, teachers must learn how to use it to teach us, and show that it's worth it, but you could tell that they did not completely understand it. Because if there's something extra to learn, it's hard to use, and it can be done with other better known tools, so you will not find the sense to learn it. However, if reality is shown, its uses beyond a kind of Facebook wall, WhatsApp group, even, Google Drive, surely, students will find meaning" (Student 09, original in Spanish).*

The student above found benefits in the 3DS, but a lack of meaning to learn it. He considers the partners had not any incentive to use it, pushing them to use two popular social networks and an on-cloud drive. Even the lack of participation of the facilitators was a factor in collaboration through the platform.

The study also found, that the more is the peer's participation, the more is the social pressure to participate in the platform. For example;

> *"As it is a platform where progress is shared, you undergo a social pressure (also personal), since it is not expected to generate a bad perception of the work that you have done, when not delivering it on time or complete" (Student 13, original in Spanish).*

In the platform, there were consensuses about the internet speed to load 3DS over other social media. Some students want to use it in smart phones, but the internet network was too slow, so that they prefer to use other slender media.

Peer learning

Students consider they could learn from the platform if there is a continuous teacher's participation. It seems to stimulate students to upload information and sharing ideas about difficulties to use it.

> *"Yes, you can learn by using it, keeping your continuous review and continuous publication of all. But, in a certain way the professors do not even publish there, it was just something that after forgetting and forgetting, I clearly associate it with a very heavy platform, full of so many options on all sides..." (Student 07, original in Spanish)*

According to the students' content in the community on 3DS, they share videos, documents and templates regarding the project work process. The study did not ask students about it, but the quantity and quality of the information available on the 3DS, shows that. Students have even uploaded technical information to use the 3DS after the course completion.

Summing out, students found advantages in 3DS for project management, collaboration, ideas sharing, communication and peer learning. They believe it could improve group performance, but they also claim lack of training to use it and meaning for the project. They also consider that it is complex to learn, since the 3DS have lots of functionalities for the project. Finally, they demand more facilitation and teacher's participation on the platform.

6 Discussion

During the study, the research found 3DS useful for the project-work since it integrates collaboration, management and engineering tools. Although there were difficulties to implement it for the first time, students agree in its potential for the project work. AL thought, teams currently have a consultant facilitator, they claim more guidance from them. In turn, students need incentives to use it. According to the PBL learning principles for the project work (Kolmos & de Graaff, 2015), the study put forward a facilitation strategy for 3DS.

6.1 Introducing 3DEXPERIENCE

The 3DS platform has many tools for engineering. Despite ILICE only has five dashboards, when students logged in, their first impression is having many things to learn, feeling threats to previous knowledge. In consequence, some students decline to work there or feel unmotivated. Learning new things is easier than changing them, that is, students from last semesters have been working projects with their own procedures, and they need to transform their traditional practices. It is a kind of transformative learning. According to Rogers (1958), people feeling threats to their previous acquire knowledge, do not want to learn anything else (Rogers, 1965). In addition, many resources in the platform cause uncertainty without previous training. The 3DS should be introduced gradually while the student finds its meaning, but responsibility for the learning should rely on them. In PBL, students learn by themselves, thus they should discover and incorporated the tools of the 3DS, in the own process.

6.2 Facilitating course relationships

Students collaborate more when they feel an appropriate climate for work, based on interpersonal relationships. In the platform, students miss face-to-face contact, which could affect the interpersonal relationship (Mathisen, Einarsen, Jørstad, & Brønnick, 2004; Nisula & Kianto, 2016). In consequence, students feel less commitment and trust than when they have personal relationships (Heller, Laurito, & Johnson, 2010). In ILICE, the *Innovate* dashboard is focused on collaboration in a community. That community could setup according to the PBL course. For example, in this study, the community consisted of 22 students and six teacher working in four teams.

Building relationships increases the chances to collaborate and learn. When people feel respected, important and looked after by their partners, they tend to collaborate more. Hence, for an effective collaboration community relationships should be encouraged in the course. It is harder to work online than face-to face.

The interpersonal relationships could be encouraged immediately, at the beginning of the course, previous to the platform training, by face-to-face meetings focused on friendship, trust, commitment, respect, and confidence (Pauleen & Yoong, 2001).

Additionally, the creation of a e-leader is another option to foster relationships, but it is time consuming, and demands high level of commitment (Jawadi, Daassi, Favier, & Kalika, 2013).

6.3 Facilitating collaboration

The 3DS displays students' participations during the project work, includes statistics of usage and activities performed by each student. The visualization of the students' participation have positive effects on the collaboration (Janssen, Erkens, Kanselaar, & Jaspers, 2007). Participation indicator encourages messages, and helps to engage team members in a process.

6.4 Teacher and facilitator participation

Students need to be facilitated through the teacher and facilitator participation. Teachers have to upload fresh course material, but comments about the project process during the whole course cannot be left aside.

7 Conclusions

The study analysed the student's perceptions of the contribution of the 3DS platform to the project-work. The 3DS found potential was referred to project management and collaboration. Since students have been using other social media to communicate, they found less advantages for communication and idea sharing. The main difficulties to use 3DS were caused by the lack of training and previous immersion in 3DS.

Students who participate in 3DS have to develop other process competencies. Process competencies were defined as skills to project management, collaboration, communication and sharing ideas. However, doing it online is not attractive for them because they have to integrate its habits with new tools in the 3DS. Thus, they prefer face-to-face meetings blended with popular social media communication. But it is also explained by the fact that some students found uncomfortable collaborating and sharing tasks online for project management, since for them is too much work to do. Its dynamic is slow, and they seem to not have used any other project management software before.

Consequently, fostering participation in the platform is fostering process competencies. This study discuss an strategy to facilitate process competencies in the field of CSSL. Further research could focus on the strategies to facilitate learning in online process competencies. In addition, the whole participation of each member involved in the 3DS platform, is needed to be effective.

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Experiencing the Implementation of Flipped Learning in Statics

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Abstract

As many universities of the world, in the engineering programs offered by the Universidad Nacional de Colombia, Statics is one of the first core courses, and is also a prerequisite for other important courses such as Dynamics, Strength of Materials, and Design. The fundamental concepts learnt in Statics are necessary for the good performance of the students and professionals of engineering. Despite its importance, high number of students have difficulties to understand and apply the statics key concepts and as consequence they fail or withdraw the course. In one course of a Civil and Agricultural Engineering programs, a Flipped Learning intervention was planned, applied and studied in order to analyse the possible effect of the implementation in the achievements levels of the students and in the conceptual change at the beginning and at the end of the semester. It was found that there was no significant statistical difference between final grades average in the intervened and the non-intervened group, neither in the results of the concept inventories. However, two aspects are remarkable: the similar results in both groups, although Flipped Learning is based on the students' prior preparation of the content by their own and the perception of students of the intervened group regarding the improvement of their skills and competencies.

Keywords: Flipped Learning approach, Statics, students' achievement level in Statics, students' conceptual change in Statics

Type of contribution: research paper

1 Introduction

In the engineering programs offered by the Universidad Nacional de Colombia, the professional or core component goes after the fundamental component. The fundamental component is related with sciences courses and it is expected that after learning these subjects the students are enabled to *"use the mathematical language of the methods of analysis to quantify the responses of structures and systems"* and "*construct their conceptualizations, models and theories for the complete understanding of the phenomena"* (Universidad Nacional, 2017).

In the core courses, it is supposed that the students learn "*the applications on which knowledge of materials is based, and the prediction of their behaviour as an integral part of a civil construction, when are subjected to the forces produced by the loads to which they will be exposed*" (Universidad Nacional, 2017). Among the core courses, Statics is one of the first ones; but the percentage of failures and dropouts in this course is high and is one of the causes of desertion in engineering programs (Zapata et al., 2013; Kim, 2015; Haron & Shaharoun, 2018). In the Universidad Nacional de Colombia, the average failures of the Statics course reached 31%

and the dropouts were up to 9%, from the first semester of 2013 to the second semester of 2016. As consequence, the Statics poor performance not only discouraged some students to finish their career, but also caused a longer permanence since it is a pre-requisite for others courses.

Besides, Statics is a very important subject, because the fundamental concepts learnt in this course are necessary for the good performance of the engineering students in posterior courses related with their specific career (for example hydraulic structures, structural analysis and design, and geotechnics for civil engineers; or structural analysis and design of rural construction for agricultural engineers and design of machine elements for mechanical engineers). Additionally, good bases of Statics are fundamental for an adequate design and construction of damps, bridges and buildings; for rural constructions as silos, grain storages and greenhouses; and the design and manufacture of tools and machines.

However, the students have difficulties to understand the statics key concepts (Maneeratana et al., 2012; Litzinger et al., 2010; Venters et al., 2014, Dwight & Carew, 2005) and also have misunderstandings (Steif & Dantzler, 2005). As consequence, they "*fail to see the connection between solving a problem mathematically and real-world engineering application*" (Mariappan, 2004) and "*emerge from statics unable to effectively use its ideas and methods to solve engineering problems*" (Steif & Dollar, 2005).

The high percentage of failure and dropouts was the motivation to initiate a change towards active learning and Project Based Learning PBL, because as Kolmos (2010, p.3) says, change could be based on "*management and funding issues such as the possibility that PBL might decrease drop-out rates and improve the percentage of students who finish their study on time*" and on the "*improvement of quality of learning for students*".

To plan the change strategy in Statics courses, the specificities of the organizational culture and the institutional norms that could impact the intervention were considered (Guzmán et al. 2018).

Among the aspects related to organizational culture, the following should be mentioned:

- The Universidad Nacional de Colombia is the biggest public university of Colombia and according to its mission, university students represent all the richness of Colombian diversity.
- Some teachers misunderstood the academic liberty principle. For this reason, it is not easy to establish guidelines, regarding the teaching practices and learning methodologies to be applied or developed.
- For an institution with 150 years of tradition and customs inherited by generations of teachers and students, there will be strong resistance to change some specific aspects, such as lectures or outcomes assessment through the solution of end-of-chapter exercises.
- During the first years, engineering students receive courses in fundamental subjects from teachers of the Faculty of Sciences. As part of their Faculty, these teachers have defined their own methodologies, practices and, to a certain extent, the contents of the subjects, exercising some degree of independence with respect to the guidelines and suggestions from the Faculty of Engineering. Therefore, it could be difficult to count with their participation when applying a longitudinal or transverse project.

Among the aspects related to institutional norms, the aspects considered were:

- The structure of curriculum plans established in the academic reform of 2009 promotes the flexibility. The prerequisites among subjects were minimized and the free election component was created. As a consequence, each semester, the students can decide the courses to take and, consequently, the number of academic credits to attend, thus it is not possible to guarantee that two students, who are attending a course in a given academic semester, coincide in other courses.
- The regulation states that "*students could cancel courses freely, without any requirement, before completing the fifty percent (50%) of the academic period*" (Universidad Nacional de Colombia, 2008). This means that, in the first half of an academic semester, students can withdraw from a course, if they want it. The consequences of this institutional policy are huge. For instance, in the Faculty of Engineering, students cancelled 2236 inscriptions between the first and the eighth week of the second academic period of 2016.

The analysis of those aspects and their impact defined the fundamental guidelines of the active learning mode selected. It was concluded that a pioneering experiment with modes of active learning was not pertinent if it implies coordination between teachers of different subjects, participation of students simultaneously enrolled in the same courses and inclusion of all the courses of the semester of the curriculum plan. Considering this analysis, the implementation of the intervention should be done gradually and without an abrupt break with the university context mentioned. Flipped Learning approach was selected as intervention because it promotes the active participation of the students (Willey & Gardner, 2016), critical discussion (Papadopoulos & Santiago, 2010) and minimizes resistance to changes (Guzmán et al. 2018).

Thinking in the aforementioned problems (percentage of failures and dropouts, and learning of fundamental concepts), an intervention with Flipped Learning was studied in a Statics course of a third semester of the Civil and Agricultural Engineering program.

The study was focused on two aspects: students´ achievement levels (grade performance, dropout rates, and failure rates) and students´ conceptual change. The research questions were:

What is the effect of implementing Flipped Learning as teaching approach, on the students´ achievements levels in the Statics course?

What is the effect of implementing Flipped Learning as teaching approach, on the students´ conceptual change in the Statics course?

2 Research Methodology

In order to answer the research questions, the research design was quantitative. The experiment, instruments and intervention are described in the following paragraphs.

2.1 Experiment

In the experiment, the dependent variables were the students´ achievement levels and the students´ conceptual change. The independent variable was Flipped Learning.

The active learning module designed, planned and implemented was framed in the intervention in one group of Statics and one control group, both offered by the same teacher during the second academic semester of 2017 (16 weeks). In the intervened group (IG), the Flipped Learning approach was implemented. The control group was the non-intervened group (NIG), which was offered in the traditional way. Some details of both groups can be seen in Table 1, where the Grade Point Average (GPA) of each student is calculated as the average of the numerical grades in a scale from 0 to 5.0 of all the courses taken (approved and non-approved). The population and the sample were the students of both courses.

Table 1: Characteristics of both groups.

Group	Students	Classes time	(GPA)
Intervened (IG)	33	16-18hr	3.4 / 5.0
Non-intervened (NIG)	33	9-11hr	3.8 / 5.0

2.2 Instruments

To determine the effect of Flipped Learning approach in the students´ achievement levels, the data collected and used were the quantity of students´ dropouts, the number of students that fail the course, the GPA, the final grades and surveys.

To determine the students´ conceptual change regarding statics concepts, the data collected were the results obtained in the Statics Concept Inventory of Steif & Dantzler (2005), which was applied at the beginning and at the end of the course. From the Concept Inventory (CI), 21 questions were selected, taking into account the themes covered in the courses.

2.3 The Flipped Learning Intervention

The intervention was carried out in three stages: First, the identification of the learning outcomes; second, the definition of assessment methods; and third, the planning of learning experiences and instruction.

Stage 1. Identification of the learning outcomes

For the identification of the learning outcomes, the curricular priorities of the course were established, defining the "*enduring understanding*", the concepts and procedures "i*mportant to know and do*" and "*worth being familiar with*" (Wiggins & McTighe, 1998).

According to the curricular priorities, the desired results were defined. Based on them, the following learning outcomes were proposed:

- Students will be able to apply the understanding of equilibrium of forces, acting on particles to determine what is required for a particle to be in equilibrium.

- Students will be able to apply the understanding of equilibrium of forces and couples, acting on rigid bodies to determine what is required for a rigid body to be in equilibrium and to calculate the reactions in the supports and the internal forces and moments.
- Students will be able to apply the understanding of equilibrium of external forces, couples and forces between bodies acting on a system of connected bodies to determine what is required for the system to be in equilibrium, as well as to calculate the reactions in the supports and the internal forces and internal moments for each body of the system.

Stage 2. Definition of assessment methods

To make a continuous assessment of the students' progress, students answered a conceptual quiz for each new theme. Besides, workshops were carried out, where the students had to pose the problem, apply the right concepts, find the numerical answers and write down a report that was assessed by the teacher taking to account the procedures and the calculus made.

Stage 3. Plan Learning Experiences and Instruction.

As part of the implementation plan, in the first session, the themes and the knowledge learning outcomes were exposed to the students, as well as the assessment method and the methodology.

With respect to the methodology, the Flipped Learning approach was explained with the skills and competences included in the Program Educational Project (PEP) of the Civil and Agricultural Engineering programs. It was emphasized that a prior preparation of new themes by students and their commitment during the workshops were necessary to guarantee the achievement of the academic goals.

In order to facilitate a conscious preparation, some materials were exposed in the Moodle platform of the course. For each session, some pages of books that include explanations and exercises solved and proposed were uploaded, thus the students could read and analyse them. Additionally, PowerPoint presentations of each theme were prepared and animated so that the students could review each “virtual class” as many times as they needed to study or understand. Finally, some links of videoclips of the web with theory or exercises were chosen to show different points of view or procedures of solution.

In the course sessions, concept quizzes related with the uploaded material were applied with the purpose of stimulating that students prepare the subject before the session. Besides, the students participated in workshops in groups where in most cases the students had to think how to fulfil a real necessity formulated by the facilitator with the application of Statics. Then, the students answered some questions related with the activity, did some calculus and wrote a report of the exercise, that the facilitator reviewed in order to give them a feedback in the next session. The members of the group were not the same in all sessions to foster the integration of all students.

3 Results

For the analysis, two samples have been selected. The first sample (Intervened Group - IG) included the results of 33 students, who were the total enrolled in the course with Flipped Learning intervention, and the second sample (Non-intervened group - NIG) included 33 students, who were the total enrolled in that group.

3.1 Students´ achievement levels

To measure the students' achievement levels, the percentage of failures, the final grades and the dropouts were taken into account.

Percentages of failures

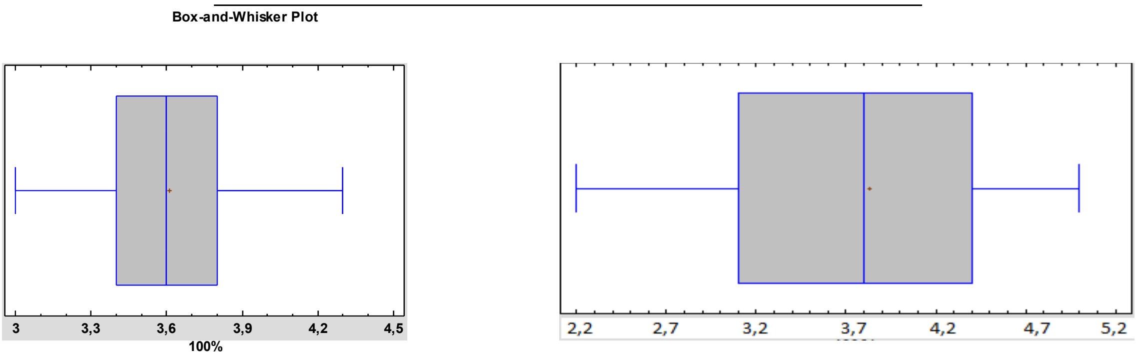
In the IG, all the students passed the course, while in the NIG, 9% (3 students) failed the course.

Final grades

A statistical analysis using Statgraphics software was performed. For both groups, the IG and the NIG, the statistical summaries are presented in Table 2 and the Box and Whisker Plots, in Figure 1.

Table 2. Statistical Summary of Final Grades.

Statistics Summary for final grade	IG	NIG
Count	33	33
Average	3,6	3,8
Minimum	3,0	2,2
Maximum	4,3	5,0
Range	1,3	2,8



a. b.

Figure 1. Box- and- Whisker Plot corresponding to Final Grade: a. IG b. NIG

The results show that the final grade average for the IG was slightly lower than the average of the NIG (3,6 vs. 3,8). The range between the maximum and the minimum grade for IG was 1,3 while in the NIG it was 2,8. As it is possible to observe in the Box and Whisker plots, the dispersion of the average in the IG was lower than in the NIG.

Other statistical aspects were also determined, such as the confidence intervals for final grades, hypothesis related with normal distribution and normal probability plot. According to the results, the average of the IG was 3,6+/- 0,1 while in the NIG was 3,8 +/- 0,3, both of them with a 95% of confidence interval. The statistical analysis shows that the data do not adjust to a normal distribution.

Grade Point Average (GPA) and final grades in the Statics course

The statistical summary of the final grades and GPA for both groups can be seen in Table 3. In the IG, the average in the final grade was higher than the GPA, while in the NIG, both averages were equal. In the IG, the ranges of the final grade and GPA are similar; whereas in the NIG group, the final grade range was the double of the GPA range.

Regarding the relationship between the final grade and GPA for both groups, it was found that in the IG, 85% of the students had a final grade higher or equal than their GPA, while in the NIG the percentage was 69%.

Table 3. Statistical Summary of Final Grade and GPA.

	Intervened Group		Non-intervened Group	
	Final Grade	GPA	Final Grade	GPA
Count	33	33	32*	32*
Average	3,6	3,4	3,8	3,8
Maximum	4,3	4,1	5,0	4,5
Minimum	3,0	2,9	2,2	3,1
Range	1,3	1,2	2,8	1,4
Standard Deviation	0,36	0,27	0,81	0,42

* One student of the NIG withdrew from the semester at the end of it

Drop-outs

In both groups, there were not dropouts. But, at the end of the year, the Faculty approved the withdrawal from the semester to one student of NIG due to personal situation. This student had already passed the course.

3.2 Students´ conceptual change regarding statics

The statistical treatment included 27 students of each group, who were the students that answered the CI at the beginning and end of the course. The test applied at the beginning of the courses was called “Before” and the test applied at the end of the courses was called “After”. In this case, the assessment considers the number of correct answers.

A comparative analysis of groups was carried out, in the following way:

- Comparison between before and after IG
- Comparison between before and after NIG
- Comparison of IG and NIG in the Before test
- Comparison of IG and NIG in the After test

Table 4 shows the Statistical Summary of the number of correct answers of the CI and Figure 2 depicts the Box and Whisker Plots.

Table 4. Statistical Summary of CI.

	Count	Average	Standard deviation	Minimum	Maximum	Range
NIG-Before	27	3,67	1,66	1,0	8,0	7,0
NIG-After	27	5,38	2,44	1,0	9,0	8,0
IG-Before	27	3,89	1,73	1,0	8,0	7,0
IG-After	27	4,81	2,27	1,0	10,0	9,0

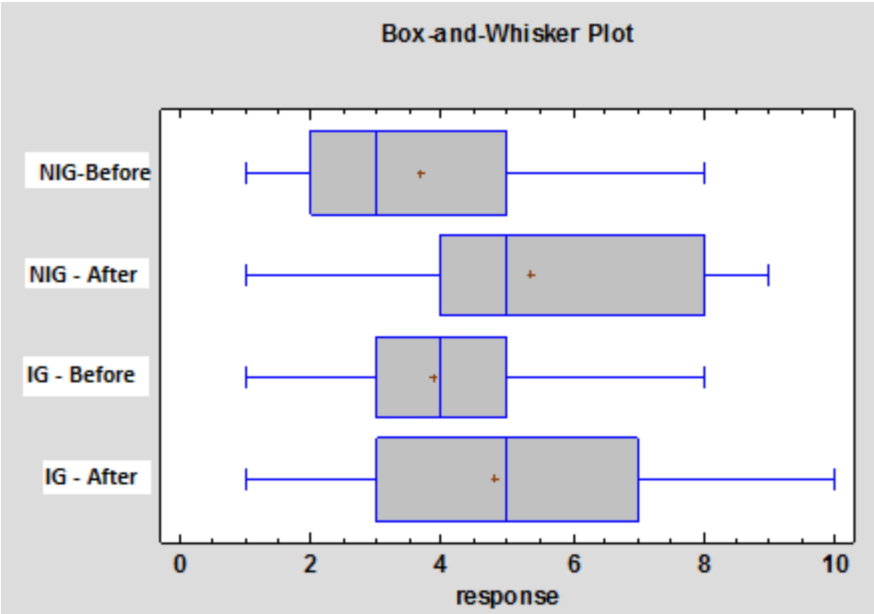


Figure 10. General comparison of CI Before and After

According to the analysis, no statistical difference was found among the average of correct answers (neither the standard deviation) in the CI at the beginning and the end of the course for the IG.

Otherwise, a statistical difference was identified among the average of correct answers in the CI for the NIG. The number of correct answers was 3,67 +/- 0,66 at the beginning of the course and 5,37 +/- 0,96 at the end of the course with a 95% confidence interval. The standard deviation did not present a statistical difference.

Comparing the results of both groups for the CI before and the CI after, no significant statistical difference was found.

4 Surveys

A survey corresponding to the evaluation of the methodologies was carried out at the end of the course through a questionnaire for students of the intervened group and for the group of professors who designed the intervention. This survey was designed based on the one proposed by Gómez-Pablos et al. (2017) and adapted to the context of the Universidad Nacional de Colombia and the Statics course. It allowed evaluating different indicators of the different aspects about the intervention. To facilitate the quantitative analysis of the results, a response scale ranged from 0 to 4 (0. Totally Disagree, 1.Disagree, 2. Neither agree, nor disagree, 3. Agree and 4. Totally Agree) was applied.

According to the survey, there was not any evidence of resistance to change from the lecture-type classes to the Flipped Learning approach. The statistical mean for the answers of the questions "*The methodology promotes the active involvement in your learning process*" and "*You had positive attitude during the development of the course*" was higher than 3 (agree).

As a result of the intervention, the students considered that they improved their skills and competencies such as: collaborative work (*As a student, you… "assumed responsibilities in group work*", "*…had enough opportunities to interact and collaborate with your peers*" and "*…were propertly integrated into your work group");* academic, digital and social skills (*As a student you developed… "creative ability", "academic skills", "digital skills",* and *"emotional an social skills*); and autonomous learning ("*As a student, you were autonomous in your learning*").

According to questions *Do you think that the methodology… "…will Increase the teacher's workload in the preparation course phase"* and *"…will Increase the professor's workload in the development course phase"* of the professor's final survey, the perception of the professors involved in the experiment is that the Flipped Learning approach increases their workload.

5 Findings and conclusions

In this section, some of the findings and results of the implemented intervention and the experiment carried out are discussed.

Regarding the experiment:

- No significant difference was found in the average of the final grades in both groups, neither in the number of dropouts.
- The intervention implemented raised the average academic performance of the students for the intervened Group with respect to their GPA.
- The gap between the highest and lowest academic performance, measured by the final grades, was lower in the IG.
- The results of the CI before and after for both groups did not have significant statistical difference.
- According to the statistical analysis, in the IG, there was not any statistically significant change between the results of the Concept Inventory applied at the beginning and the end of the course. In the NIG, there was an improvement in this aspect.

Regarding the Flipped Learning implementation:

- Flipped Learning is based on the students' prior preparation of the content. Although this methodology was novel for students who are used to lecture-type classes and review of content after classes, there was not resistance to change.
- Proper preparation of a course with the Flipped Learning approach requires much time for the development of materials, design of evaluations and assessment instruments, and search of audiovisual resources. In future implementations, what has been achieved in this experiment will be useful as a basis for future developments in this regard.
- The students of the IG considered that they improved their skills and competencies.

- The perception of the professors involved in the experiment is that the Flipped Learning approach increases their workload related to the preparation of the course and its development.
- Part of the success of a Flipped Learning approach is the preparation of the material with enough time to guarantee that the students could consciously study before sessions.
- The advantage of the Flipped Learning methodology is that the session time could be used for peer learning activities as workshops developed by the students of the intervened group all weeks.
- It is possible to integrate Flipped Learning with PBL because the time used for lectures in classes could be use for planning, discussion and advance of the projects. During this sessions the professor could play the role of facilitator.

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Student groups as 'adhocracies' – challenging our understanding of PBL, collaboration and technology use

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Abstract

In recent literature, socio-cultural scholars have argued that new forms of organising work within and across organisations are emerging. Engeström (2008) describes it in terms of 'from teams to knots' and in a recent book Spinuzzi (2015) explores how some forms of work are carried out, not in stable teams inside an organisation, but rather as temporary convenings or 'adhocracies' that are formed dynamically around projects, to quickly disband and take their skills to new projects when the project ends. The value of these adhocracies (or their 'edge') relies on their ability to form links both inside and outside an organisation. Both accounts analyse how teams are becoming more dynamic, multidisciplinary and need to work across organisational, as well as geographical boundaries in quickly changing configurations of people. Spinuzzi, further argues how these changes are associated with new and emerging digital technologies, and how these technologies change how we communicate, coordinate and collaborate. In this paper, we critically discuss these conceptualisations in relation to long-term group work within the frame of problem and project-based learning, as it is organised for example in Aalborg University. We explore what these changes might mean for the competences students should acquire in relation to collaboration and working in teams, and how this might impact on our understanding and design of problem and project based learning.

Keywords: Problem and Project Based Learning, digital technologies, collaboration, adhocracies

Type of contribution: research paper or conceptual paper.

1 Introduction

In recent literature, socio-cultural scholars have pointed to changes in how new ways of organising work are emerging within and across organisations. In his book 'All edge: inside the new workplace networks' Spinuzzi (2015) is exploring how stable organisational teams and divisions are increasingly supplemented by agile, multidisciplinary, temporary teams that help organisations think and work across boundaries and tackle complex problems that require drawing on different disciplinary skills and competences within an organisation. These changes are also reflected in professional engineering practice and engineering education, where there is an increasing awareness of the need for transversal competences. While transversal competences are increasingly being recognised it is also clear that such skills are needed due to the rising need for working in interdisciplinary teams:

"Presently, one of the major developments in engineering professions is the invention of integrated product teams (IPT) and integrated product development (IPD), where processes of design, manufacturing and marketing are integrated by bringing together interdisciplinary groups (including customers)" (Guerra, Ulseth, Jonhson, & Kolmos, 2017, p. 1225)

These changes and challenges resonate well with Spinuzzi's claim that stable organisational teams and divisions are increasingly supplemented by agile, multidisciplinary, temporary teams, and Engeström's conceptualisation of 'teams as knots' that need continuous tying and untying in the form of renegotiating tasks, focus and members. But how does it resonate with how we educate students for their professional and civic life? In this paper, we critically discuss these conceptualisations in relation to long-term group work within the frame of problem and project-based learning, as it is organised for example in Aalborg University. We explore what these changes might mean for the competences students should acquire in relation to collaboration and working in teams, and how this might impact on our understanding and design of problem and project-based learning. We do so by initially presenting problem and project-based learning as it is conceived and practiced at Aalborg University. We use this model as a case in point, but these discussions are equally valid for similar orchestrations of problem and project-based group work. We then introduce the ideas of 'adhocracies' and 'knotworking' building on the work of Engeström (2008) and Spinuzzi (2015) and we contrast and compare these ideas with how problem and project-based work is organised. We do so by drawing out seven dimensions highlighting differences in how collaboration is perceived from these two perspectives. In the section following, and before the final discussion, we add some nuance to our initial characterisation of problem and project-based learning as practiced in Aalborg University. We conclude by discussing how the seven dimensions identified might be helpful in challenging our current understanding of collaboration within PBL, and how they might help us to conceptualise and design novel PBL models and forms of collaboration.

2 Problem and Project Based Learning - The Aalborg PBL model

In Aalborg University (AAU) a particular PBL model has been employed as a University-wide pedagogical approach since the University's inauguration in 1974 (Kolmos, Fink, & Krogh, 2004). This model has more recently been formally described in a number of principles (Aalborg University, 2015):

- The problem as point of departure
- Projects organised in groups
- The project is supported by courses
- Collaboration – groups, supervisor, external partners
- Exemplarity
- Student Responsibility for learning

These principles underpin how PBL is practiced at AAU (although with some variance across the different programmes). In practice, this means that students each semester: work in groups; identify their own real-world, societally relevant problems to address (often with external stakeholders); engage in long-term collaboration (3-4 months) where they - together with a supervisor - choose relevant theories and methods; carry out empirical and theoretical studies; analyse and discuss empirical data and/or theories to address their problem. The 'solution' to the problem is disseminated in a final project report that accounts for (typically) half of the students' credit for a semester (15 ECTS). Thus, it is a pedagogical model, which is heavily participant-driven, collaborative and problem-oriented and is inspired by the work in critical pedagogy (e.g. Paolo Freire and Oscar Negt). The model operates at a programme and semester level, rather than being confined to an individual course. This means that the model is implemented at a systemic level where it pervades the organisation of the entire curriculum of an educational programme. This affects the design of relations between courses and project work within a semester, as well as the physical architecture of the university. For example, students should - ideally - have their own group room or space.

It has often been argued – and shown – that this particular pedagogical orchestration is well-suited to support students in acquiring transversal competences such as communication, collaboration, critical thinking and problem-solving skills (Du, Emmersen, Toft, & Sun, 2013; Guerra et al., 2017). While we do not fundamentally disagree with this, our purpose in this paper is to critically discuss this orchestration of work and highlight some challenges it is facing. For one thing, it is worth noting that students work together in the same group over a lengthy period, and in some cases have access to a group room or group space meaning that the students often work physically co-located. Secondly, while students have other priorities and tasks, their main focus for the extended period of time is the collaboration around a single project where the 'team' is stable. Thirdly, although the Aalborg PBL model emphasises interdisciplinarity, it does so mainly through students within a programme adopting theories or methods from different disciplines rather than groups that are formed as inherently inter- or multidisciplinary. While arguably the students are developing very important competences for their future professional and civic life, we would argue that some emerging trends within both work and learning are challenging this particular orchestration of work and suggest that we may need to reflect on how we can develop new forms and models for problem and project-based work, which can *supplement* the existing.

3 Adhocracies and knotworking

In the book 'from teams to knots' Engeström (2008) argues how historically new modes of work are emerging and thus changing how we should understand the notion of 'teams'. Much in line with the previous quotation from (Guerra et al., 2017, p. 1225) he explores how "*processes of design, manufacturing and marketing are integrated by bringing together interdisciplinary groups (including customers)*" through the notion of 'co-configuration' adopted from (Victor & Boynton, 1998), and – as we shall return to – the idea of 'social production':

"Unlike previous work, co-configuration never results in a "finished" product. Instead, a living, growing network develops between customer, product, and company. (Victor & Boynton, 1998, p. 195)

Engeström defines six criteria of co-configuration work as an emerging new form of work and production: "(1) an adaptive product or service; (2) a continuous relationship between the customer, product/service, and company; (3) ongoing configuration or customization; (4) active customer involvement; (5) multiple collaborating producers; and (6) mutual learning from interactions between the parties involved." (Engeström, 2008, pp. 195–196). In such a landscape, Engeström argues, the notion of relatively stable teams with clear boundaries becomes problematic, if not obsolete (p. 192), and suggests that stable teams might be just one type of collaboration among a multitude of more fluid forms (p. 194). Further, he discusses how such teams are increasingly internetworked, global or virtual teams whose collaboration are mediated by digital technologies. In understanding how such teams learn and collaborate, Engeström turns to the notions of 'knots' and 'knotworking':

"The notion of knot refers to rapidly pulsating, distributed, and partially improvised orchestration of collaborative performance between otherwise loosely connected actors and activity systems. Knotworking is characterized by a movement of tying, untying, and retying together seemingly separate threads of activity." (Engeström, 2008, p. 194)

What we notice here, is how the locus of collaboration and learning moves away from being primarily a property of a stable team towards a notion of collaboration and learning that explores improvisation and the bringing together of loosely connected actors and activities where there is no 'center' of activity. This form of collaboration Engeström further explores through the notion of 'social production' or peer-production, which are forms of collaboration existing outside formal organisations and are (often) oriented towards production of 'public goods'. To exemplify such types of production Engeström refers to open source development, the free science movement and Wikipedia. These are forms of collaboration, which have also been referred to as mass-collaboration (Ryberg, 2018 in press). Mass collaboration is a more diffuse, uncoordinated mass of people contributing individually or in clusters to sustained or more ephemeral constructs. Examples of sustained mass collaborations could be open source development communities or the distributed maintenance and development of Wikipedia pages. However, they can equally be of a more ephemeral nature where there is a short-lived activation of massive participation across many networks. For example, multiple people congregating around a particular hashtag on social media, such as #metoo to debate, share, illustrate gender inequality and sexual harassment. In both cases, the notion of 'collaboration' does seem to become a bit stretched, but the examples illustrate emerging forms of orchestrating 'working together' via diffuse networks mediated by digital technologies.

Particularly, the aspects of digitally mediated collaboration, coordination, and communication are brought to the fore in Spinuzzi's (2015) idea of all-edge adhocracies. Spinuzzi studies and analyses how small contractors work and show how these contractors, which are in reality often one-person firms, take on larger projects of e.g. website development, but then dynamically and ad-hoc bring together a distributed team of people to tackle the concrete project; thus, they are able to:

"[…] able to rapidly link across organizational boundaries, combine into temporary work groups, swarm a project with a team of specialists, and disperse at the end of the project, often to re-form in a different configuration, with some different members, for the next project" (Spinuzzi, 2015, p. 2)

This is a form of work that is both developing inside organisations, as a way of dealing with the challenges outlined above, but equally a type of work an increasing number of people within the academic workforce are engaging with, as it offers flexibility and self-management over being part of a larger organization. This type of work, Spinuzzi argues, has predominantly been enabled by information- and communication technologies and the ability to coordinate, communicate and collaborate via numerous – often 'free' – social media or web 2.0 tools that exist as alternatives to the large corporate groupware or enterprise systems that were previously a condition for engaging in distributed work. Instead, Spinuzzi studies how dynamic teams with shifting membership, create particular and singular *constellations of technologies* (Rossitto, Bogdan, & Severinson-Eklundh, 2014; Spinuzzi, 2015) for the project at hand, and how the 'project managers' engage, not with a stable team, but rather a loosely connected 'knot' to borrow the term from Engeström, or that which Spinuzzi refers to as all-edge adhocracies. Further, many of these project managers are engaged in simultaneous projects with different constellations of people and technologies. In both these accounts, we see a move away from understanding the 'core' of a group or team i.e. their inner dynamics and negotiations, to study rather their relations at the 'edges' and how they are related to other 'knots'. As such, some contrasts and differences start to emerge if we look at the conceptualisations of teams or groups between the Aalborg PBL model and the notions of adhocracies and knotworking.

4 Contrasts and differences

In the following, we draw out some contrasts and differences that emerge from comparing the AAU-PBL group model with the conceptualisations highlighted by Engeström and Spinuzzi. We do so by returning to some of the characteristics previously highlighted in relation to the Aalborg PBL model. In doing so, we are necessarily reducing the variation and complexity underpinning the model, how it is adopted across the university, as well as how students work in practice. We initially highlight and discuss some overarching traits of the model, to which we shall subsequently add more nuance. Further, we stress that we do not see these discussions as related to only this particular model, but equally to other orchestrations of PBL that bears resemblance to the Aalborg PBL model i.e. a strongly-tied collaboration in smaller groups over an extend period of time focusing on a particular problem and/or project. In this sense we treat the model as a wider example of a 'small-group' model of work and learning (Damşa, 2014).

As we noted, the PBL - or small-group model - rests on students working on a single project, in a stable, monodisciplinary group over an extended period (3-4 months). The work is often co-located with students occupying the same room or space. Their collaboration is strongly tied, and there is a high-level of mutual dependence within the group. In contrast to this, we can glean from Spinuzzi and Engeström's characterisations of work and collaboration that other features of 'team-work' are starting to emerge. These are characterised by unstable or dynamic membership, shorter-lived processes, parallel engagements, and interdisciplinarity. Further, the progress is not only driven by the individual group or the center, but rather is fuelled by work at 'the edge' or periphery where multiple strands of activities and actors across different knots continuously need to be tied, untied and re-negotiated. As such, there is no 'center' which is in full control of the direction and development of the work. Rather this is negotiated amongst actors in a wider network. In addition, these forms of work can take place at different levels of scale, where participants can be part of 'greater wholes' or 'mass collaborations' such as developing complex open source software in a larger, distributed network possibly composed of smaller, agile teams.

In the following we draw out some central dimensions of these two types of collaboration and discuss them further:

Expertise – monodisciplinary vs interdisciplinary: In the AAU-PBL model the dominant mode of work is carried out by monodisciplinary groups of students within the same educational programme. While the group can draw on theories and methods from multiple disciplines, they are not as such an interdisciplinary team, and their main objective is not to function as such, but to complete a project within a particular programme/discipline. In contrast, adhocracies and knotworking processes are characterised by being formed as and function as interdisciplinary teams and their capacity to function are dependent on the individual actors bringing their unique perspective into the process and negotiating these with the other members.

Membership and scale of collaboration: stable vs dynamic: In the AAU-PBL model membership in the group and the scale of collaboration is stable throughout the entire process, whereas in processes of adhocracies and knotworking members may dynamically change over time and the scale of collaboration can shift between few members to involving wider and more complex networks. For example, in mass-collaborations participants may join to solve a particular sub-tasks and then leave again, and there may be shifts between working in smaller teams and in wider networks.

Space: Co-located vs distributed: In the AAU-PBL model members are often co-located occupying a shared room/space or convening when possible for large parts of the collaboration. In processes of adhocracies and knotworking participants are often geographically dispersed or engaged in other activities, and thus bound together via digital technologies for large parts of the collaboration.

Decision making: central vs. distributed boundary work: In the AAU-PBL model students have a high- degree of autonomy and decisions are negotiated within the group, whereas in processes of knotworking and adhocracies decision making can be of a more distributed nature reconciling perspectives across different actors and activities i.e. involving more stakeholders than a small group.

Collaborative orientation and dependencies: internal/inward vs edge/outward: In the AAU-PBL model group members are primarily oriented towards their own common project and are highly dependent on the internal collaboration and coordination in the small-group. In contrast, adhocracies and processes of knotworking are oriented towards the periphery, are dependent on other actors and activities, and their success depends on being able to work at the 'edge' by continuously negotiating with neighbouring activities and crossing boundaries.

Task focus: Singular vs parallel: In the AAU-PBL model the task focus is on the concrete problem-based project work and this is the primary focus. In processes of knotworking and adhocracies there may be multiple, conflicting projects in play or separate activities that need to be tied together.

Temporality: extended and fixed vs shorter-lived or dynamic: In the AAU-PBL model, the collaboration usually is performed within an extended and fixed period of e.g. 3-4 months, whereas in adhocracies and knotworking activities may be shorter-lived bursts, intense and dynamic or take forms where the collaboration lies dormant for a while to re-ignite.

Clearly, contrasting the two illustrate very different types and conceptualisations of collaboration. While there are great learning benefits associated with the small-group PBL model, in terms of developing competences (such as collaboration, critical thinking, problem-solving, problem identification and project management) the AAU-PBL model also favours particular modes of collaboration leaving other areas less explored. In saying so, we should remain conscious that the notions of adhocracies and knotworking are not 'pedagogical models', but analytic observations of patterns of collaboration observed in various organizational and work-related contexts. Nevertheless, these conceptualisations do illustrate glimpses of emerging forms of learning and work in the contexts we wish to prepare students for within engineering education and higher education more broadly. The comparisons can thus provoke us to ask critical questions such as: Do students gain sufficient experience working in interdisciplinary groups? Are students sufficiently prepared to work in contexts with multiple loosely connected stakeholders that are geographically dispersed? Are students able to alternate between working in small-groups and larger networks and in dynamic constellations of people? More broadly we could ask whether the competences acquired through small-group work are applicable and transferable to processes of knotworking and adhocracies? As Engeström argues, small-group work or stable teams might be just one type of collaboration among a multitude of more fluid and dynamic forms of collaboration. The question is whether students gain sufficient experiences and competences with varying types of collaborative engagements?

However, as earlier indicated, we have deliberately reduced the variations and complexities underpinning the AAU-PBL model in these comparisons e.g. how it is differently adopted across the university, and how students work in practice. In the following section, we therefore add some nuance and present examples of practices where students engage in activities bearing some resemblance to processes of knotworking and adhocracies, particularly including their use of digital technologies.

5 Nuances and variations – nomadic groups and digital technologies

For one thing, it is worth noting that many students do gain experiences with interdisciplinary work. Often in Master programmes, the participants come from widely different disciplinary backgrounds, and students have opportunities to engage with events such as case competitions (http://www.aaucasecompetition.dk/) where they work intensively for two days in interdisciplinary groups to address a challenge or case from an industry partner. Another example is the DADIU event where students from art schools and universities work with interdisciplinary game development during an entire semester (http://www.dadiu.dk). Further, there are examples of semesters where students alternate between small-group work and engaging with the whole cohort as a learning network (Ryberg & Davidsen, 2018).

However, more importantly, we wish to highlight how the daily work of students bear some resemblances to processes of adhocracies and knotworking. Particularly in their use of digital technologies as part of the problem and project-based group work. In a series of studies, we – and others – have investigated students' use of technologies in relation to group work (Guerra, 2015; Khalid, Rongbutsri, & Buus, 2012; Rongbutsri, Forthcoming; Rongbutsri, Khalid, & Ryberg, 2011; Ryberg & Davidsen, 2018; Ryberg, Davidsen, & Hodgson, 2018; Sørensen, 2018; Thomsen, Sørensen, & Ryberg, 2016) and in the following we briefly discuss some of the results and insights.

While students' group work is often co-located, it is at the same time heavily underpinned by digital technologies. In writing and managing their projects, students commonly use Google Docs/Office 365 for collaborative writing; Dropbox/Onedrive for file-sharing; Facebook for internal communication and coordination in the group; MeisterTask or Kanbanflow for project and task management; Skype/Hangouts when they are not able to meet. In this sense, the groups resemble the adhocracies described by Spinuzzi, where they negotiate a *potential constellation of technologies* (Rossitto et al., 2014; Spinuzzi, 2015) for their particular project – a constellation that might change over time as new technologies are brought in, experimented with and adopted or discarded (Rongbutsri, 2017). This is a process we have previously described as 'the orchestration of multiple technologies' (Ryberg et al., 2018). The constellations of technologies are flexible, dynamic and characterised by adopting 'freely' available social media tools (or the Microsoft tools provided by the institution). They are light, flexible packages composed of several tools rather than 'professional' groupware or enterprise systems (students can even find such solutions cumbersome and overwhelming (Sørensen, 2018)). In this way, students experiment with a variety of digital technologies to support their group work over time and although students tend to cling to particular tools they know, some changes occur over time as students come into new groups and need to negotiate a new constellation of technologies (Sørensen, 2018).

In our studies of groups, we have equally found that many student groups are what we have termed 'nomadic' (Ryberg et al., 2018); these are groups who have no common permanent group room or space, and therefore need to reserve group rooms for shorter periods of time (two hours), work in the hallways, cantina, libraries, cafes or at home. These groups often work in more distributed ways where they alternate between occasional group meetings and working individually coordinating and communicating via their selected communication and collaboration tools. For these groups in particular they continuously engage in the 'orchestration of work phases, spaces, and activities' (Ryberg et al., 2018), where they on a daily basis need to make decisions of where and how to work. Do they need a common, quiet space, can they use the cantina, should they work individually from home and coordinate online? Such decisions are taken ad-hoc in the group and depend also on which phase they are in their project e.g. do they need to discuss the overall direction of the project and write closely together, or can they read the material and write independently? This was also a pattern observed with groups having their own spaces. They would often change constellations and break into smaller groups, do some work and congregate later. As with the nomadic groups their planning of activities and tasks was dynamic and agile and while they do have longer-terms plan for their work, it was also characterised by ad-hoc planning and flexibility depending on the situation at hand. With this, we want to draw attention to the fact that although the groups are stable, and the time-period is fixed, the groups also work and attune themselves to shifting conditions and tasks; break into smaller groups to work for a period of time on shorter-lived task, untying and tying together again different activities, doing fieldwork, experiments, interviews etc.

In this way, the groups' practical day-to-day work bear resemblance to the adhocracies described by Spinuzzi, and the 'knotworking' together of different strands of activities and actors. We believe this needs mentioning to counterbalance the initial diagnosis that could leave the reader with the impression of PBL group work as a static, stable phenomenon with clearly described roles, functions, tasks. When zooming in on the everyday group work we do see a myriad of knotworking like practices that in many ways – on a micro-scale – function as quite dynamic adhocracies. However, there are some traits of adhocracies and knotworking that are not present in the current practice which are worth exploring to guide reflections on new ways of practicing PBL.

6 Final discussion

In comparing and contrasting the AAU-PBL model (or widely: small-group PBL work) with the notions of adhocracies and knotworking some markedly different dimensions emerge. Dimensions which can provoke critical questions in relation to how we are currently practicing small-group PBL. These are the dimensions of *mono-disciplinarity vs. interdisciplinarity; membership and scale of collaboration; Space - co-located vs distributed; Decision making – central vs. distributed boundary work; Collaborative orientation and dependencies – inward or outward; Task focus: Singular vs parallel; Temporality – extended and fixed vs shorter-lived or dynamic.* Bringing out these contrasts, we can begin to ask questions such as: Do students gain experiences with distributed, interdisciplinary work? Do students gain experiences working in more complex networks of decision making and collaboration where the locus of control is distributed amongst different stakeholders? Do students find themselves in situations where the collaborative orientation and dependencies extend beyond the individual group and into larger more complex networks or mass-collaborations that need to continuously 'knotwork' together different strands of activities and actors? Do students attain experiences with short-burst, intensive forms of mass-collaboration where a large number of participants co-construct, in a distributed manner, a shared 'product' or solution? Are students exposed to working on multiple parallel projects that require coordination amongst several overlapping and conflicting stakeholders?

We do not raise these questions to suggest that the current PBL practice is obsolete and should be completely re-designed. Rather we suggest that we could begin to work with designing modules or semesters that features other forms of collaborative engagements than primarily small-group PBL work. The small-group PBL work does provide students with valuable competences in terms of collaboration, critical thinking, communication, project management etc. and as we have highlighted in the section on nuances and variations, the actual practices of small-group work do carry some resemblance to the notions of adhocracies and processes of knotworking. Students' work is heavily underpinned by a variety of digital technologies and the work is characterised by a certain agility, flexibility and ad-hoc planning encompassing - in a micro-perspective – also processes of knot-working where different actors and activities are tied together. However, particularly the dimensions of decision making, the collaborative orientation, membership and scale of collaboration remain within the boundaries of the (monodisciplinary) group. The groups can be viewed as relatively stable, autonomous units that do not rely on interaction across boundaries. Nor do the individual units' work feed into, or need to be coordinated with, a larger, more diffuse and geographically distributed network of actors and activities. We conjecture that designing for such experiences might strengthen, broaden and extend the collaborative competences students develop through the existing forms of small-group PBL, and we believe the seven dimensions we have identified by contrasting and comparing the AAU-

PBL model with notions of knotworking and adhocracies can be helpful as conceptual tools to design and craft new models and ideas for collaborative engagements that expands the scope of the small-group PBL orchestrations.

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Student Engagement and Study Intensity in Flipped PBL Curriculum and Blended Learning Activities

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Abstract

This paper explores and discusses the connection between *student engagement* and *study intensity,* particularly in relation to flipped curriculum initiatives in problem-based learning (PBL) environments. Drawing from educational psychology and motivational theory as well as empirical findings from the PBL Future Project and two flipped curriculum case studies at Aalborg University suggesting students' experience of study intensity and engagement might not necessarily correlate in flipped classroom and peer-learning approaches, the paper proposes a differentiated approach to assessing participation in and quality of study activities, particularly in the development of future innovative flipped and blended-learning PBL scenarios.

Keywords: flipped curriculum, student engagement, study intensity, PBL, blended learning

Type of contribution: conceptual paper

1 Introduction

In Denmark, the terms *student engagement* and *study intensity* are often used interchangeably, however whereas the intensity of studying, referring to the total amount of time spent studying including preparation and project work (The Danish Evaluation Institute EVA, 2016), might be an indicator of motivation, student engagement is a much broader term understood as behavioural, emotional and cognitive engagement in studies (Trowler, 2010). In addition, it is commonly known from motivational theory that the personal experience of time spent on engaging and immersive activities is somewhat distorted (Csikszentmihalyi, 1997). Thus, the increasing attention to study intensity in quality assessments of courses and curricula as well as in the self-evaluation and accreditation of study programs and institutions poses certain challenges, particularly within a problem-based learning environment that emphasises self-directed learning through problem-based project work.

This has initiated discussions and developments of new study activity models across educational institutions to increase students' and teachers' awareness of and support reflections regarding all study activities taking place in problem-oriented and project-based learning environments. However recent research on flipped classroom initiatives at Aalborg University (AAU) as part of The PBL Future Project suggests that new blended teaching methodologies and student-centred approaches to learning such as flipped classroom might increase the complexity even further by intensifying this seemingly inverse correlation between student engagement and experiences of time spent studying (Bertel, 2017). Thus, whereas student-centred learning is generally argued to increase study intensity (EVA, 2016), our research suggests that successful student-centred and self-directed designs for learning may reduce the visibility and awareness of study intensity, thus requiring new evaluation methods with regard to student engagement and quality assessment of such initiatives.

The purpose of this paper is to present the preliminary findings from a cross-case study on flipped curriculum initiatives at AAU and discuss their implications in relation to different perspectives on the relationship between student engagement and study intensity as well as in relation to the assessment of new, blended and often asynchronous teaching and learning approaches. In the following we will discuss the terms *study intensity* and *student engagement* more in depth, particularly in relation to educational psychology and relevant motivational theory. This is followed with an introduction to the PBL Future Project and the particular subproject dealing with flipped blended learning strategies, and findings from cross-case study on existing flipped curriculum initiatives at AAU are presented. These findings and their implications in relation to the development of an AAU study activity models as well as the assessment of such study activities are discussed and directions for future work is proposed.

2 Study Intensity vs. Student Engagement

The term *study intensity* refers to the total time the student use in their studies and is considered an important indicator of student motivation and learning impact, i.e. high study intensity leads to high motivation and learning, whereas low study intensity leads to lessened motivation and learning and perhaps even increased drop-out rates (The Danish Evaluation Institute EVA, 2016). Suggestions to increase study intensity include efforts in the commencement of study, explicitly estimating the expected time used for studying in a course or a program, monitoring actual time spent studying (e.g. inspired by Studiebarometeret in Norway) as well as active, student-centered learning methods and feedback. More frequent exams are also considered an effective way of increasing study intensity (EVA, 2016).

In the quality assessment and accreditation of higher education programs and institutions the student full-time equivalent (FTE) is often used for measuring the activity of full-time programs. 1 student FTE is defined as study activity corresponding to the workload of one academic year and is equivalent to 60 ECTS points (with 1 ECTS point corresponding to 28 hours). A recent Study Environment Evaluation at AAU from 2016 showed a great diversity in the amount of time spent on studying (see figure 1) with most students (25%) responding they spent 36-40 hours on studying pr. week but with a 49/51 percent distribution of students who responded they spend less or more than 36 hours, respectively (Dissing & Haslund, 2016).

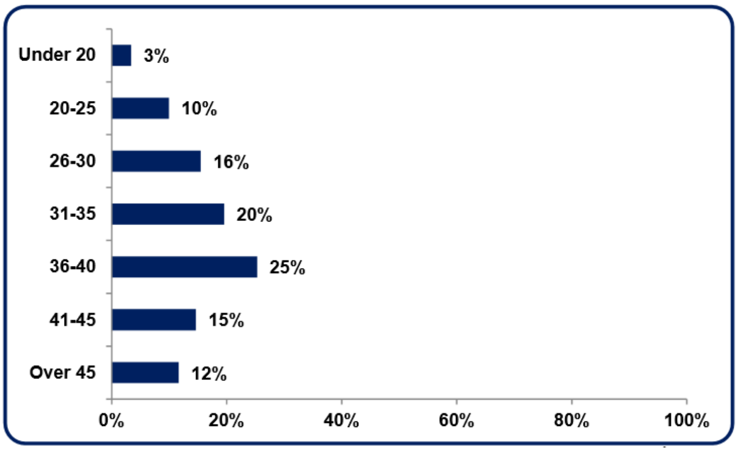

Figure 1: Total time (hours) spent on an entire semester (Dissing & Haslund, 2016).

The evaluation also demonstrated great diversity in the distribution of time spent studying throughout the semester (see figure 2) across faculties (Dissing & Haslund, 2016).

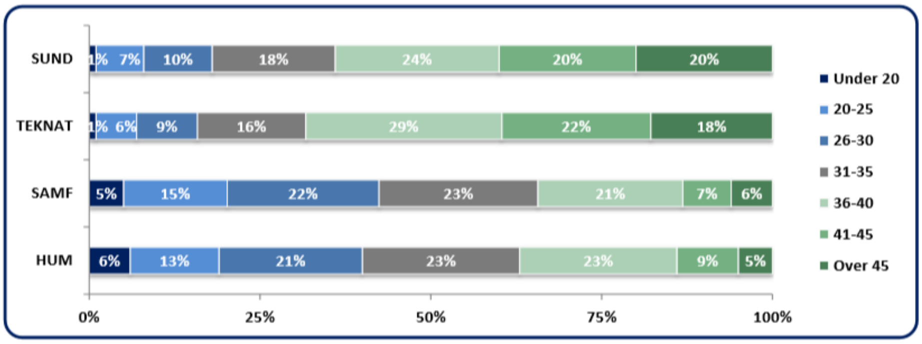

Figure 2: Time distributed throughout the semester on the faculty of Health Science (SUND), Science and Technology (TEKNAT), Social Sciences (SAMF) and Humanities (HUM), respectively. (Dissing & Haslund, 2016)

This indicates differences between Health/Science/Tech faculties and Social Sciences/Humanities with regard to distribution of workload and study intensity throughout the semester, with increased study intensity at the end of the semester on Health/Science/Tech study programs e.g. for exam preparations in comparison to Social Science/Humanities, which in contrast has a higher study intensity at the beginning of the semester, e.g. in relation to courses.

When it comes to student engagement, the general guidelines regarding study intensity and its relation to student engagement as proposed by e.g. EVA, refer to the 'Student Engagement Literature Review' from Lancaster University (Trowler, 2010), which defines student engagement as:

> *"…concerned with the interaction between the time, effort and other relevant resources invested by both students and teachers and their institutions intended to optimise the student experience and enhance the learning outcomes and development of students and the performance, and reputation of the institution." (Trowler, 2010: 2)*

Whereas the term *study intensity* seems to reduce engagement to time spent on studying, Trowler's approach to student engagement represents a much more holistic approach and involve both a *behavioral*, *emotional* and *cognitive* dimension of engagement, drawing from both Fredricks, Blumenfeld and Paris (2004) and Bloom (1956):

1. *Behavioral engagement* understood as attendance and involvement;

2. *Emotional engagement* understood as affective reactions such is interest, enjoyment and sense of belonging; and

3. *Cognitive engagement* understood as investment in learning, seeking to go beyond the requirements and relishing challenge.

According to Trowler, these dimensions can have both a 'positive' and a 'negative' pole, each of which represents a form of engagement separated by non-engagement (withdrawal or apathy), thus one can engage either positively or negatively along these dimensions and e.g. behavior that could be considered disruptive, delaying or obstructive could also be considered a certain form of engagement (Trowler, 2010: 7).

2.1 Emotional and Cognitive Engagement – Theoretical Perspectives

Whereas *behavioral* engagement (whether positive or negative) is included in the understanding of study intensity, emotional and cognitive engagement is not as easily quantified. Drawing from educational psychology and motivational theory, particularly Self-Determination Theory (Ryan & Deci, 2000) as well as Flow Theory (Csikszentmihalyi, 1997), what further complicates the relationship between these types of engagement and the experiences of study intensity is, that high levels of emotional and/or cognitive engagement might affect the students' understanding of what is considered 'work' (i.e. study activities) as well as their experience of 'time' (i.e. study intensity).

Self-Determination Theory (SDT) as a formal theory defining intrinsic and varied extrinsic sources of motivation in cognitive and social development is often applied to education, empathizing the individual's experience of autonomy, competence, and relatedness to foster volition and high quality forms of motivation and engagement in activities, including enhanced performance, persistence, and creativity (Ryan & Deci, 2000). Csikszentmihalyi's Flow Theory connects this motivation-dimension to cognitive engagement, since motivation is not just a result of expected pleasure or pain, but rather mediated by perceived challenges and skills to perform the activity (Csikszentmihalyi, 1997). Engaging just-manageable challenges and continuous feedback about progress may facilitate a subjective state with intense concentration and a sense of capability, a merging of action and awareness and distortion of temporal experience and an experience of the activity as intrinsically rewarding (Nakamura & Csikszentmihalyi, 2014). Based on this, the flow model (see figure 3) describes different stages of cognitive engagement and their connection to emotional states:

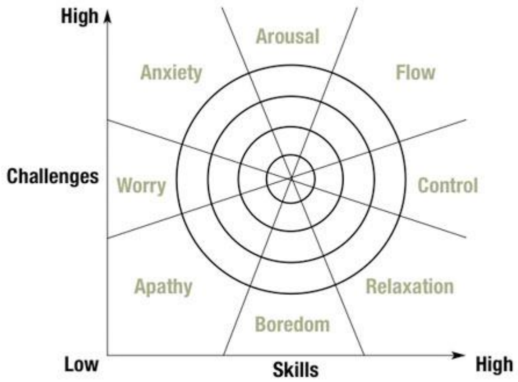

Figure 3: The Flow Model (Csikszentmihalyi, 1997)

From the perspective of Self-Determination and Flow Theory, emotional and cognitive engagement is not inherently "intrinsic" or "extrinsic" but contextually embedded and mediated by social relations and experiences of self-efficacy and self-determination. Thus, engaging in team-based project work based on problems that the students themselves determine might in some cases blur the lines between what is considered 'studying' (extrinsically motivated e.g. by exams) and what is considered necessary actions in pursuing a specific, intrinsically motivated goal (individual or determined by the group). Thus, extra-curricular and self-study activities such as company visits and engaging with external stakeholders might not initially be perceived as a study activity unless it is explicitly required of the students. In extension of that, engaging in problem-based project work will also in many cases involve varying degrees of immersion and flow throughout different phases of the project, thus although students might consider for instance the writing process a study activity, their experience of the time spent especially in the final stages of writing up the report, they may not always be aware of how much time is actually spent during these phases.

2.2 Study Intensity and Student Engagement in a PBL Environment

This poses particular challenges to PBL environments that seek to support students in taking responsibility for their own learning through active learning methodologies such as project work and blended learning activities, since although research shows that PBL can enhance experiences of Self-Determination and cognitive engagement (Rotgans & Schmidt, 2011), this might not translate into a reported increase in study intensity. Similarly, increasing the number of traditional lectures and tests might enhance the students' awareness of how much time they spend studying and thus increase the reported study intensity, however this would not necessarily be a valid indicator of neither engagement nor learning.

At AAU, PBL is implemented at institutional level which means all study programs involve problem-based project work and take departure in PBL principles that constitute the Aalborg PBL model (Aalborg University, 2015), thus although PBL is practiced slightly different across faculties, departments and study programs, they generally share a focus on students' contextual problem understanding, team-based and self-directed learning as well as interdisciplinary and exemplary project work supported by courses (Kolmos & Graaff, 2014). Consequently they also share the common challenge of ensuring the consistency and sustainability of these PBL principles, skills and competences in the development of next generation blended PBL learning models and principles at AAU.

Thus, the former mentioned Study Environment Evaluation (Dissing & Haslund, 2016) gives rise to discussions about study intensity both in relation to student awareness and visibility of study activities as well as to the continuous development of problem-based designs for learning that are engaging. This initiated a process of developing a study activity model to support increased visibility of study intensity and new PBL research initiatives was launched, both situated development projects that explore and evaluate novel, active teaching methods and a larger research project 'PBL Future' that aims to systematically investigate PBL practices and potential future scenarios across faculties, departments and study programs at AAU (PBL Future, 2017).

3 The PBL Future Project

This extensive cross-faculty research initiative aims to develop research-based directions for problem- and project-based learning in a digital age (PBL Future, 2017) and encompasses five subprojects covering diverse aspects of PBL related to (1) problem design and analysis as a social practice, (2) students' use of ICT for collaborative learning, (3) supporting student reflections regarding life-long learning competencies and individual learning trajectories, (4) flipped curriculum and innovative technology-supported designs for learning, as well as a (5) baseline study covering existing practices of and attitudes towards PBL at AAU, including a comprehensive student- and staff survey as well as a mapping of local faculty development projects, resources and planning processes in relation to curriculum design and scenario development, implementation and transition into the future of PBL in a digital and post-digital age.

3.1 Flipped PBL Curriculum

The traditional approach to Flipped Classroom as "inverting the classroom" (Lage et al, 2000) has been further elaborated in recent years, extending the understanding of the flipped "classroom" as one specific approach to blended active learning, where students use e.g. online materials and ICT tools to prepare for classes and engage in workshop, discussion groups and peer-learning activities rather than traditional lectures (Jenkins et al., 2017) to expand the idea of "flipping" classroom activities to flipping entire semesters and curricula to meet students' needs and expectations regarding the integration of digital tools and digitized learning environments in their education and to facilitate pedagogical innovations taking advantage of Massive Open Online Courses (MOOCs) and Open Educational Resources (OERs) in problem-driven and open exploratory processes negotiated amongst students, teachers and supervisors (Ortiz, 2016).

At AAU, several small-scale flipped classroom-experiments have been carried out continuously, however these initiatives are seldom internally coordinated and have yet to be systematically studied and disseminated both internally in the organization and externally to relevant stakeholders. Thus, the PBL Future research initiative includes an initial analysis of current initiatives involving flipped classroom/curriculum and blended learning elements at AAU, identifying potentials and barriers and relevant aspects related to the efficiency and quality of the teaching and supervision as well as student engagement in flipped learning processes. This involves several case studies across faculties, departments and study programs of which two will be presented here.

Flipped Curriculum Case Studies

The goal was to design and evaluate a number of PBL practices that radically change the relationship between and organization of courses and project work an integrate new ICT skills into the programs, where entire modules and semesters in two teaching cases were redesigned to accommodate a more problem-oriented approach in which formulated problems to a large extend were determining for course- and material selections made by the teachers rather than vice versa.

The first case involved a 6 week, 10 ECTS module at 5th semester Communication and Digital Media, in which 63 students and a team of three teachers participated. In the module, the students were to design, execute and evaluate a 2-day workshop for 1st semester students on a self-chosen IT tool, working creatively with the development of relevant ICT skills and digital competency in an academic PBL practice under the guidance of a supervisor and completed with an oral exam based on a project report. The flipped curriculum concept was implemented so that the lecturers made relevant literature, assignments, short streamed lectures (via YouTube), and links to lectures by other academics available online. Face-to-face time between teachers and students was organized as short lectures, but mostly as workshops and discussion groups, with a specified weekly structure of introduction on Mondays, workshops on Tuesdays, literature discussions on Wednesdays, preparation and production of digital products on Thursdays and feedback and supervision on Fridays.

The second case involved the integration of a 5 ECTS course into a 15 ECTS project module at the 1st semester Master Program in Networks and Distributed Systems involving approx. 15 students and two teachers. The course is traditionally close to the project unit and is usually examined through mini-projects. The course structure was reorganized in modules that were planned and prepared after and in alignment with the students' choice of problem, and the deliverables in each module integrated into the semester project report. The course was organized in a number of themes, each topic containing a combination of online material, workshops and either a mini-project or a presentation on which the students received feedback from both teachers and fellow students. The examination was integrated into the project exam with a separate pass/fail assessment.

The purpose of doing a cross-case study was to explore possibilities and challenges related to the organization of and interplay between course activities, self-directed study activities and supervised project work from the perspective of both teacher and student, to understand teachers' goals, planning and preparation processes and related challenges as well as students' experiences. Data in the analysis included curriculum designs, online resources and materials, interviews with coordinating teachers in combination with the teachers' own observations of students through the semester and at the exam, students' written semester evaluations as well as focus group interviews with students.

3.2 Flipped Study Intensity and Student Engagement: Preliminary Findings

In general, the students have been positive about the new designs of courses, and the learning outcomes demonstrated in project reports and at exams have generally been up to expected academic standards. However, the case studies also highlight certain challenges related to flipped curriculum designs, particularly in relation to the distribution of responsibility between students and teachers as well as in the experiences and documentation of study intensity.

Whereas students report increased gains on learning outcomes and experiences of being more motivated to and engaged in the proposed flipped PBL activities, these students simultaneously claim to have spent less time on flipped curriculum modules compared to traditional lectures, i.e. indicating a decrease in study intensity. As the performance of the students is reported by the teachers to be consistent, as earlier mentioned this might be a psychological effect of increased motivation and thus states of flow or the fact that some of the self-determined peer-learning activities are not always consciously categorized as study activities.

Another issue turned out to be encouraging students to take ownership of both the learning process and its products, thus students in both cases were uncertain about the module structure and specifically requested more guided structuring (e.g. assigned time slots for online preparation) and the teachers reported increasingly goal-oriented behavior (e.g. an extensive, narrow focus on guidelines and how to meet requirements), which stand in contrast to students usual approach to self-directed learning in project work. This might be caused by the fact that the modules differ greatly from their usual practices and thus more information about the process and expectations might improve these aspects, however as it is something the students usually are perfectly capable of managing themselves in regular project work, this also illustrates the problems related to study intensity as a measurement of quality and highlights the need for new ways of assessing participation in and quality of flipped learning activities, particularly in the development of future innovative flipped and blended-learning PBL scenarios.

4 Participation and Quality Assessment: Towards a Flipped PBL Study Activity Model

As mentioned earlier, a process of developing a study activity model to support increased visibility of study intensity has been initiated to increase students awareness and give a more accurate image of time spend studying inspired by other matrix models based on two continua, that have been used to describe variations in approaches to teaching and learning and to provide a basis for explaining and understanding the processes involved and the motivations behind these (Jenkins et al., 2017). These continua include e.g. content/process an students-as-participants/-audience (Healey, 2005) or initiated-by-students/-teachers and participation-of-students/participation-of-students-and-teachers as in the study activity model for University Colleges in Denmark, implemented in 2012/2013 (University Colleges Denmark, 2018).

Naturally, in a PBL environment there is particular attention to the degree of problem-orientation in the activities in which students engage. Thus, although the first drafts of the AAU PBL study activity model (see figure 4) can be considered somewhat similar to these matrices, the continua focus on problem-orientation/discipline-orientation (as opposed to Healey’s content/process) on one dimension and organized-by-teacher/organized-by-student on the other (as students are considered participants in both, although the initiative may vary from teacher-led to student-led).

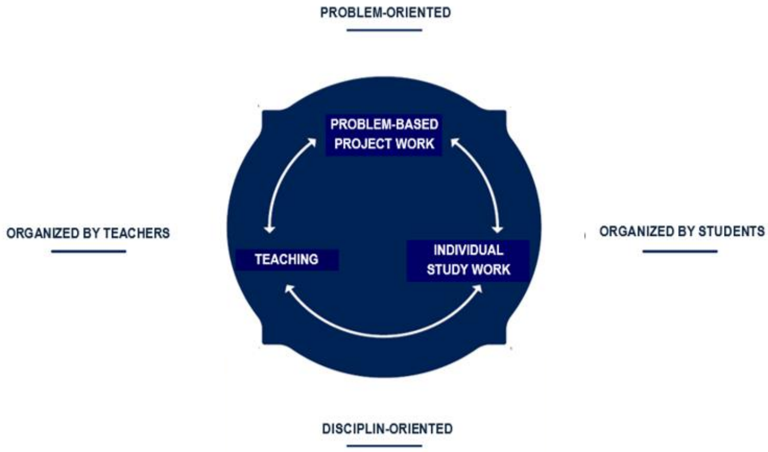

Figure 4: Draft-version of the AAU Study Activity Model

As with other learning matrices, this first version of a study activity model forms four categories of study activities and in addition to traditional discipline- and/or problem-oriented activities organized by teachers (e.g. lectures, courses and seminars, lab- and other assignments, exams as well as PBL and project related lectures and workshops, supervision and project exams) it emphasizes student-led study activities as well whether discipline- or problem-oriented (e.g. preparation, reading and writing as well as group meetings, presentations and feedback, company visits and field trips, experiments, casework and internships).

However the preliminary findings from our research within the PBL Future project suggest, that aspects regarding self-determination and motivation must be taken into account when designing such a study activity model that also includes flipped learning strategies and scenarios, since these new teaching methodologies may affect the otherwise logical connection between students' experiences of study intensity and their experiences of engagement. The following Flipped Learning Matrix (figure 5), inspired by Levy et al.'s (2009) inquiry-based matrix, uses two continua similar to the AAU study activity model: a) experiential learning (process/ content) and b) autonomy and decision-making (teacher-/student-led) (Jenkins et al., 2017):

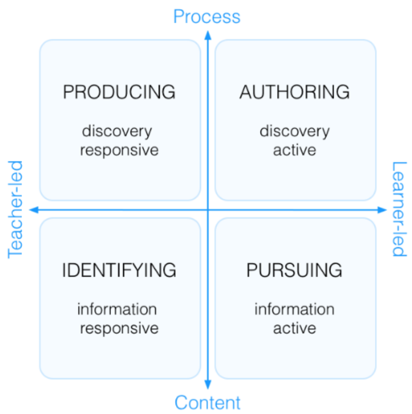

Figure 5: Flipped Learning Matrix (Jenkins et al., 2017)

Whereas this model covers the same activities as the AAU study model, it connects these activities to particular levels of participation and initiative; from responsive to active and from information to discovery, and whereas 'responsiveness' might be measured by means of study intensity in the traditional sense, the concept of 'active' is taxonomic and much more complex and thus complex methods of quality assessment are required to evaluate students engagement in 'pursuing', 'producing' and 'authoring' processes.

This perspective adds to our approach to development of a future Flipped PBL Curriculum Model (figure 6) an understanding of the processes of moving from 'identifying' (i.e. traditional lecturing) to 'pursuing' (e.g. peer-learning and study groups) or 'producing' (e.g. requested digital student production).

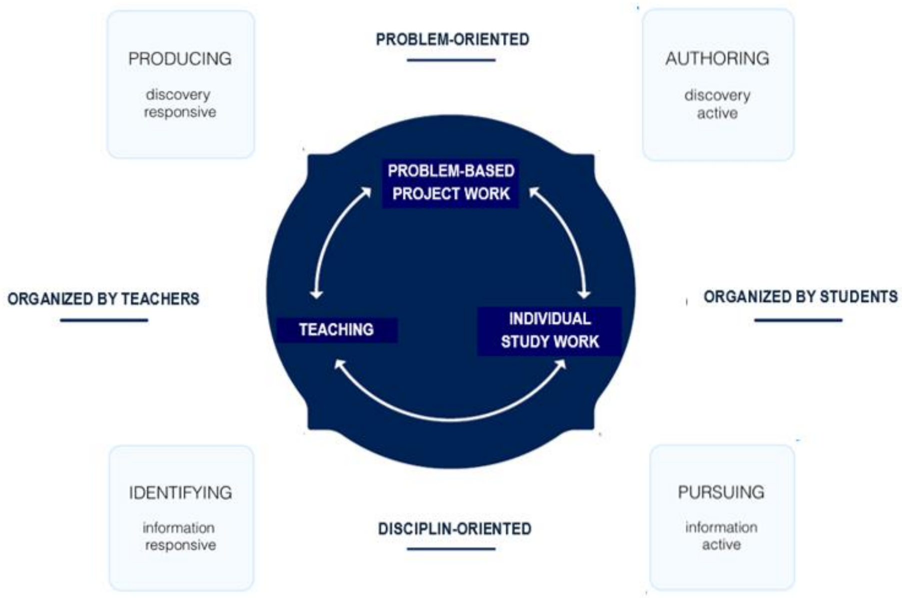

Figure 6: Flipped PBL Curriculum Model

Whereas the transition from 'identifying' to 'pursuing' was successful and fairly smoothly implemented in the flipped curriculum case studies, the transition to (teacher-led) 'production' became very oriented towards meeting the teachers' requirements and did not naturally transcend into 'authoring', i.e. students did not claim responsibility for these productions unless they were integrated directly into project work, which is by definition student-led and thus inherently self-determined.

5 Conclusion and Directions for Future Work

This paper explored and discussed the connection between *student engagement* and *study intensity* in relation to flipped curriculum initiatives in problem-based learning (PBL) environments and proposed a model for Flipped PBL Curriculum that draws from educational psychology and motivational theory. Based on this mode, future work involves exploring and developing quality assessment methods for taxonomically evaluating student engagement in study activities in future flipped and blended- learning PBL scenarios.

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Interdisciplinary humanitarian projects with PBL to motivate team performance

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Abstract

The benefits of social humanitarian projects demand more studies about its implications in project-based learning since it favours both educational learning practices and social contributions for solving problems. This study examines performance responses of a PBL interdisciplinary course to social humanitarian projects. Fifty-three students were enrolled in the course. They belonged to from 14 different undergraduate programs, including Engineering, Political Sciences, Architecture, Pharmacy, Physics and Design. Those students carried out 12 projects in teams. The projects were based on real-life problems of poverty areas. The course aims to: 1) generate real actions and reflections on the relationship between science, technology and society; 2) stimulate collaborative, interdisciplinary spaces and continuous dialogue with knowledge outside the academic environment; and 3) contribute to the implementation of the peace agreement in Colombia for the construction of a country with social justice and durable peace. Data were collected using a 5-points Likert scale of 36 statements and analysed using statistics Principal Component Analysis (PCA). The study found success in the project-work and process, rising the Unconditional Positive Regard (UPR) between team members and in the working climate. Moreover, research concludes that the team performance was positively associated with UPR and the climate.

Keywords: PBL, humanitarian, Unconditional positive regard, Self-directed, EWB

Type of contribution: Research paper.

1 Introduction

Societal dimension of projects focused on humanitarianism is a strong instrument to foster motivation within Project-based Learning (PBL). In PBL real problems in projects are useful for increasing motivation. The more realistic or useful for the industry is the project, the more interesting is for the students. Those projects are often work opportunities from industries without any additional incentive to students. However, problems solving in humanitarianism has incentives involving aspects such as personal feelings and service (Barak, 2010; Donini, 2010; Steinmayr, Dinger, & Spinath, 2012).

Although there are successful cases of PBL in humanitarianism (Wittig, 2013), PBL often addresses social dimension in a small scale within the learning principles (e.g. Andersen, Heilesen, & Kjeldsen, 2015; Kolmos & de Graaff, 2015)- Hence, PBL social aspects involve academic collaboration in educational contexts, close community, and encourage situated social relationships while the projects is done. In consequence, less is known about a wider society outside academic environment and open participation, where students have to be immerse with scarce assistance from teachers.

This study explores the relevance of the humanitarian subject to carry out projects in PBL. In turn, it explores the PBL effectivity to fulfil the course purpose, generating actions between science, technology, and society; stimulating collaboration between disciplines and not academic communities and contributing to the implementation of the peace agreement in Colombia for the construction of a country with social justice and durable peace.

2 Conceptual framework

2.1 PBL learning principles

PBL works with six basic learning principles: (1) problem oriented, (2) interdisciplinary, (3) exemplary, (4) self-directed, (5) made by teams (Kolmos & de Graaff, 2015); and in addition, the project (6) is social to fulfil the whole triangle of knowledge (Illeris, 2007). The problem into the project is ill-structured or complex. In turn, the project is interdisciplinary, illustrating a more general, applicable, social or societal situation with exemplarity (Zeuner, 2013). Additionally, projects are self-directed to transform mental schemes in the whole person participation (Rogers, 1965).

Social problems stimulate the analysis of societal conditions in its contexts (Negt in cited Zeuner (2013)). Furthermore, participants need translate scientific knowledge to a social form of communication, motivating learning acquisition.

2.2 Team work

In PBL, a project is performed by a team of students. Team is a structured group of individuals which concentrate interaction and continuous, working for a common goal, requiring coordinate interaction to perform task, and stressed by outcomes (Forsyth, 2010; Levi, 2013). The social and individual aspects for successful teams meet the characteristic of discipline for real teams stated by Katzenback and Smith (2001, p. 4). A successful team (1) gathers in one individual and collective goals, (2) has individual and collective products, (3) individual and mutual accountability, (4) good communication, (5) time management, (6) clear task and roles assignation, (7) members use skill for individual and collective purpose, and (8) hard working is driven by members and adaptable to collective interest.

A successful team is measured holistically by task completion, social interaction of performance, and individual growing (Hackman, 1983; Levi, 2013). Task completion refers to meet task goals or project product. But social and individual activities and their outcomes are linked to the team process. In PBL, project work aims to increase knowledge and skills (de Graaff & Kolmos, 2003), hence, a successful team brings out successful project work for learning.

2.3 Factors affecting team performance

Team performance in PBL is supported by facilitation. Whereas novice students tend to have frequent support from a facilitator for the team-work, advanced students need support in expertise areas. In some PBL models, the facilitator is not an expert in the subject, but in other models, facilitator guides concepts and issues of the projects (de Graaff, 2016). Therefore, facilitation depends on the human resources, facilities, and schedule of the project. There are also diverse roles for facilitation according to the background of the students for the team-work (Heron, 1999).

The incentive dimension in learning assists student in spending energy to learn (Illeris, 2007). Consequently, fostering motivation in teams is important for the team performance, in addition to other interdependent factors such as cohesion, satisfaction, trust, confidence and commitment (Jaques & Salmon, 2007; Levi, 2013).

3 Methodology

The semester program blended project and active participation in communities. Projects took place in Bogotá, Iconozo and Guajira (centre, north and south of Colombia), but the course was given at Universidad Nacional in campus Bogotá. The project ran in 15 weeks, mixing open lectures focused on social aspects such an education, poverty, and politics. There were 12 projects developed by interdisciplinary teams of 4-6 students (Table 1).

Table 1 Humanitarian interdisciplinary projects made by team

Projects	Location
Fog catcher for "El Verjón"	Bogotá
Community Broadcaster in Puerto Matilde	Puerto Matilde
Arduino for renewable energies	Bogota
Water heater for El Verjón"	Bogotá
Composting machine for Plaza de la Hoja	Bogotá
Urban agriculture	Bogotá
Water filters	Bogotá
Rainwater collection system	Iconoso
Water desalination La Guajira	Guajira
Urban infrastructure for Plaza de la Hoja	Bogotá
Arduino implementation in farming activities	Bogotá
Nubometer	Bogotá

The students belong to 14 undergraduate engineering programs, and are located of diverse educational levels, from the first to the last semesters. Then, teams were interdisciplinary and heterogeneous.

The effectivity for team performance was measured from the whole perception of the team members by a 5-points Likert scale in an online survey. Table 2 gathers statements regarding team work factors and performance inspired in some authors (Curşeu & Schruijer, 2010; Jehn & Mannix, 2001; Katzenbach & Smith, 2001).

Table 2 Survey Statements

Variable	Statement
X1	The team outcomes exceeded my own personal goals

X2	My team partners integrated their knowledge in the project-work
X3	My team partners integrated their skills to the project-work
X4	The project product was a consequence of unifying individual efforts of team members
X5	My teammates adapted to my own work approach
X6	I adapted to the work approach of my teammates
X7	There is a mutual commitment to success
X8	I was clear about the purpose of the team
X9	This team has confidence in itself
X10	This team believes it can be unusually good at producing high-quality work.
X11	This team expects to be known as a high-performing team.
X12	This team feels it can solve any problem it encounters.
X13	This team can get a lot done when it works hard.
X14	This team believes it can be very productive
X15	No task is too tough for this team.
X16	This team expects to have a lot of academic influence around here.
X17	I like being a member of the team
X18	Team members recognize and respect individual differences and contributions
X19	The members of the team have been open and straightforward when expressing their ideas
X20	The relationships or interactions of the team members have also been kept out of the team meetings
X21	I think the team has provided emotional support to its members.
X22	I was pleased with the quality of the team's interpersonal relationships
X23	I communicated with the team members through social networks
X24	I communicated with the team members by e-mail
X25	I communicated with the team members face to face
X26	My teammates understood when I explained an idea to them
X27	I understood when the team members tried to explain their ideas
X28	My teammates listened to my ideas
X29	I listened to the ideas of my teammates
X30	I had an established function in the team
X31	The function I had was shared
X32	The duration of the meetings was productive
X33	There was a schedule for meetings
X34	The scheduling of meetings was met
X35	There was commitment among all the members of the team
X36	My individual goals contributed to the team performance

4 Findings and analysis

Data were analysed by Principal Component Analysis (PCA) to group students' perceptions and find relevant relationships between them of team-work and performance.

There were 35 answers out of 53 students (p=0.67) with a high internal consistence (alpha= 0,92). The answers were reduced with the PCA analysis until getting eigenvalues over 0,4 while test of sample adequacy. The KMO was keeping high (KMO=0,73). In turn, statistical analysis extracted 3 factors according to the eigenvalues test. Table 3 shows the statistical data grouped by the PCA factors.

Table 3 Principal component analysis results with “promax” rotation

Variable	Performance	Climate	UPR
This team feels it can solve any problem.	0,86		
My team partners integrated their knowledge..	0,83		
This team expects to be known as a high-performing team	0,78		
This team believes it can be come unusually good at producing high quality work.	0,77		
This team believes it can be very productive	0,68		
My team partners integrated their skills to the project-work	0,66		
There was a schedule for meetings		0,93	
This team can get a lot done when it works hard		0,88	
I understood when the team members explain		0,80	
The duration of the meetings was productive		0,73	
My teammates understood when I explain		0,70	
My teammates listened to my ideas	-0,48	0,64	
Team members recognize and respect differences			0,94
Teammates have been open to talk straightforward in expressing their ideas and feelings			0,90
I like being a team member			0,87
I was pleased with the quality of member’s interpersonal relationships			0,82
Cumulative Variance	0,25	0,49	0,71

Table 4 Factor correlation

	Performance	Climate	UPR
Performance	1,00	0,30	0,25
Atmosphere	0,30	1,00	0,45
UPR	0,25	0,45	1,00

According to the variables, the factors were called performance, team climate, and Unconditional Positive Regard (UPR). The average agreement for performance was between 3.57 and 4.6 (mean=3.9) indicating that teams are agree in general. The climate factor was characterized by a good meeting’s communication. The average agreement between variables was between 3.43 and 4.26 (mean=3.9) indicating they are almost agreeing. The UPR factor was between 4.2 and 4.34 (mean=4.3). Although the three factors were the most important for the teams, there is low correlation between them, but it exist. Climate and UPR are positively associated to performance. Also, climate and UPR are positively associated between them (Table 4).

Some variables were removed due to PCA analysis, but they are useful for the findings. They were identified by a simpler name. Figure 1 shows graphically the students perceptions about the team work from the survey. Then, teams and individuals were characterized by hard work, commitment, collective and individual efforts and confidence, and goal-oriented. The latter was obtained despite most of the students did not have a clear purpose at the beginning of the course, as shown in the figure. Teams also recognised emotional support and good relationships, despite the scarce facilitation.

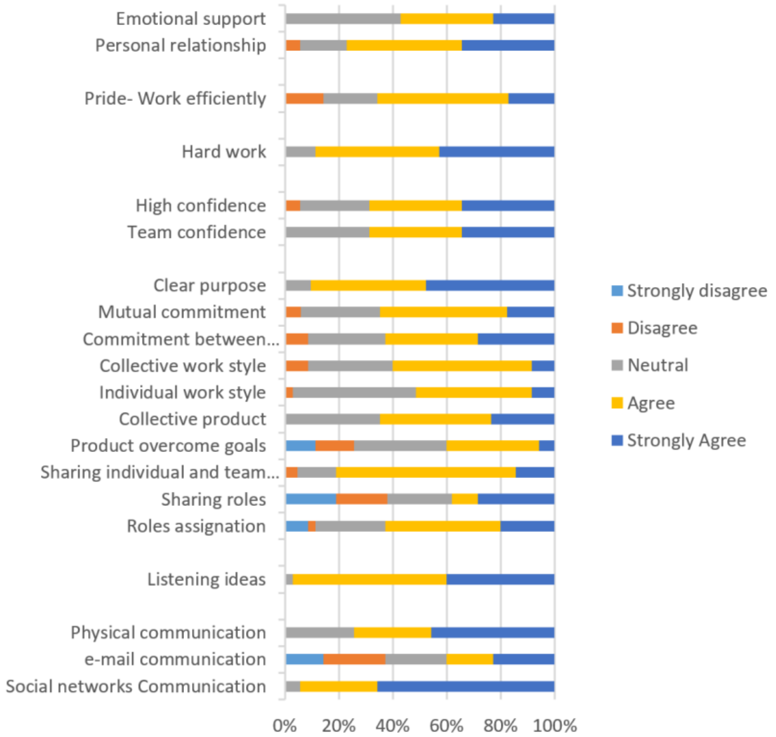

Figure 1 Student' perceptions of team performance

5 Discussion

Humanitarian subject in PBL motivates students to spend time making successful projects and applying knowledge and skills, encourages caring and mutual relationship, and fosters ideas interactions. Social and political themes facilitate collaboration among participants, including students from several disciplines, social leaders and public politics.

There were two important characteristics of these courses in contraposition to traditional PBL practices (de Graaff & Kolmos, 2003; Neufeld & Barrows, 1974; Schmidt, 1983). First, teams work almost alone, with scarce facilitation, despite some team members were in the first semester of the undergraduate programs. Second, it included lectures focused on political and philosophical themes in education, aiming to train and put the students in context.

Facilitation for the teams depends on the expertices and human resources to do it. In this large course, there were 12 teams from 14 diverse disciplines, diverse programs and schedules. In turn, the curricular scenario is differente from PBL, sincelectures were the common practice to teach students in those disciplines. In consequence, the course did not have enough experience, resources, neither spaces for students' facilitation. Thus, addressing PBL was a challenge for teachers exploring options to motivate students with satisfactory results.

Lectures were an alternative to facilitation. There were 12 independent projects with several kinds of social problems to address. Moreover, the course only had three teachers , who were not experts in the 14 disciplines neither in the specific team project problems. The lectures were made by guest professors who had knowledge on academic and social themes, including learning theories, politics, poverty, humanitarian engineering and skills to meet people. They were made by guests teachers. In consequence, it used to be unaligned withthe learning outcomes of the course (see Biggs & Tang, 2011). However, lectures pursue reflection in the students (e.g. Cowan, 2006) but as they where unaligned with the project studens miss course purpose (see Figure 1).

5.1 Accions among science, techology and society

The PBL course put in contact the students' knowledge and skills with societal participants through real actions. The students visited poor areas and distant zones, and lived there a few days to experiment, with the communities, their needs. Then, from the problems identified,, the students formulated projects in agreement with the community. Hence, the projects were real solutions for real communities.

During the project, they had to adapted scientific knowledge to applications in context. For example, the team for the desalinization system in Guajira for the Wayuu people (1000 km far from Bogotá) was aware of using local resources to find solutions to this need (e.g. UNDP.org, 2018). Other students working in Iconoso (136 km far from Bogotá) supplied water needs by the collection of rain water.

According to results, the performance factor in Figure 1 was characterized by the application of knowledge and skills for solving problems. They had to adapt scientific knowledge to the context (Kolmos & de Graaff, 2015; Zeuner, 2013). The project satisfied the students' expectative of the students by achieving a clear purpose and being proud about the results, as showed by the "pride-work efficiency "and "clear purpose."

Although the teams worked alone with some support from facilitation, the projects were successful. Motivation was present since the project setup when incorporating humanitarian social problems. During the lectures, students were sensitised and trained on how to address communities. Teams formulated solutions of the problems according to societal needs, and their products exceeded goals (Figure 1). Product satisfaction is explained with the performance factor in Table 3, and then confirmed with the high levels of confidence in Figure 1. The students had to use their background in engineering and the own skills because during the project work no disciplinary themes were addressed.

5.2 Stimulation of collaborative and interdisciplinary spaces

At the beginning students had to contact communities to understand local problems, and then formulate and develop the project. Humanitarian projects were successful, stimulating interdisciplinary collaboration between students and non-students. It is indicated by performance factor in Table 3 and the students' perception about project overcoming goals, commitment and pride in Figure 1.

Despite there is not a direct question regards collaboration, there are some indicators such a team commitment, integration of knowledge and skills to the team Table 3 and collective product in Figure 1. But also, PCA grouped characteristics labelled as team climate which indicated communication and freedom to express ideas.

Furthermore, collaboration was stimulated by the UPR and the team climate. PCA positively correlated performance, climate and UPR. Then correlation could be interpreted as a mutual incentive. PBL meet learning principles for make learning to happen satisfying three dimensions of learning: Content, incentive and social (Illeris, 2007). UPR concerns the incentive dimension.

The Self-directed Learning (SDL) fosters a transformation in the whole individual. It was prominent among the teams. During the project, students went to the poor communities to talk with them. Many of them spent some days and nights among the communities, sharing resources and understanding problems. It produces a perception of overload about the project-work (Figure 1). But. it also increases the personal relationships between teammates. Team members were aware of mutual caring and freedom to express ideas. The students were alone for the project, taking more responsibility and freedom to do the project, as is confirmed by the PCA.

Project realization fulfilled Carl Rogers statements about the SDL (Rogers, 1965). Despite scarce facilitation to foster SDL, students conducted the project by themselves in the communities. Results show a remarkable UPR in the teams in Table 3. It was characterised by respect and quality in the personal relationships. It is important, because the students were introduced to the communities at the beginning of the project, blending disciplines. Thus, there were low success possibilities in terms of group composition and roles (e.g. Meslec & Curşeu, 2015).

There is a consensus among students about many characteristics of a real team or success (e.g. Katzenbach & Smith, 2001; Levi, 2013). But this area needs to be improved in work adaptability, commitment and roles assignation. On the one hand, the adaptation to the different work styles is difficult to achieve in short time. Team members were introduced to each other to do the project when it started. On the other hand, there are lacks of work participation in some team members. As well as disagreements regarding information sharing and roles assignation (Figure 1). It is needed to improve skills in this area, but this could be due to the short duration of the team work in the semester.

5.3 Contribute to the implementation of the peace post-agreement in Colombia

The course promotes reflection about social problems of Colombia. It concerns with humanitarian need but mobilization of knowledge from the academy to small towns and far zones from the University. The success of the projects showed PBL courses could support problems solving using active students. Also, it showed there was commitment students to work for zones in poverty with many things to do. In consequence, this course evidence academic capability to implement public politics in the post conflict.

6 Conclusions

The humanitarian projects contribute to team performance, support group climate and facilitate UPR among teammates. Furthermore, group climate and UPR are positively associated to team performance in this kind of projects. Humanitarian themes diminish the effects of poor facilitation in large courses replacing it with the students' living in the communities. In turn, UPR is characterized by good relationships and emotional support. The climate was characterized by good communication in the team meetings.

The team performance was directly characterized by the skill to solve problems, productivity and product quality. But, indirectly, it evidenced individual and mutual confidence and commitment, goal-oriented work and a product that overcome expectations.

Both, social sensitisation and fostering UPR should have more relevance in projects to favour team performance and group climate, especially in environments with poor facilitation. As shown by the study, results indicate that the effects of scarce tutoring or supervision on knowledge application can be diminished by integrating interdisciplinary members.

Further studies about the implication of lectures regarding politics and philosophical aspects are required. Its role in the performance is still unknown. However, in the discussion, its importance to sensitize students was stated.

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"PBL for the graduate attributes and professional competencies of international development and the engineers of tomorrow"

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Abstract

The low interest and enrolment of young people in engineering continues to be an issue in many countries, and the need for increased investment in infrastructure, innovation, entrepreneurship, employment and economic growth - which require engineering capacity and capacity building. At the global level, engineering and technology will be vital in addressing the seventeen United Nations Sustainable Development Goals (SDGs) and related international development goals, especially poverty, hunger, health, water supply, sanitation, energy, sustainable living and consumption, climate change reduction and adaptation. Not only is there an urgent need to promote interest and enrolment of young people in engineering and the development of engineering capacity, there is an equally urgent need that the engineers of tomorrow themselves have capacity to address the UN SDGs, and the engineers of tomorrow need engineering education today. This will require engineers with graduate attributes and professional competences as outlined by many national and international organisations, such as the Washington Accord and International Engineering Alliance - not only in such traditional fields as engineering theory and practical knowledge, problem investigation, analysis, design and project management, but increasingly in wider areas such as engineering and society, the environment, teamwork, communications and lifelong learning, and the development of skills in innovation and entrepreneurship. It will also benefit from the greater participation of women and unrepresented groups. Promoting the interest and enrolment of young people in engineering requires more interesting and engaging ways of learning, as does the acquisition of newer areas of expertise and competence. Problem- and project-based learning, and related approaches, are interesting and engaging, and ideally suited to learning traditional and newer areas of knowledge and competence. This review/conceptual paper will discuss these new and emerging needs, issues and challenges for engineering and the engineers of tomorrow and associated graduate attributes and professional competences, and the engineering education they need today, with particular reference to the UN SDGs and related international development goals.

Keywords: Engineering education, accreditation, PBL, international development, SDGs
Type of contribution: this is a review/conceptual paper.

1 Introduction

Many countries, developed and developing, face the ongoing challenge of reported shortages of engineers, low interest and enrolment of young people in engineering. This is largely due to perceptions of engineering education being boring, nerdy (tedious, dull, studious), hard work and dirty - part of the problem of sustainability, rather than the solution. This reflects the traditional curricula-driven educational approach of having to learn large amounts of abstract facts, figures and formulae, with little apparent purpose. At the same time, many countries also face the need for increased investment in infrastructure, innovation, industry, entrepreneurship and employment for economic growth – for which engineering capacity and capacity building will be essential. Without enough or the right type of engineers, the "jobs and growth" mantra of politicians around the world will ring hollow. Shortages of engineers occur mainly due to low enrolment, dropout and retirement, but can be accompanied by graduate un- and under-employment. In Australia, for example, reported shortages of engineers are addressed by including engineers on the Department of Home Affairs skilled occupation list for professional migration, and also the issuing skilled temporary visas for overseas engineers. This also has the unfortunate effect of increasing the difficulty for young graduating engineers to find appropriate employment, discouraging the interest and enrolment of young people in engineering. In Timor Leste, on the other hand, recovering from the aftermath of 25 years of Indonesian occupation from 1975-1999, graduate engineers find difficulty getting jobs because of limited employment and an employer perception that they are too theoretical and hands-off, with little practical or teamwork experience. This reflects a traditional theory- and teacher-lead model at the University of Timor Lorosa'e based on the Indonesian approach, where research, analytical and critical thinking was not supported. A Timorese Master's student of engineering in Sydney has observed, "There is a huge difference between studying in Australia and studying back home in Timor Leste, because in Australia students are independent and encouraged to be active, whereas in Timor students are expected to just listen to the teacher" (Da Silva, 2013).

These are part of the broader issues facing engineering and engineering education, as modes of knowledge production and application transition from "Mode 1" (academic/disciplinary) toward "Mode 2" (problem-based/interdisciplinary) (Gibbons et al 1994; Nowotny et al 2001; Marjoram 2017). Other issues and challenges include new and emerging needs and wider change in education and learning occasioned by the disruptive power of the internet and on-line learning, and internal pressure to attract and retain students - all call for new modes of learning and the transformation of engineering education (Beanland and Hadgraft, 2014; Marjoram, 2015/1).

Engineering and technology are vital for the provision of infrastructure, innovation and industry for employment and economic growth (Metcalfe, 1995; Stewart, 1977), and addressing the seventeen United Nations Sustainable Development Goals (SDGs) and related international development goals, especially addressing poverty and hunger, promoting health, water supply, sanitation, energy, sustainable living and consumption, climate change reduction and adaptation. Already it appears that the goals of the Paris Climate Agreement of 2016 and long term goal of limiting greenhouse gas emissions to hold the increase in global average temperature to 1.5°C to reduce the impacts of climate change will not be reached, as pledges are not being met or policies enacted due to limited political will, or little done to develop vital capacity in engineering to do this. It must be noted in this context that it takes ten years to train an engineer – so the engineers of tomorrow need to be trained today. These considerations reinforce the already urgent need to promote interest and enrolment of young people in engineering, and to transform engineering education to develop engineers capable of addressing sustainability and the SDGs. Fortunately, young people are more passionate about sustainability than many politicians, and are attracted to engineering when they see it as a vital part of the solution to sustainability. Engineering education needs to respond to be more attractive and relevant to young people, and sustainability is an important part of this. Young people are inspired to go into engineering when they hear politicians talking about sustainability, climate change, zero-carbon and renewable energy – engineering as part of the solution, and are put off with talk of coal and engineering as part of the problem.

Engineering education and practice will require engineers with graduate attributes and professional competences called for by many national and international organisations, and at the international level by the Washington Accord and International Engineering Alliance (IEA) (Washington Accord). This includes not only traditional fields such as engineering theory and practical knowledge, problem investigation, analysis, design and project management, but also broader fields of engineering practice relating to society, the environment, teamwork, communications and lifelong learning, and the development of skills in innovation and entrepreneurship. Engineering education with greater reference to sustainability will also attract and benefit from the greater participation of women and unrepresented groups, such as aboriginal Australians – who were perhaps the first engineers 60,000 years ago, with sophisticated understanding of environment and associated management (Pascoe, 2014), who proportionately take a greater interest in sustainability and humanitarian engineering.

Promoting the interest and enrolment of young people in engineering, in terms of theory and practice, requires more interesting and engaging ways of learning, linked to professional practice and competence. One learning approach that is gaining increasing interest and application around the world is the move from curricula/teacher centred to student-centred problem- and project-based learning, and related approaches, which are ideally suited to combining theory and practice and continued professional development in the rapidly changing lifelong learning world. The combination of theory and practice was in fact the basis of the 'Humboldt Model' at what is now the University of Berlin, the 'Mother of modern universities', in 1810, a model that slowly changed to a focus on engineering science rather than practice that is now, thankfully, resurgent.

2 Engineers for today and tomorrow

The engineers of today and tomorrow, as the engineers of the past, will be vital in driving infrastructure, innovation, industry, entrepreneurship and employment for economic growth, but in a changing atmosphere of new modes of knowledge production and application, new and emerging needs, issues and challenges for engineering, new modes of learning and continued professional development. New modes of knowledge production and application relate particularly to practice and teamwork, with converging bodies of knowledge, professional practice and employment, and need to be reflected by change in science and engineering. New modes of learning and continued professional development are based on interdisciplinarity, networking and a problem-solving, systems approach, with an increasing focus on applications. New and emerging needs, issues and challenges for engineering relate particularly to the UN MDGs and SDGs – with a focus on poverty and hunger, education, gender equality, child mortality and maternal health, various diseases, sustainability and partnership for development. The engineers of today and tomorrow are central in the challenge of meeting the 17 UN Sustainable Development Goals by 2030, under the "Transforming Our World - the 2030 Agenda for Sustainable Development". This follows the similar challenge of meeting the similar objectives of the 8 UN Millennium Development Goals, 2000-2015.

The ongoing demand for engineers is happening at a time of change that is driven by engineering and technological innovation and change and disruption, and will require engineering to work in this changing environment and is in turn driving engineering education that can produce such engineers. This is not new, despite talk of the complexity of issues and challenges facing the world, need for a systems approach, and for engineering and engineering education to reflect this in order to produce 'solutions' to such issues and challenges. The world, however, has long been complex and multidimensional, seemingly at odds with relatively simple, technical-fix, 'solutions' that may have limited effect, and risk of potentially more serious side effects. For example, geoengineering, intended to reduce climate change and global warming by greenhouse gas removal and solar radiation management, may be tempting to politicians as time runs out for change, while there is agreement among scientists that climate engineering is not a substitute for the need to mitigate climate change by reducing carbon emissions (Marjoram, UNESCO, 2010). Geoengineering may transpire to be the biggest technical fix, and fixation, of them all. Simple solutions, however, have an appeal to politicians and the electorate - President Carter, with a background in nuclear engineering, often spoke about the complexity of the world, and lost his re-election.

Technological change and innovation has taken place since the stone axe, through the Stone, Bronze and Iron Ages, into the first Industrial Revolution. The Stone Age did not end because they ran out of stones, or the Steam Age because they ran out of steam, but because of innovation. Six major successive engineering-driven Kondratiev 'Waves of Innovation' (Freeman and Louçã, 2001) and industrial, economic and social development proceeded, from iron and water, coal, steel and steam, electricity and oil, autos and electronics, computers and ICTs to the bio/nano/materials 'new knowledge' of the new millennium, what has more recently been called the 'Fourth Industrial

Revolution' (Schwab, 2016). The hopeful forecast is that the next wave of innovation will focus on sustainability and green engineering and technology, although this will require an effective global and national policy push, rather than political business-as-usual (although the business community has largely accepted the need for future sustainability, as indicated by the increasing investment in renewable energy around the world).

The engineers of yesterday, and many engineers today, were mainly educated in Mode 1, discipline-specific, theory-based engineering science - narrow technical training to give the basics for professional practice, where, for example, engine design for mechanical engineers meant that exhaust emissions were regarded as someone else's problem. The education of the engineers of today and tomorrow will need a change in science and engineering education toward Mode 2, interdisciplinary/problem-based, toward project- and problem-based, student-centred learning. These changes will be needed in the transition to a seventh wave, based on cleaner/greener technology for climate change mitigation and adaptation, where a focus on interdisciplinary practice, teamwork, converging knowledge, applications and innovation will be necessary.

This appears in reflection on the MDGs and SDGs - how the MDGs were narrow and technocratic (8 goals, 18 targets and 48 indicators), and, while statistical achievements were made, changes may have happened anyway with economic development in larger developing countries, there was little progress in addressing the needs of the poorest, most disadvantaged (Easterley, 2006). The SDGs are regarded as broader, more holistic, with greater input and buy-in (from a High-Level Panel of Eminent Persons), with more goals, targets and indicators (17 goals, 169 targets and 304 indicators). It is now admitted that the MDGs were more aspirational than realistic, engineering type objectives - time will tell if the same can be said for the SDGs.

3 Graduate attributes and professional competencies

Educational practice changes slowly, evolving to match cognitive and professional paradigms, requirements and expectations. In engineering education, "engineering science", following the Humboldt model, became the dominant paradigm. The waves of technological innovation and industrial revolution were reflected in transformation in engineering education and epistemologically in changing knowledge production, dissemination and application. In the 1900s the professionalisation of engineering continued with the development of learned societies and the accreditation of engineers. Universities and professional societies facilitated education, research and the flow of information. This activity continues with the development of international accords, standards and accreditation, and the mutual recognition of engineering qualifications and professional competencies. These include the Washington Accord (established 1989), wider International Engineering Alliance and associated agreements. Changes in knowledge and technology production, dissemination and application lead to the need for change in associated learning approaches - toward cognitive, knowledge- and problem-based learning. Engineering is a problem-based profession, and needs a problem-based approach to learning (Marjoram, UNESCO, 2010). Emerging needs in terms of changing knowledge production, dissemination and application, cognitive and professional paradigms for the next generation of engineers are reflected in the twelve graduate attributes and professional competencies as identified in the Washington Accord (Washington Accord) of the International Engineering Alliance (IEA):

1 Engineering knowledge
2 Problem analysis
3 Design and development of solutions
4 Investigation
5 Modern tool usage

6 The engineer and society
7 Environment and society
8 Ethics
9 Individual and team member
10 Communications
11 Project management and finance
12 Life-long learning

As can be seen - less than half of these criteria relate to the "old" engineering curricula, with the majority relating to contemporary and emerging needs of professional practice. All are ideally suited to problem- and project-based learning, as originally advocated by von Humboldt, before practice gave way to theory. The accreditation of engineering education institutions has moved from approving curricula in accordance with national criteria, on the input side, toward the assuring the assessment of graduate attributes and professional competences, as an output. Accreditation in the past was often seen as a barrier to change, a conservative influence enforcing conformity and compliance with past needs and values. Now it is seen more as a transformative driver of change. Another barrier to change relates to academic engineering appointments and promotions focus on research and papers published, favouring lecturing over student learning. Hopefully accreditation may also facilitate a change in this direction.

4 Engineering Sustainability and the SDGs

The UN Sustainable Development Goals, 2015-2030, built upon and developed the Millennium Development Goals, 2000-2015, and related international development goals, with the SDGs having a wider and deeper scope, although people said similar things about the MDGs in 2000. Both MDGs and SDGs had an essential focus on poverty, hunger, health, water supply, sanitation, energy, sustainable living and consumption, climate change reduction and adaptation. The MDGs were introduced at the Millennium Summit for the period 2000-2015, and were hailed as the most successful global initiative for reducing poverty, halting the spread of HIV/AIDS and providing universal primary education by 2015. The MDGs were superseded in the post-2015 development agenda by the Sustainable Development Goals for the period 2015-2030. In terms of their reference to the important role of engineering and technology in development, the eight MDGs, with 18 targets and 48 indicators, had limited reference to technology (mainly as IT, in goal 8), and no specific mention of engineering. The draft SDGs, with 17 goals, 169 targets and 304 indicators, again have limited reference to technology (mainly as IT), and include one specific reference to engineering, in the context of education and training. Limited reference to the role of engineering in the MDGs and SDGs is a moot point, and it is worth examining why this is so and how this situation might be addressed.

Figure 1 – the eight UN Millennium Development Goals, 2000-2015

The eight UN Millennium Development Goals, represented above, have 18 quantifiable targets and 48 measurable indicators, which align with the goals and are based on associated statistical data (or metadata), which are often less complete and accurate in more disadvantaged countries. The MDGs were admittedly aspirational rather than actual, based on diplomatic and public relations protocols, rather than an engineering project-managing approach. There were going to be 7 goals, until it was realised that sustainability had not been included. The MDGs were designed by a small expert group, and then debated and agreed at the Millennium UN Summit – so there was potentially a limited sense of country ownership, although the MDGs were agreed by all 191 UN member nations. MDG goal 8, target 18, the last MDG and target, mentions knowledge, S&T, ICTs, but there was no specific mention of engineering. The MDGs were reinforced by the "Make Poverty History" movement, one of 'the most successful anti-poverty movements in history'. In terms of achievement, the MDGs had limited success, with only 3 targets achieved – poverty was halved, lack of access to drinking water was halved and there was a 66% increase in ODA. Poverty and hunger, along with other MDGs were mainly reduced in China and India as a result of ongoing government programmes, although over 50% of the world's population still went hungry, and ODA has declined in real terms in many countries since 2015. Lessons learnt from the MDGs in general was the need to be more precise, realistic, goal-oriented, less aspirational, and to get better engagement and buy-in and for engineering – the need for better recognition of vital role of engineering in sustainability and better lobby for engineering as a key enabler, facilitator of the MDGs.

5 The Sustainable Development Goals

The UN Sustainable Development Goals, consisting of 17 goals, 169 targets (at first there were 212 targets) and 304 indicators, represented below, were designed in a complex process involving eminent people with input from various stakeholder groups, including engineers (through WFEO). The SDGs are not just about sustainability, they more comprehensive than the MDGs, building upon the experience of the MDGs. The nine additional Goals of the SDGs relate mainly to water and sanitation; energy; work and economic growth; industry, innovation and infrastructure; consumption and production; climate action; life below water; life on land; peace and justice. The SDGs are still based on associated statistical data (or metadata) that is often less complete and accurate in more disadvantaged countries, and are still significantly aspirational. The emphasised greater sense of ownership will depend on how effective the SDGs are implemented.

In terms of engineering - of the 17 SDGs, engineering and technology is of vital importance in addressing 12 areas - poverty; hunger; health; water and sanitation; energy; employment and economic growth; industry, innovation and infrastructure; sustainable cities and communities; responsible production and consumption; climate action; life below water and life on land. Engineering and technology is vital in facilitating education, and education is vital for engineering. Similarly, gender considerations are also vital for engineering, as are considerations relating to inequality – women are underrepresented in engineering, as are disadvantaged groups and their communities, where engineering and technology are vital in humanitarian, social and economic development. Engineering is vital in peace and justice in such areas as post-conflict, post-disaster response and reconstruction. Engineering and engineers and technology are vital for networking and partnerships for development. As regards reference to the important role of engineering and technology in development – there is one specific reference to engineering, in education (Goal 4b) "By 2020, substantially expand scholarships available to developing countries … for enrolment in higher education, including … technology, engineering and scientific programmes", and in relation to global partnerships for sustainable development (SDG Goal 17), along with two references to "science, technology and innovation". Engineering is therefore still largely overlooked in the SDGs, as it was in the MDGs.

Figure 2 – the seventeen UN Sustainable Development Goals, 2015-2030

6 The SDGs and Engineering

Engineering is of vital importance in sustainable development and a vital and central factor in directly addressing most of the SDGs, as indicated below.

Poverty: Engineering and technology are essential in the provision of basic services, infrastructure, income generation and humanitarian engineering and development
Hunger: Sustainable agriculture, food production, processing depends on engineering
Health: Health services, well-being and the quality of life depends increasingly on engineering and medical technology
Education: engineering is essential for schools, services and teacher training, and education is essential in the enrolment and training of the next generation of engineers
Gender: gender equality is important to ensure that a greater percentage of engineers are women, who also have greater interest in sustainability and humanitarian engineering
Water and sanitation: Engineering and technology are central in the provision of clean water and sanitation
Energy: Affordable, sustainable energy, energy efficiency and renewable energy technologies are developed by engineers
Employment and economic growth: Engineering and technology supports economic growth and employment
Industry, Innovation and infrastructure: Engineering and engineers drive innovation, infrastructure, industry and economic growth
Inequality: Engineering helps reduce inequality in terms of access to resources, including access to engineering for women and underrepresented groups
Sustainable cities and communities: Sustainable cities and communities depend on engineering, construction and infrastructure
Responsible production and consumption: Engineering and technology underpins sustainable production and consumption.
Climate action: Climate change mitigation and adaptation, sustainable energy and reduced emissions depend on engineering and technology
Life below water; Life on land: All life on Earth will depend increasingly on the use of sustainable engineering and technology.

Peace and Justice: Engineering is vital in such areas as post-conflict and post-disaster response and reconstruction
Partnerships for development: Engineering and technology are also vital in promoting global partnerships for sustainable development and in reducing global inequality.

Engineering and engineering education will need to transform to incorporate dimensions of humanitarian engineering in poverty, hunger, health, water supply and sanitation, dimensions of sustainability in energy, cities and communities, production and consumption, the environment and of course climate action, and dimensions of economics and business in employment and growth, industry, innovation and infrastructure.

7 PBL for graduate attributes, professional competences and the SDGs

As noted above - of the twelve graduate attributes and professional competencies as identified in the Washington Accord (Washington Accord) of the International Engineering Alliance (IEA), five relate to technical knowledge and the 'old' engineering curricula (engineering knowledge, problem analysis, design and development of solutions, investigation, modern tool usage) and seven relate to contemporary and emerging needs and professional practice (the engineer and society, environment and society, ethics, individual and team member, communications, project management and finance, life-long learning). Engineering education needs to transform from the 'old', curricula- and lecturer-centred model to make engineering more interesting and attractive to students by adopting a more student-centred approach to engineering knowledge, problem analysis, design and the development of solutions, investigation and modern tool usage, and to embrace 'new' areas relating to society, the environment, ethics, teamwork, communications, project management and life-long learning. There is an overall need to change the perception of engineering education being boring, nerdy and hard work by making it engaging, real, relevant and fun through the use of problem- and project-based learning and humanitarian, sustainable, clean and green engineering. The attraction of humanitarian engineering is illustrated by the growth of the growth of Engineers Without Borders (and Ingénieurs Sans Frontières) groups at universities around the world – with many universities actively supporting and promoting such groups as a means of attracting students.

The transformation of engineering education from the 'old' technical model, to embrace new and emerging non-technical attributes and competences, to include humanitarian engineering, sustainability, business and economics, is ideally suited to a student-centred, problem- and project-based learning approach. PBL is also ideally suited to engineering, as a problem analysing and solving profession (similarly, PBL is suited to medicine, in "patient-based learning", and law, although some might say that law is more focused on problem-finding). Problem- and project-based learning, and related approaches, were pioneered first in medicine, then engineering, in the swinging, student-centred 1960s, particularly at new universities of the time, in response to dissatisfaction with traditional pedagogy (for example McMaster, Maastricht, Aalborg) (Kolmos, Krogh and Fink, 2004; de Graaf and Kolmos, 2007; Du, de Graaf and Kolmos, 2009; Barge, 2010). These universities were motivated by the need for active-learning, real-world problems and teamwork. PBL and related approaches have proliferated over the last ten years, as more universities around the world face declining enrolment in engineering and recognise the need for change. There are several particular approaches to PBL, for example the 'Aalborg Model' (combining PBL and traditional lectures), and several related approaches, for example, most recently, 'Challenge-Based Learning' at Tsinghua University and the fast-track engineering degrees such as the New Model in Technology and Engineering (NMiTE) at Hereford University in the UK. In Australia Monash University was an early exponent, more recently Deakin University and the 'Engineering Practice Academy' at Swinburne University. The main advantages of such PBL approaches relate to better learning and understanding, learning how to learn and teamwork, while disadvantages include cost, need for student space and student load (although this often includes the additional costs of conversion to PBL).

The move from a focus on curricula to a focus on professional attributes and competences in engineering education accreditation in the Washington Accord/International Engineering Alliance framework is a move of focus from input to output, teaching to learning and understanding, and expected levels of professional practice, judgement, problem analysis and solution. Problem-Based Learning is a very appropriate educational approach for engineering, involving problem orientation for guided problem analysis/solving, project organisation for guided problem analysis and learning, the integration of theory and practice to link knowledge and application, student direction to help define problem and project work, a team-based approach for problem and project work in student groups, and cooperation and feedback for peer/supervisor feedback. With a student-centred focus on student learning needs, PBL links theory and practice again from the successful Humboldt model, emphasising active learning rather than teaching and passive listening. As Confucius said 2500 years ago (or Xunzi, or another follower) “I hear and I forget, I see and I remember, I do and I understand”.

8 Concluding remarks

Particular challenges for engineering include shortages of engineers in some fields, areas and countries, a decline of interest and enrolment young people in engineering and associated need for engineering to attract and retain young people, especially women underrepresented groups. To do this, engineering and engineering education needs to address negative perceptions that it is boring, hard work, nerdy and dirty. There is an ongoing need to promote clean and green engineering as part of solution of the SDGs, rather than part of the problem of pollution, and the important role of engineering and technology in sustainability, climate change mitigation and adaptation, poverty reduction and the other SDGs. The opportunity here is that young people are attracted to engineering when they see engineering as part of the solution to sustainability, poverty reduction and the other SDGs. But engineering education also needs to change perceptions that it is boring, hard work and nerdy, and can actually be fun. The opportunity here is that young people are attracted to engineering education when they see it as more student-centred, involving problem and project-based learning, linking theory to practice, learning by doing, rather than listening, responding to changing knowledge and needs.

Engineering and engineering education is changing, but is it changing fast enough, and in the right direction to meet the pressing issues and challenges we face? Engineers are innovators and accreditation is helping to drive change toward problem and project-based learning, a just-in-time, hands-on, knowledge-based approach, combining theory and practice, learning to learn for lifelong learning, with a focus on graduate attributes and professional competencies to meet changing knowledge and needs and better position engineering to address the UN Sustainable Development Goals (Marjoram, UNESCO, 2010). Further transformative actions will also help, including an emphasis on the need for change, the change process and results of change. Better statistics, indicators and metadata on engineering, and the important role of engineering in reducing poverty, sustainable and humanitarian development and addressing the SDGs are also required (Marjoram, 2015/2). To help achieve these needs, issues and challenges, and facilitate the development of the engineers of tomorrow, toady, it is important to develop engineering policy and planning, as a subject in itself or as a vital component of science, engineering and ‘S&T’ policy (Marjoram, UNESCO 2010).

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Washington Accord - an international agreement established in 1989 recognising equivalencies in accreditation for professional engineering academic degrees between national bodies responsible for accreditation in its signatory countries. Signatories in 2010 included Australia, Canada, Chinese Taipei, Hong Kong China, Ireland, Japan, Korea, Malaysia, New Zealand, Russia, Singapore, South Africa, Turkey, the UK and USA. Now part of the International Engineering Alliance.

Integration of sustainability into Engineering Curricula in Southern African Universities: An explorative outlook

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Abstract

Higher education, specifically engineering education has become an integral part of a global shift to a new way of creating and using knowledge. Further, globalisation and market economy has put pressure on engineering education to create competent professionals to develop engineering solutions for complex socio-economic and environmental problems. Also, sustainability added another dimension to this scenario. Accordingly, efforts are being made to develop apposite curricula to make the students skilled and competent. However, integration of sustainability into the engineering curricula remained a challenge locally in South Africa and globally. Therefore, the aim of this study is to explore the sustainability indicators that are needed to be considered- and how they can be integrated into engineering curricula. Literature review will be used as precursor for this study. Findings suggest that integration of sustainable indicators such as local and national economic attributes (potential and resources), political- cultural aspects, impacts on environment, indigenous knowledge and practice are highly essential. These indicators need to be linked to the graduate attributes and learning outcomes of programmes which will also be a compulsory ingredient of the curricula and syllabi. Further, it is revealed that sustainable development can be considered as a standalone subject in engineering curricula as well as incorporating into the syllabus of the subjects. The findings will contribute to the discourses and debates on curriculum development in engineering education which can assist in the problem-based learning practice of curriculum development of engineering programmes.

Key words: engineering education, engineering curricula, sustainable development, problem-based learning, graduate attributes, Indicators.

Type of contribution: research paper

1. Introduction

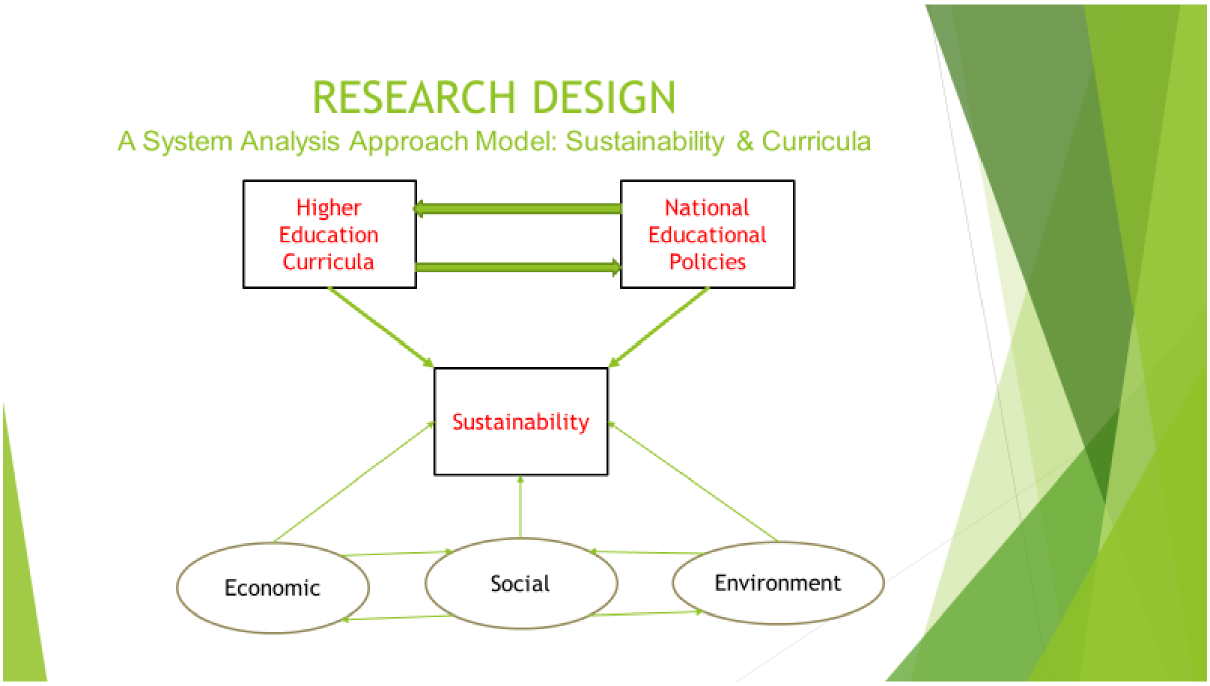
The goal of sustainable development is powerful and innovative, but it is not obvious how to go about sustaining it for the future generations. Educational system including higher education is an important means of furthering the sustainable development agenda. This has brought enormous pressure on higher education to be responsive in bringing about best innovative teaching pedagogies for emerging 21st century graduates for a transformative sustainable society. In the last two decades, higher education institutions have become involved in embedding sustainable development into their academic systems. Following the launch of the 1983 World Commission on the Environment and Development (WCED) report, various scattered initiatives were implemented to integrate sustainable development concepts and approaches into higher education, Chapter 36 of Agenda 21, the outcome of the 1992 United Nations Conference on the Environment and Development in Rio de Janeiro, later highlighted the important role that education can play in realizing sustainable development with a further push to stimulate its introduction was needed. Higher education being recognised as a key site for change, should be the catalyst for a sustainable, innovative and a productive society. With all efforts to incorporate Sustainable Development in the higher educational sector, it is rare to find a University that has fully embraced the sustainability imperatives (Lotz-Sisitka, 2004; Lozano, 2006; Stephens and Graham, 2010). Hence It is vital that Sustainable development and innovation are looked at with effective different lenses to bring about positive reflective changes.

In the recent years, our world is known of its rapid change, uncertainty and increasing interconnectedness (Morin & Kern, 1999). Science such as engineering is looked upon to contribute to solving the complex sustainability challenges holistically, not only biophysical issues but also social and economic issues ranging from global to local. Apart from the increase in availability of scientific knowledge, a lot must still be learned in sustainability for Higher Education Institutions (Mulder et al., 2012) to have interactions at the disciplinary level (Waas et al., 2010) and to play a bridging role for societal collaboration in sustainability (Sedlacek, 2013). Sustainable development needs to be core of the curriculum in educational policies in HEI to solve societal problems and sustainability in engineering curriculum is one of the key areas. Sustainable development over the years has been greatly developed, shaped and encouraged globally, regional and national scale through several international meetings of the conferences, declarations and strategies that have influenced the inclusion of sustainability into higher education since they provide guidelines for the inclusion. Sustainable education, as explained by Bornman (1997:61); Lebeloane (1998:29); Loubser (1997:74-75); Mosidi (1999:24); the United Nations (2002:5) and (Stani_skis and Katili_ut _e (2016). It is important to note that all the above international conferences have in a way contributed towards the position and understanding of Sustainable development globally including the Southern Africa of today. Furthermore, Agenda 21 in Rio Declaration, the Ubuntu Declaration (2002), the Earth Charter for the Engineering Education for Sustainable Development (EESD) and the Barcelona Declaration (2004) specifically emphasise the role of engineers in the society and how they are faced with a wide variety of possible practical applications. The last declaration is particularly important as it emphasises the role of engineers in society which can be achieved when sustainability becomes critical in engineering courses (Segalas et al., 2008) (Glassey and Haile, 2012; Ortega-S_anchez et al., 2018).

2. Approach of Study

For the research, an explorative qualitative research method based on the literature review was used. For this purpose, literature from the established and authentic sources were reviewed and discussed. However, the study aims at using the System Analysis methodology for the Sustainability in Engineering education because it is a complex problem to solve.

Applied Systems Analysis methodology will be used in the research as it can deal with complex problems. Both qualitative and quantitative data will be collected. Pretested questionnaire survey for primary data from stakeholders such a student, alumni, employers, academicians, policy makers, economist, etc. In addition, statistical data relating to engineering education be collected from authentic organisations. Applied Systems Analysis induced mathematical models. (Social- economic engineering education will be a subsystem of the system)



The methodology approach used here was based on the literature review of sustainable development in engineering education. Desktop research was used for the overall search for journals, book chapters, conference proceedings and online websites. From these, about hundred literature review articles were looked at. To filter this number down to limit my search of relevant information for the research paper, we did a critical review using words like sustainable development, engineering education, problem-based learning, graduate attributes, problem-solving skills, innovation, 21st century graduate. I then got about thirty papers and twenty journals that were relevant which were used for critical review of my study towards addressing problem-based learning in sustainable development in engineering education

3. Perspectives of Sustainable Development in Engineering Education

3.1 Sustainable Development

The Sustainable Development that is being emphasised globally today evolved from Environmental Education which was recognised world-wide as far back as the 1960s because of the impact of humans on the environment (Irwin 1990:3; Mosidi 2000:3). This Sustainable Development that has become vital to education today, is because of a milestone of conferences, declarations and strategies of Environmental Education from 1972-2002. Bornman (1997:61); Lebeloane (1998:29); Loubser (1997:74-75); Mosidi (1999:24) and the United Nations (2002:5). Sustainable Development is a contested concept making it very difficult to define and quite challenging to comprehend the integration and application in educational system. Its definition is still an abstract to many even though the concept is well accepted. The commonly used definition globally is that of Brundtland (1987; 8) which gives a general definition of sustainable development, as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Another very accepted definition focusing on the educational system is that of (UNESCO 1972 & 1977) which defines Education for sustainable development as the means of enabling students to develop the knowledge and understanding, skills and attributes needed to work and live in a way that safeguards environmental, social and economic wellbeing, both in the present and for future generations.

3.2 Indicators of Sustainable Development

Sustainable development is a very complex abstract that finding an appropriate set of indicators of sustainable development in engineering education is quite challenging. Furthermore, the complexity makes also necessitates for indicators that will assess and pave way for comprehension and improvement (Bossel 1999). Sustainability is measured by assessing the performance of Social, Environmental, and Economic domains, as individually and in their various combinations. The assessing methods can be measured against existing best practices which go beyond just the basic requirements. The metrics use for the measurement include indicators like benchmarks, audits, assessment, appraisal and other reporting (Bossel 1977, p. 245-253).

3.3 Challenges in Engineering Education

The main issue for engineering education is “contextual awareness”, which means the ability to view actions, problems, solutions and consequences in a broader context of economic, social or cultural aspects. The nature of Engineering education already addresses substantially the environment, professional ethics and behaviours, matters of health and safety, as well as discipline specific problems related to engineering processes and practices. The area of challenge will be objectives of engineering education in the aspect of social responsibility in relationship to sustainable development.

Higher education is now facing new challenges of sustainability in engineering education. On one hand, it is encouraged that the new generation of systems for example the buildings have increased complexity to answer sustainability issues but on the other hand resources are limited to meet up the standard of these complexities. Another challenge is that though there is the need for more engineers in the society, but the number of programs duration has been shortened and the contact time of student – teacher is diminishing progressively. Worse still in addition is that the number of students who opt to graduate in engineering education is decreasing drastically. This situation poses new challenges on higher education institutions. In addition, there are some challenges which are associated with the integration of sustainable development into engineering education creating a gap of inclusion. If these challenges are meant, there will be way forward to the integration. I will list some of the challenges as; Difficulty in integrating disciplines and contents aimed at transdisciplinary in teaching sustainability, (Shields et al., 2014). Difficulty to debate the inclusion of new activities related to sustainability because many professionals believe that the curricula of engineering courses are overloaded, (Sivapalan et al., 2017). Lack of access to adequate and constantly updated didactic material that contemplates all sustainability dimensions for engineering courses. (Nowotny et al., 2018). Difficulty in debating economic and social aspects in engineering disciplines, with a focus on environmental sustainability. (Hopkinson and James, 2010). Lack of alignment between what is taught in engineering courses about sustainability and the real market needs, (Sharma et al., 2017). Difficulty in training lecturers for sustainability teaching. (Mulder et al., 2012). Lack of interest of engineering undergraduate students for subjects related to sustainability, (Biswas, 2012). Lack of motivation of lecturers for the inclusion of sustainability in the engineering course. (Schneider et al., 2008). Lack of adequate facilities and/or resources to develop activities associated with sustainability. ((Desha and Hargroves, 2010). Difficulty in changing disciplines and/or implementing new practices for the teaching of sustainability due to the rigidity of institutional structures, (Sivapalan et al., 2017). Lack of support from university's top management and/or the establishment of a broad program aiming at greater promotion of sustainability teaching. (Hopkinson and James, 2010)

3.4 Sustainable development in Engineering Education

There isn't a direct definition of sustainable development specifically to engineering education, rather the already known and accepted definitions can be applied to the context of engineering in other to put it into practise from engineering perspective.

Drawing on both the Brundtland definition, its 2005 recalibration and the QAA- HEA Guidance, defines ESD as follows (QAA- HEA, 2013), *"Education for sustainable development means enabling students to develop the knowledge and understanding, skills and attributes needed to work and live in a way that safeguards environmental, social and economic wellbeing, both in the present and for future generations."*

These definitions encourage students with Sustainable Development Engineering Curricula to achieve the following objectives:

• consider what the concepts of global citizenship and environmental stewardship mean in the

context of their own engineering discipline

• think about issues of social justice and equity, and how these relate to ecological and

economic factors

• develop a future-facing outlook, learning to think about consequences of actions, and how

systems and societies can be adapted to ensure sustainable futures

There are four high level principles contained within these objectives supporting the

development of:

1) global citizenship;
2) social justice and equity;
3) environmental stewardship;
4) and a future facing outlook.

These represent the expectations that a graduate of engineering with ESD skills, knowledge, capabilities and competencies will be able to demonstrate for the achievement of graduate outcomes relevant to ESD. Furthermore, United Nations World Summit (2005) affirmed the concept of three 'pillars' of sustainability – the economic, social and environmental factors that need to be taken into consideration in their cultural context. There is increasing recognition that these three factors are interconnected, overlapping and interdependent.

3.5 Problem-based learning and sustainable development in Engineering Education

The roots of problem-based learning can be traced to as far as the belief of John Dewey's that teachers should teach by appealing to students' natural instincts to investigate and create. Dewey affirmed that "the first approach to any subject in school, if thought is to be aroused and not words acquired, should be as unscholastic as possible" (Dewey 1916, 1944, p. 154). More than 80 years after, new theorists such as Vygotsky (1978), Kolb (1984), Lave and Wenger (1991) and Gardner (1993) still have a common idea and make reference to the theories and curriculum of Dewey (1933), Lewin (1948) and Piaget (1974) which view the gaining of experience as an important approach to the further process of motivation and learning. Educators give pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking, or the intentional noting of connections; learning naturally results. Students still learn best by doing and by thinking through problems.

Problem-Based Learning (PBL) can be defined as a teaching method in which complex real-world problems are used as the vehicle to promote student learning of concepts and principles as opposed to direct presentation of facts and concepts. In addition to course content, PBL can promote the development of critical thinking skills, problem-solving abilities, and communication skills. It can also provide opportunities for working in groups, finding and evaluating research materials, and life-long learning (Duch et al, 2001). The context and principles of PBL are common to that of Sustainable development in (3:1) requiring critical thinking skills with the holistic problem-solving abilities. The main connecting thread between the two is the various use of real-world problems in solving the problems at hand.

Universities are now facing crucial responsibility and role to integrate sustainable development in their educational task. The concept of competencies for sustainable development and the idea of using real-world sustainability issues in education are promising approaches to transform sustainability programmes at universities into student-centred learning environments. This ideal real-world sustainability is problem-oriented which needs an innovative learning strategy such as problem-based learning in engineering education. This will provide a structure for discovery that helps students internalize learning and leads to greater comprehension.

Problem-based Learning can be incorporated or adapted into any learning situation or subject area when the core problems vary among disciplines as characteristics of good PBL problems transcend fields (Duch, Groh, and Allen, 2001)

PBL can be incorporated into any learning situation. In the strictest definition of PBL, the approach is used over the entire semester as the primary method of teaching. However, broader definitions and uses range from including PBL in lab and design classes, to using it simply to start a single discussion. PBL can also be used to create assessment items. Any subject area can be adapted to PBL with a little creativity. While the core problems will vary among disciplines, there are some characteristics of good PBL problems that transcend fields (Duch, Groh, and Allen, 2001). This makes problem-based learning an educational approach well placed to develop sustainable development in engineering using the graduate attributes students must have acquired. PBL in Engineering Education places an emphasis on cultural and social approaches to learning and education in engineering by using interdisciplinary research methods mainly based on theory of science, education and technological development. These interdisciplinary approaches also encompass inter cultural learning, gender studies, creativity, appliance and development of virtual technologies in education and learning, and meta-theoretical reflection which is all encompassed by sustainable development.

4. Imperatives of Sustainability in Engineering Education

Sustainability is an idea, a process as well an overarching objective that ideally allows to address the current situation of concatenated ecological, social and economic crises, labelled together as 'global change' (Biggs et al., 2011; Hug_ et al., 2016). The variety of sustainability interpretations as well as the diversity of ways in which the concept is used, makes it attractive and explains its enduring relevance (Hug_ et al., 2013). Universities have described four student sustainability attributes — Holistic Systems Thinking, Sustainability Knowledge, Awareness and Integration, and Acting for Positive Change — to help guide academic units to develop sustainability learning pathways in sustainability in engineering education. Instead of teaching basics and applications in engineering, developing the strategic and analytic capabilities to contribute to sustainable development should be leading the engineering curriculum design: Systems analysis, technology history and future studies could be fundamental in developing techno-strategic competences. The issue is not replacing science, modelling- and design courses; it is enabling students to connect science, modelling- and design work to the main challenges of society. Engineering education already deals, in varying degrees, with the.

With the demand and challenges faced by engineering graduates to be more competent and perform work in the world's current complex situation, new learning method based on the principle of using problems as a starting point for the acquisition and integration of new knowledge need to be incorporated in the curriculum development and as innovation in students' learning strategy. The traditional method of teaching need to be improvised to enable students to be innovative, creative with critical thinking skills, effective communication and problem-solving skills are much required of graduates to be sustained and succeed in the real world. Future engineers must receive essentially multidisciplinary education. Much has been written about the requirement to adapt teaching both to the new generation of students and to the more recent technical needs. It is a global problem of sustainability of higher education institutions.

The additional capabilities that this requires could also help students in developing their own curriculum. Far more individualized curricula might help students acquiring the capabilities that fit to their own future. Of course, a far more individual curriculum does not imply far more individualised education, on the contrary. Problem-based and project-based learning have proven their value to engineering education (Perrenet et al., 2000).

4.1 Progress in Sustainability in Engineering Education

Globally, there is an increasing move to reform traditional engineering education programmes to integrate the concepts of sustainability in solving global socio-economic challenges in undergraduate curricula. Engineers are increasingly working to achieve safe and sustainable development in a cost effective, environmentally protective and socially responsible manner. (Augusti, 2007; Desha *et al.*, 2009; Lopez *et al.*, 2011). Institutions of higher education play a vital role in addressing contemporary sustainability challenges and opportunities, as their teaching, research and community engagement functions can impact global environmental issues and influence societal change. By educating future leaders and community members, conducting research. and demonstrating best practices, universities can have a profound impact on the state of our current and future society [Ralph M, Stubbs W 2014]. The idea of the sustainable university [Sterling, et al .2013], and particularly the transformative orientation of the institution towards sustainability, implies that the university's vision, values and practices have been re-oriented to reflect a tight framing around specific conceptualizations and expressions of sustainability of which is the arrow mainly pointed at engineering departments [Scott et a,l 2014).

4.2 The gap and way forward

A lot of theoretical aspects of sustainability in educational system in general to transform the globe has been discussed with reference to engineering education but not enough focus has been emphasised on the practical application on the three main sustainable domains of economic, social and environment in the higher education institutions hence the reason for the research gap. It is of paramount importance for the integration and applications of the three sustainable domains especially the social aspect to effect change in the society. As a first step, a paradigm shift of engineering education is necessary for humanity to realize the goal of sustainability. The need arises to equip engineering students with a wider horizon on concepts in terms of environmental, economic and social attributes, for decision making sensitive to sustainability issues. Pedagogic frameworks must address a multidisciplinary analysis of sustainability. The teaching / learning concepts of Control Systems Engineering are presently of importance because they are based on their development and application in systems that are intended to be increasingly sustainable. The government should also invest in Curriculum policies of sustainable transformation of engineering education that emphasises on awareness, attitudes to mention a few towards sustaining the environment.

Engineers have a very important role to plan in the society with their impacts of their activities on the environment as affirmed in Barcelona Declaration (2004).The knowledge and skills acquire in sustainable development engineering education should contribute to improve social conditions. Engineering education must be integrated with sustainability aspects.

The development of an adequate curriculum for engineering education, that contemplates the sustainability concepts requires planning, time, the involvement of stakeholders (Mälkki and Paatero, 2015) and the greater challenge: a "paradigm shift in engineering" (Mulder, 2017, p. 1107). This paradigm shift can be developed through critical thinking and creative skills such as:

1) improving problem-solving skills
2) increases motivation
3) helps students learn to transfer knowledge to new situations

5. Conclusion

Sustainability in engineering education is a paramount important type of education in providing the nation with innovative, creative and critical thinking human capitals which will contribute to sustainable development of the country. To achieve this, a good and holistic program of engineering education at the tertiary level should be provided. One of the suggestions is the implementation of Problem based Learning approach. This structured approach that integrates research elements, generic skills to interdisciplinary curriculum drawn from real life situations. Students work in collaborative groups to identify what they need to learn to solve a problem holistically in the society and eventually globally.

As a conclusion, the PBL innovative approach can help learners gain inter-disciplinary knowledge and develop diverse skills needed to tackle sustainable development challenges. Traditionally, engineers have been educated to contribute to the production potential of societies. With the acknowledgement that the sustainable development of today's societies relies on more than this potential, it inherently becomes necessary for engineers to contribute with other potentials as well. However, core engineering skills today still focus on the production potential. PBL adds to these skills by providing (and promoting) the linkages to and the understanding of other items and dimensions of the sustainability potential through context-based, interdisciplinary learning. This enables the engineers to solve complex and situated problems. In other words, in engineering education, PBL adds interplay, mix and diversity to the core skills and thus creates the basis for a more integrated approach. This approach is needed for engineers to be able to discuss, understand and decide whether the progress in one potential may take place at the expense of other potentials. As affirmed by theorists throughout the article, all education involves either problem solving or preparation for problem solving and this does not leave sustainable development in engineering education out. Examples, from mathematical calculations ("What does this equal?") to literary analysis ("What does this mean?") to scientific experiments ("Why and how this happens?") to historical investigation ("What took place, and why did it occur that way?"), educators show students how to answer questions and solve problems. When teachers and schools skip the problem-formulating stage—handing facts and procedures to students without giving them a chance to develop their own questions and investigate by themselves—students may memorize material but will not fully understand or be able to use it. In the end, PBL paves the way for innovation, thus matching and solving the problems of society.

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Problem Based Learning (PBL) for the Sustainability of Textile Engineering Education-Bangladesh Perspective

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Abstract

PBL involves hands-on teaching and learning systems that encourage and enable students to gain knowledge, skills, attitudes and values crucial to outline a sustainable future by modifying their behavior and take stroke for sustainable development. The main purpose of this study is to identify the gaps that exist in the present curriculum of Textile Engineering Education of Bangladesh and to find out the importance of implementing PBL to overcome those gaps. To achieve the goal, a survey has been conducted by supplying the questionnaire to different universities of Bangladesh who have been providing Textile Engineering Education since last five years and more. The collected data regarding curriculum and the teaching methods were analyzed to identify the issues that to be incorporated for sustainable Textile Engineering Education. From this study, it was unveiled that most of the universities of Bangladesh have the remarkable lack of sustainable issues in their existing textile curriculum and there is an obvious scope to upgrade the curriculum which would be functionalize through providing PBL teaching and learning methodology. The paper also concludes that PBL is an effective tool to make the Textile Engineering Education sustainable in Bangladesh by developing a strong linkage between educational institutions and industries.

Keywords: PBL, Sustainability, Textile Engineering, Curriculum, Bangladesh

Type of contribution: Research paper

Introduction

Problem-based learning (PBL) is an evolving teaching method which has been run for practice in university level education in recent years (Yeo, 2005). PBL guides the students to come out from their teacher-dependence by improving their self-confidence (Dixon, 2000; Walker et al., 1996). The teaching strategy, PBL gives the confidence to the students to take lead and responsibility (Galvez et al., 2007). It provides learners the opportunity to work collaboratively and develop the ability to learn under their own direction (Hmelo-Silver, 2004; Gwee, 2009). It also introduces the learners with the problem solving processes (Woods, 2006).

Essentially, PBL involves people working in small groups with someone, usually the trainer, to facilitate their learning and stimulate their thinking through interactive discussions. Typically, learners are given an exciting and challenging problem at the start of the session to brainstorm relevant issues and discuss practical solutions. They are also given the responsibility of taking charge of their own learning, using the chosen “problem” as a guide to decide on the scope of what needs to be critically learned (Enger et al., 2002).

So, PBL could be an emerging method for the learning of Textile Engineering students (Graaff & Kolmos, 2003; Savin-Baden & Major,2004; Dolmas et al.,2005).

PBL based learning is more than learning pedagogy or model, it can be interpreted in terms of educational philosophy rooted in most innovative learning theories (e.g. constructivism, experiential learning), in which different problem scenarios combine, for example, different knowledge, disciplines, and learning goals leading to different practices, curriculum organizations and learning outcomes (Savin-Baden & Howell, 2004; Savin-Baden, 2007).

PBL is widely recognized as suitable to develop the aimed 21st century engineer profile due to, for example, relation between theory and practice and the development of competencies such as problem solving skills, communication, collaboration, (de Graaff & Ravesteijn, 2001; Graham, 2010; Graham, 2012). This learning approach is also used to educate for sustainable development. Similar to engineering education, PBL is used due to its characteristics to promote, for example, metacognition, interdisciplinary, contextual and self-directed learning, critical thinking and problem solving skills (Mogensen, 1997; Steiner & Posch, 2006; Bourn & Neal, 2008; Segalàs, 2009).

PBL is one of the approaches used to incorporate sustainability in engineering education. PBL is an innovative, student-cantered learning approach capable of enhancing students' interdisciplinary knowledge, collaboration, problem-solving abilities, communication, critical thinking and self-directed learning. Several studies have been published reporting the use of PBL to integrate sustainability in engineering education (Sipos et al., 2008; Brundiers et al., 2010; Dobson & Tomkinson, 2012; Mulder et al., 2015; Mulder et al., 2012).

An inter-disciplinary, problem-based approach to education for sustainable development has been implemented in Manchester for a number of years and is already well documented (Tomkinson et al., 2008; Tomkinsion et al., 2007).

The main purpose of this study is to identify gaps exist in the present curriculum relating to sustainability of Textile Engineering Education of Bangladesh and to find out the importance of implementing PBL to overcome those gaps.

Methodology

In order to address the importance of Problem Based Learning (PBL) and to minimize the curricular gap for the sustainability of Bangladesh textile engineering education, a set of survey questionnaire were sent directly to university faculty members. There were twelve questions in that set of questionnaire. These questions were formulated relating to their existing curricular, sustainable curriculum (economic, social and environmental dimensions), implementation of PBL and present teaching-learning methods. Most of the questions were prepared focusing on 5-Likert scale. This survey was completed on 100 faculty members of Textile Engineering Departments of 10 universities of Bangladesh who have been providing B. Sc. in Textile Engineering education since last five years. The feedback received from participants of the survey was then analyzed and presented by using pie charts.

Results and Discussion

The feedback received from participants of this study are presented as follows:

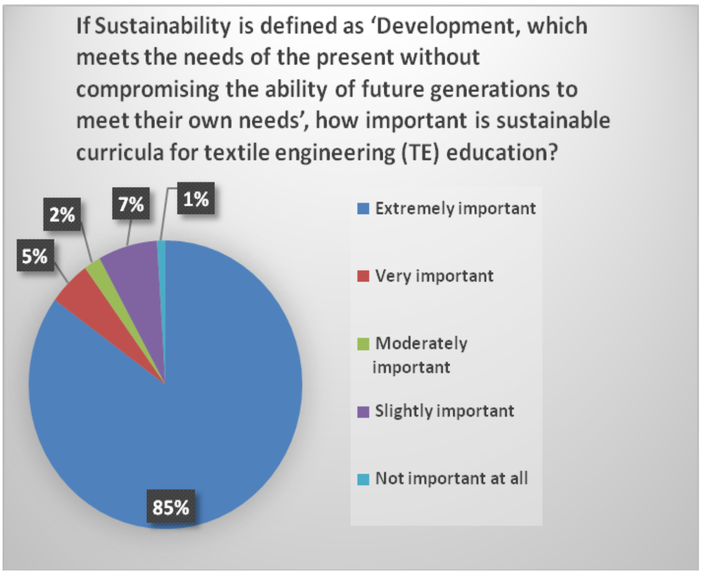

Figure 1: Importance of sustainable textile engineering curricula.

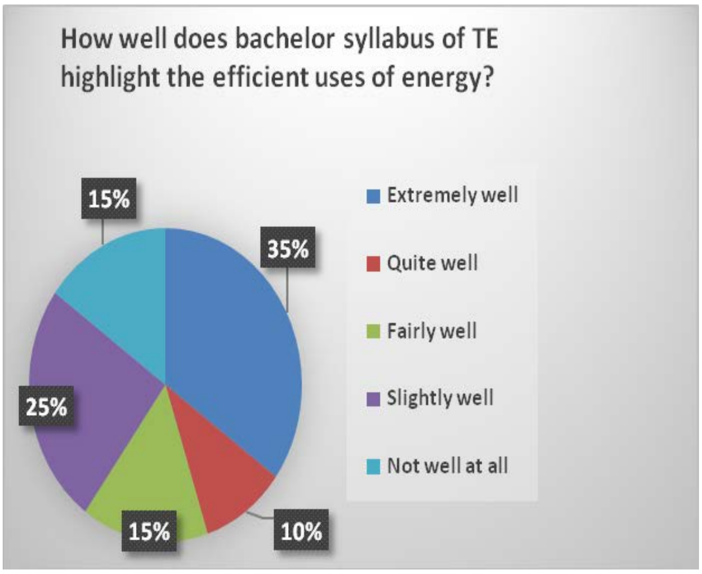

Figure 2: Highlighting to efficient uses of energy by bachelor syllabus of TE.

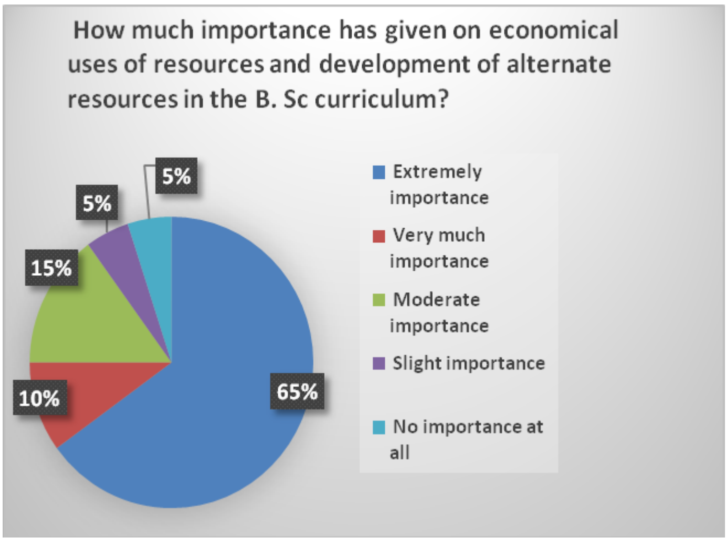

Figure 3: The importance on resources in the B. Sc. curriculum

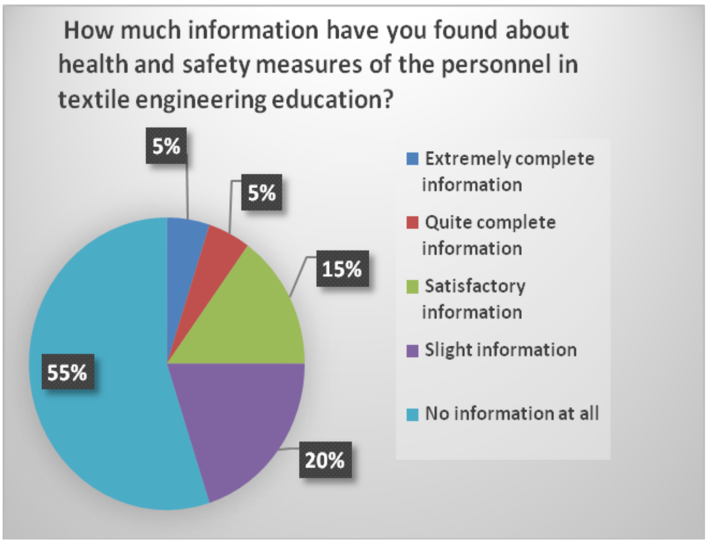

Figure 4: Information about health and safety in textile engineering education

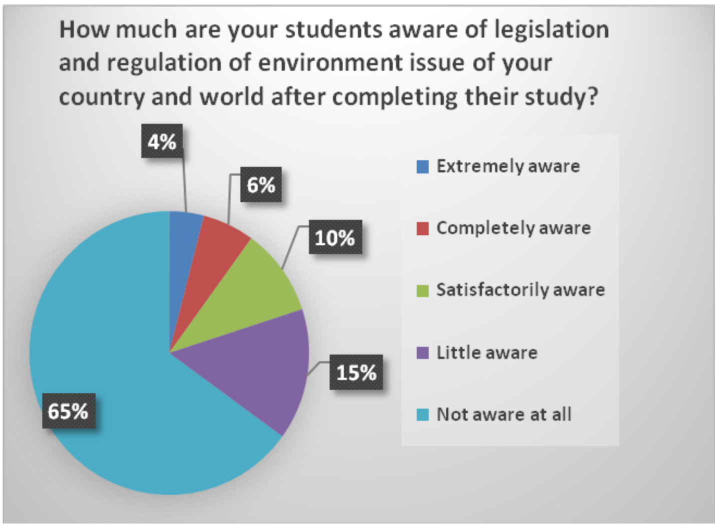

Figure 5: The students' awreness of environmetanl issues received from the study.

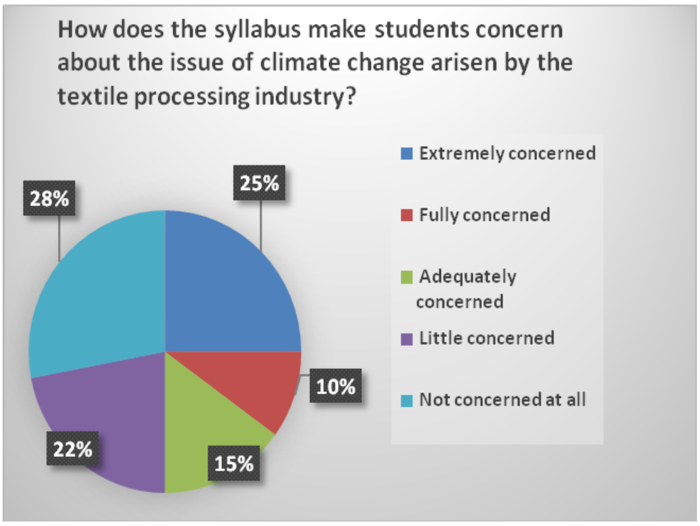

Figure 6: Guiding of syllabus to the studetns about climate change

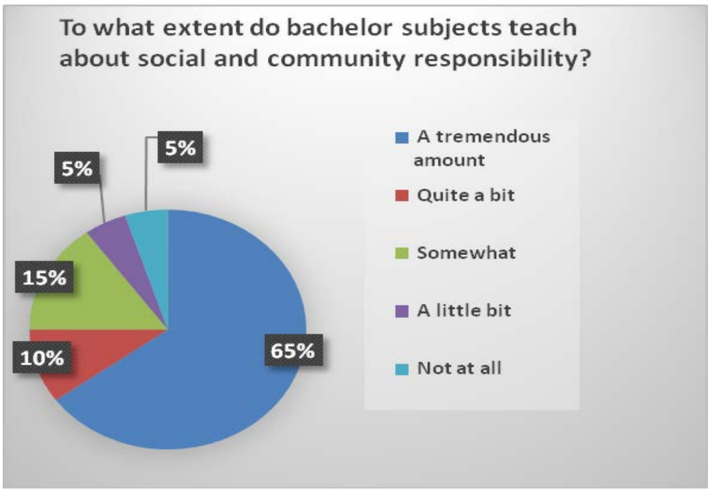

Figure 7: Social and community responsibility aspect of subjects.

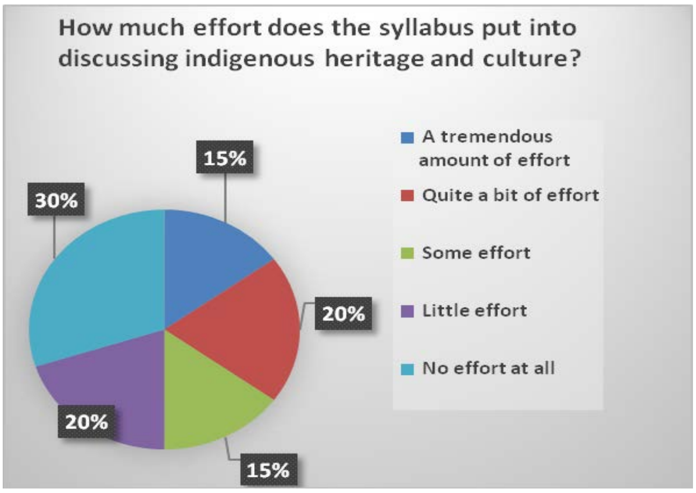

Figure 8: Presence of indigenous and culture related discussion in the syllabus.

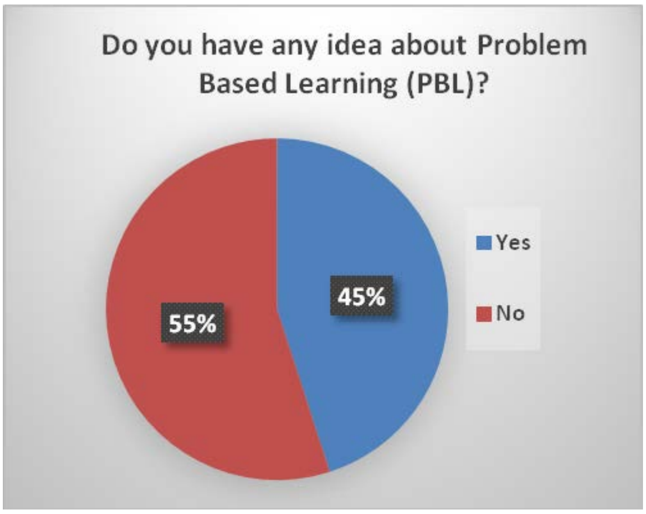

Figure 9: Introduction of PBL.

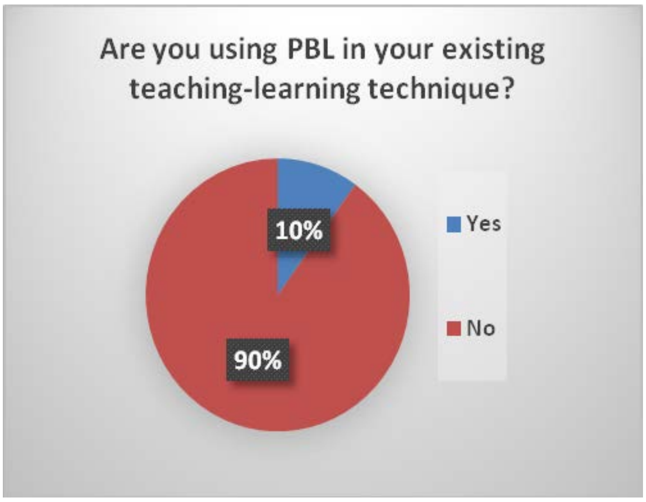

Figure 10: Use of PBL in existing teaching-learning technique

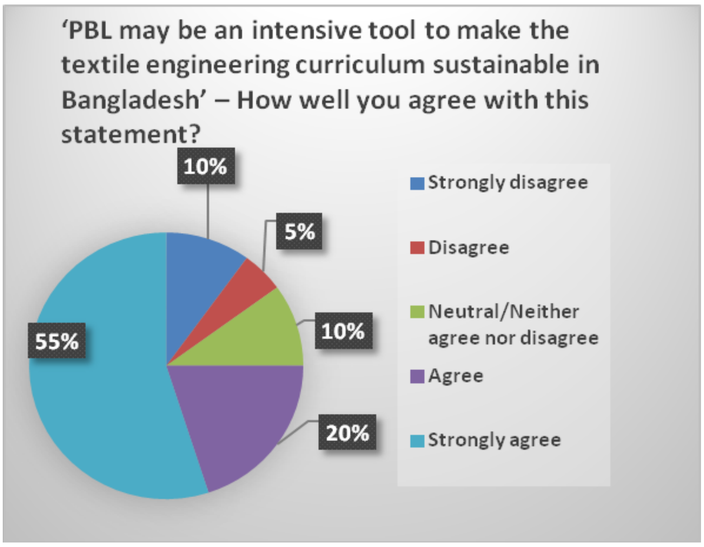

Figure 11: The acceptability of PBL as an intensive tool to produce sustainable textile engineering curriculum.

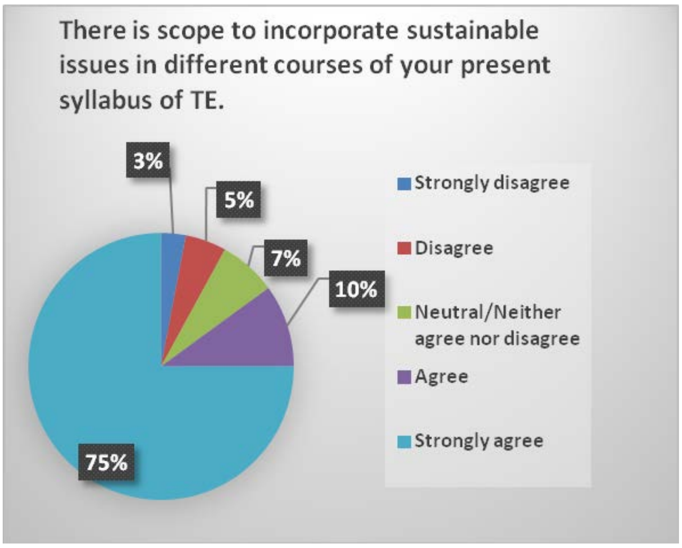

Figure 12: Scope to incorpoate sustainable topcis in existing syllabus.

The figures (1-12), show the participants' perception on their existing textile engineering curricula, sustainable curriculum including economic-social-environmental dimensions and PBL as tool for sustainable curricula. It is clear that most of the participants (85%, Figure1) think the sustainability is important for existing TE curricula whereas 1% (Figure1) do not agree. The figure2 shows that 35% agree, 25% slightly agree and 15% do not agree with extremely well highlighting on the efficient uses of energy. About 5% (figure3) faculty members think the existing syllabus gives extremely importance on the message related to economic uses of resources and alternative resources whereas 53% do not agree. A higher percentage (55%, figure4) of participants deliberate that the information about health and safety of personnel is not complete at all in the syllabus. According to the comment of participants, it is clear that a large number (65%, figure5) do not agree that the present study provides legislation and regulations of environmental issues whereas only 4% are satisfied. Less number (25%, figure6) participants agree that the existing syllabus is fully concerned with climate change whereas 28% are totally disagree with this comment. The syllabus which is followed by different universities teaches a tremendous social and community responsibility to students (65% agree and 5% totally disagree, figure7). 15% (figure8) teachers think the syllabus has a tremendous amount of effort to discuss the indigenous heritage and culture whereas 30% (figure8) totally disagree with the statement. Only 45% (figure9) participants are familiar with the concept of PBL and only 10% (figure10) participants are following PBL in their teaching method. PBL may be an intensive tool to make the existing textile engineering curricula sustainable – 55% (figure11) strongly agree, 20% (figure11) agree and 10% (figure11) only disagree among the participants with the statement. To make the curricula sustainable some topics related to sustainable to be incorporated in the existing syllabus of TE. In this regard, 75% (figure12) teachers strongly agree.

Conclusion

From this study, it was unveiled that most of the universities of Bangladesh have the remarkable lack of sustainable issues in their existing curriculum and there is an obvious scope to upgrade the curriculum which would be functionalize through providing PBL teaching and learning methodology. The paper also concludes that PBL is an effective tool to make the Textile Engineering Education sustainable in Bangladesh that can be functionalized by developing a strong linkage between educational institutions and industries.

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The context of linear algebra problems in university mathematics projects

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Abstract

Aalborg University (AAU) in Denmark has practiced project and problem based learning (PBL) since its start in 1974 on all faculties. A principle behind PBL is that students work with projects where they solve a problem that origins in society. Mathematics, however, is an abstract discipline where the results are sometimes applied in other disciplines but other times, mathematics only deals with abstract objects. Linear algebra is taught as part of most mathematics, engineering, and science university programmes in the world usually during the first year of study. At AAU, mathematics students work in groups on a project in linear algebra during their first semester and this is documented in a joint report. During this semester they have a course in linear algebra. This paper analyses all five student reports done during the autumn 2016. The purpose of the analysis is to answer the following research questions: "To what extent is a concrete problem and its context addressed and acts like the goal of these projects? How do the projects show the theory?". The analysis is a combination of quantitative and qualitative content analysis of the curriculum and the reports particularly focusing on the problem analysis, context, problem statement, and mathematical content and competencies. The paper includes a discussion about the principles of PBL at AAU in relation to mathematics. The paper concludes that the projects showed the students' abilities in a range of mathematical competencies. In three of the projects, the outset of the projects was a real problem in society, while in the two others, theory was presented, then a case added to apply the theory. All reports had extensive theory sections and therefore showed both pure and applied mathematics.

Keywords: mathematics, PBL, linear algebra, context, applied mathematics

Type of contribution: research paper.

1 Introduction

When Aalborg University (AAU) in Denmark was established in 1974, the founders decided that the university should be organised around the principles of problem and project based learning (PBL) at all faculties. The structure of the AAU PBL Model has since then undergone several changes (eg. Kolmos et al., 2013 & Dahl et al., 2016) but the AAU PBL principles have remained roughly the same. These principles may not be exactly like PBL principles applied in other institutions but since this study takes place at AAU, it is the AAU PBL principles that will be in focus. The newest formulation (Askehave et al., 2015) states six basic AAU principles:

1. The problem as point of departure
2. Projects organized in groups
3. The project is supported by courses
4. Collaboration – Groups, supervisor, external partners
5. Exemplarity
6. Student responsibility for learning

The AAU PBL principles are therefore based on student centred learning where students work in groups with projects where theory is applied to solve or to explain a problem that origins in society. Particularly at the start of the education, supervisors provides the problems in project catalogue. The problems are therefore contextualised. The problem formulation is developed through a problem analysis of an initiating more loose problem found within a prescribed semester theme, and the problem formulation becomes the guide for the project. The students are responsible for their own learning including project planning, and they collaborate in teams of up to eight students. The student groups receive feedback from other student groups and from supervisors who act like facilitators. The overall structure of a semester allows for half the time to be spent on the project while is other half is reserved to more traditional courses where some of the courses are supposed to support the project, others are more general courses. When appropriate, the projects also have an inter-disciplinary focus. Exemplarity refers to both content and process and implies that the learning outcomes of a project can be transferred to similar problems relevant to the students' future professions and the learning outcomes are therefore applicable beyond the project itself (Kolmos et al., 2004, Kolmos, 2009).

AAU offers a study in mathematics. De Graaff (2016, p. 397) argues that "working in a project is a natural preparation for a professional career in engineering. For other professions such a link to a project is less obvious". Ravn and Henriksen (2017) argue that university engineering education in the abstract aspects of mathematics can be done in a contextual way. However, this paper focuses on university *mathematics* education. Dahl (2018) discusses that a study in mathematics must include both real (abstract) and applied mathematics in order to fully educate students as mathematicians. This raises the question if PBL is able to provide adequate training in pure mathematics since problems here typically origins in a theoretical realm and PBL might therefore not develop the students' abilities in all the mathematical competencies. These competencies are described by Niss (2015) and they are also part of the OECD PISA framework for comparing school children internationally. In Dahl (2018) it is argued that PBL might also fit the teaching of pure abstract mathematics if the concepts of 'society' and 'context' are interpreted to also include the 'society of researchers' (or community of researchers) indicating that all problems are not necessarily relevant to *everybody* in the society at any given point in time, but that some problems are only relevant for some part of the society, at least for the moment. Abstract mathematics is highly relevant within a context of research mathematics. Abstract mathematics is not always applicable immediately, neither is most basic research, but some basic research becomes relevant after some years - sometimes even several thousand years like was the case with number theory.

This paper focuses on PBL projects in linear algebra and the purpose of the analysis is to answer the following research questions: To what extent is a concrete problem and its context addressed and acts like the goal of these projects? How do the projects show the theory?

2 Mathematics and mathematical competencies

Niss (2015) formulated eight mathematical competencies that are supposed to be taught and learnt throughout the education system from primary through to tertiary in order for students to properly learn *mathematics*. These competencies are: (1) Thinking mathematically, (2) posing and solving mathematical problems, (3) modelling mathematically, (4) reasoning mathematically, (5) representing mathematical entities, (6) handing mathematical symbols and formalisms, (7) communicating in, with, and about mathematics, and (8) use of aids and tools. To possess a competence means to be able to perform certain actions with various mathematical contents. Niss (2015) described three dimensions of competence possession: *degree of coverage* of the aspects within a competence, *radius of action* which are the various contexts where a person can activate the competence successfully, and *technical level*.

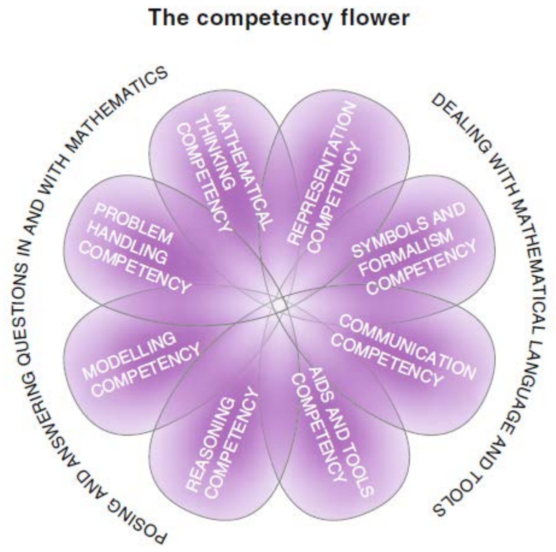

Figure 1: The competency flower of the eight mathematical competencies illustrated by Niss (2015).

Antonsen (2009) argues that the eight competencies are different as four of them may be termed 'inner' mathematical competencies (thinking, reasoning, representing, symbols and formalism) as their focus from a mathematical point of view are more relating to pure mathematics. Antonsen (2009) terms the other four 'outer' mathematical competencies (modelling, problem handling, communication, aids and tools) as they focus more on the application of mathematics. This division can be discussed as problem handling might also be within abstract mathematics and in order to apply mathematics, symbols and representations are needed. However the prime goal of the competencies differ. This division will be applied in this paper to analyse to what extent the projects are real or applied mathematics, or both.

3 Methods

This paper analyses all project reports at the first semester of mathematics in the autumn of 2016. The groups consisted of between four and seven students, and the projects were supported by a semester course in Linear Algebra. The theme of the projects was: Discrete dynamic systems. The groups had two different supervisors (the author was not one of them).

Bauersfeld (1979) distinguishes between different levels of learning termed 'matter meant', 'matter taught', and 'matter learnt'. Matter meant is the official curriculum, matter taught is what actually happens during lecturing and supervision, while matter learnt is what the students by the end of a course or project are able to do. This analysis will be on the first and the third level. The analysis is content analysis (Titscher et al., 2000) and is a combination of quantitative and qualitative content analysis of the curriculum and the reports particularly focusing on the problem analysis, context, problem statement and mathematical content and competencies.

4 Analysis

4.1 Analysis of the curriculum

At Aalborg University each semester consists of usually one project of 15 ECTS and three courses of each 5 ECTS. Students choose their topic of study before entering the university and therefore begin studying mathematics from the first day at the university. Each semester is therefore a "package" of courses and a project to be followed by each student. At the fourth and sixth semester of the three-year bachelor programme, the students have some freedom to choose courses but otherwise the courses are predetermined and each project is within a prescribed semester theme with prescribed learning objectives that are approved by the study board. During the first month at the first semester, the students do a P0 project, which is a small 5 ECTS project where the students work in groups put together at random by the administration. This project is only graded pass/fail. The purpose is that the students should have a first experience with PBL on a smaller scale before starting on the bigger projects. The second project at the first semester is called P1 and is 10 ECTS and graded. This paper analyses the P1 projects. Here the students choose their own group members within some frames such as number of group members. The nine learning objectives for P1 are divided into knowledge, skills, and competencies (Study Board for Mathematics, Physics and Nano Technology, 2015). They are listed in Table 1 and translated from Danish by the author. In brackets each objective is named (eg. K1, Knowledge goal 1) by the author to make later reference easier:

Table 1: Learning objectives of the P1 project with the theme: Discrete Dynamical Systems.

Knowledge	Should have knowledge about models for concrete dynamical systems, eg. for the description of macro economical phenomena (K1)
	Should know about iterative and numerical methods and tools that can be used to simulation of discrete dynamic systems (K2)
	Should know about and have overview over topics and concepts in linear algebra that are relevant to solution and analysis of equilibrium and stability of discrete linear dynamic systems (K3)
Skills	Is able to communicate the relevant abstract mathematical theories and their application in one or more concrete dynamic systems. This communication must be in both writing and oral using correct mathematical concepts, symbols, and rigorous reasoning (S1)
	Is able to perform a concrete analysis of a discrete dynamic system where the analysis includes determining equilibrium points, stability, and perhaps numerical simulation (S2)
	Is able to designate relevant areas of focus for assessing and developing solutions while showing consideration for the societal and humanistic context in which the solutions are be part of (S3)
Competence	Should be based on given conditions be able to reason and argue using mathematical concepts from linear algebra (C1)
	Should develop and strengthen own ability to orally and in writing give a correct and precise mathematical statement (C2)
	Should apply concepts and tools to problem based project management and reflect about problem based learning for groups in a written Process Analysis for P0 and P1 (C3)

It appears that problem based learning is stated directly as part of the competence goals (C3). Here the focus is on project management and the collaboration between group members. The Process Analysis mentioned is a 5-10 page document that is assessed as part of the project exam where the students should describe and reflect upon their project management, group collaboration, and collaboration with the supervisor(s) (Spliid et al., 2017). The learning objectives do not mention to what extent the project should take an outset in a problem, but the focus is both on abstract and applied mathematics. S3 states that the context of the problem should be considered. Table 2 gives an overview of how the listed knowledge, skills, and competencies in the curriculum fit the competence flower. Given that 'competence' may not be used in the same manner in Niss (2015) and the curriculum, the analysis also includes the learning objectives about skills and knowledge.

Table 2: Comparison of learning objectives to the eight mathematical competences.

Real or applied	Competence	Seen in curriculum
Mainly real	Thinking	C2
	Reasoning	S1, C1
	Representing	K1
	Symbols and formalism	S1
Mainly applied	Modelling	K1, K2
	Problem handling	K3, S2, S3
	Communication	S1, C2
	Aids and tools	K2

C3 does not focus on mathematics and is therefore not listed in Table 2. It appears that the learning objectives cover all eight mathematical competencies and that application competencies are covered more often than real competencies. However such a conclusion should be done with caution as the nine learning objectives are not necessarily supposed to be of equal weight. But it is clear that the projects are not intended to be just application projects but they should contain a certain amount of mathematical theory.

4.2 Analysis of the projects as a whole

The five reports are of different length as illustrated in Table 3. The reports are mentioned by the name of the group which refers to a specific room number. Often groups share a room and then one group is denoted 'a' the other 'b'. The capital A in front refers to building name.

Table 3: Overall description of the five project reports: Supervisor and number of pages.

	Group name				
	A217b	A218a	A218b	A219a	A219b
Supervisor	A	A	B	B	B
Introduction section and problem analysis	6	2	6	2	1
Theory section(s)	14	21	22	42	33
Application section(s)	8	20	20	12	26
Discussion & conclusion	4	6	4	3	3
Total number of pages in report	44	56	73	70	68

The number of pages for introduction etc. seen in Table 3 does not add up to the total number of pages in the report as this number also includes preface, abstract, table of contents, bibliography, appendices etc.

Table 4: Percentage (rounded) of introduction/problem analysis, theory and application sections.

	Group name

	A217b	A218a	A218b	A219a	A219b
Introduction section and problem analysis	14	4	8	3	1
Theory section(s)	32	38	30	60	49
Application section(s)	18	36	27	17	38

The percentage distribution of pages seen in Table 4 only gives an overall impression of the report as some sections might be written in a more compact ways than others. However based on the distribution it appears that the reports of groups A219a and A219b are quite theoretical, groups A218a and A218b have an even distribution, while A217b is between these two groups as their report appear quite theoretical, but on the other hand, they have a more extensive problem analysis. It also appears that the fact that there was two different supervisors did not influence the balance between theory and application since both of them supervised theory heavy projects and application heavy projects. The analysis below will go deeper into this.

4.3 Analysis of the introduction and context

As stated above, AAU has six basic PBL principles. In terms of Principles 2, 3, 4, and 6, it is a given that these are fulfilled as the projects are evidently organized in groups of between four and seven students, the project is supported by a course in linear algebra, the group had a supervisor, and they were responsible for their own learning. What is more interesting to investigate is the first principle (The problem as point of departure) and fifth principle (Exemplarity), which will be done below.

For all five reports, the problem analysis is done as part of the introduction and these sections are relatively short; i.e. 1-6 pages, or between 1-14% of the report. Table 5 is a first step of the analysis of Principles 1 and shows how the five reports introduced their project, argued for the problem formulation, and presented the real life context.

Table 5: The projects' introduction, problem analysis, and problem statements (translated by the author).

	Introduction and problem analysis	Problem statement
A217b	Begins by describing that most Danes are using the Internet daily to search for information. Then they discuss how it is possible that an Internet search gives useful information and then introduces the search engine Google (½ page). Before the problem statement the group has 1½ pages problem analysis where the PageRank sum formula is presented.	*How can the theory of Markov chains be used to describe the Google PageRank algorithm?*
A218a	Same as group A217b but 1 page. Before the problem statement the group has a ½ page problem analysis where the PageRank sum formula is presented.	*How can PageRank be understood and how is Google, PageRank, and Markov chains connected? Which are the characteristics of Markov chains and how can these be used to make a model of the Internet that makes successful information search possible?*
A218b	Begins by referring to the British mathematician Patrick Leslie who in the 1940s investigated the development of biological populations. Then they present the Leslie Model (½ page). The problem limitation (½ page) describes that the goal of the project is to be able to describe how a herd of sheep develops. The rest of the introduction (4 pages) after the problem	*How does a population develop and which methods from linear algebra can be used to investigate this?*

	statement gives an overall description of population growth and how the Leslie Matrices fit.	
A219a	Begins by stating that probability is a fundamental thing for all humans and that mathematics can create models that predict how problems develop. They then describe their first case which is a model for the woods around Princeton. The second case is 'Snakes and Ladders', which is an old board game. They explain that Markov chains are used in the project on these cases (½ page). Before the problem statement there is ½ page with problem analysis which is basically a description of the structure of the report.	*How can mathematical modelling using Markov chains predict how a group of trees will change over time and how can Marcov chains be used to calculate the average length of a game of 'Snakes and Ladders'?*
A219b	Begins by stating that many problems from the real world can be solved using mathematical methods for instance the distribution of trees in a wood or how an illness develops. Then they describe that Marcov chains can be used to analyse the transition in a network of conditions (½ page). Before the problem statement they have ½ page that describes the structure of the report.	*How can linear algebra be used to investigate a long term process using Marcov chains and how can this knowledge be used to describe a course of a Hepatitis B illness and to calculate the cost of this course?*

In terms of the first AAU PBL principle stating that the problem as point of departure, we see that three of the groups (A217b, A218a, A219b) appear to start their report with a problem asking how it is possible that an Internet search gives useful information (groups A217b, A218a) or a little more generally how trees are distributed or an illness develops (A219b). Their problem analysis then introduces the PageRank algorithm or Marcov chains and then they formulate the problem statements. Although the problem analyses are relatively short, they nevertheless illustrate how the projects go from a more loosely described (initiating) problem to a specific problem. The two other groups (A218b, A219a) begin by describing a mathematical area and then later introduce a case that fits this piece of mathematics but it does not appear to have been the cases that guided the projects, more the other way around. Particularly for A219a, they choose two unrelated cases. The reason for the differences cannot be determined through a text analysis as they had different supervisors and were in different part of linear algebra. The context of the projects therefore varies as two of them have the Internet and the daily consumer as the context, two have more biological contexts, and a third a game theory context.

In terms of the fifth AAU PBL principle about exemplarity, the projects all worked with the application of mathematics to real problems, which is what many trained mathematicians work with after graduation. However, in most jobs a task begins with a problem to be solved or improved. Usually a job would not involve first to get to know a theory and after that find a way to apply it. Therefore only three of the projects (A217b, A218a, A219b) are truly exemplary.

4.4 Analysis of the theory sections

Table 6 gives an overview of the theoretical chapters in the five reports. Below will be discussed how they relate to the eight mathematical competencies and the learning objectives of P1.

Table 6: Short description of the projects' theoretical chapters.

	Use of definitions, examples, theorems, and proofs
A217b	The 14 pages of theory consists of two chapters. In total seven definitions, eight examples,

	and four theorems with proof. The proofs had length between ¼ - 2¼ pages.
A218a	The 20 pages of theory consists of several chapters and in between are more application chapters. The chapters are mathematical but seldom uses formal headings to indicate when something is a definition etc. One place has an indication of an example. There is one theorem and the proof is four pages.
A218b	The 22 pages of theory consists of several chapters. In total seven definitions, eight examples, and four theorems without proofs being given. One of the theorems is actually not a theorem but a definition.
A219a	The 42 pages of theory consists of one chapter with several subsections. In total ten definitions, seven examples (as well as other examples not directly with the heading 'Example'), four theorems without proof, and ten theorems with proofs. The proofs had length between ½ - 1½ pages.
A219b	The 33 pages of theory consists of two chapters. The last section in the latter of these explains in two pages how the theory is going to be applied (not counted as theory in Table 3). In total six definitions, 21 examples (usually ½-1 page, but one examples was 4½ pages), and four theorems without proof.

The purpose is not to grade the projects, and due to the restrictions of page numbers, the analysis does not go in depth with the mathematics. Referring to the mathematical competences (Niss, 2015), the projects show different degrees of coverage of the eight competencies. Mathematical thinking was seen in all reports, but A218b and A219b showed lower level of coverage as they did not provide any proofs. A218b furthermore mixed the concepts of theorem and definition and A219b spent the theory section mostly on long examples. The three other groups had reports that resembled mathematics a lot more. Interestingly, A219b was one of the reports that were initially (Table 3) considered quite theoretical. In relation to mathematical reasoning, the text introducing the definitions and the explanation of the mathematics show a good competence coverage. This is also the case in relation to mathematical representation, symbols and formalism, which is apparent in the reports. All reports had some elements of mathematical modelling and problem solving as the introduction formulated a mathematical problem and the report then used a theory to model a piece of reality. Mathematically written communication is also seen in the reports. Regarding aids and tools, all reports except A217b used MatLab. It therefore appears that with different level of coverage, the reports train the students in all eight mathematical competencies. The curriculum covered all the eight competencies but the aids and tools competence is only asked for in K2, where it required knowledge about numerical methods and tools. Tools might therefore not necessarily be software but also algorithms.

5 Discussion and conclusions

This paper analysed all the project reports of a single semester. Since student groups change year after year, one cannot conclude that project reports would look the same another year. However, both supervisors were experienced supervisors thus leading the projects in a direction that one might anticipate is a shared understanding of what a project report is. In any case, the analysis is not intended to show a generalised picture of what mathematics PBL project *should* look, but how they *can* look regarding how the real world context fits. The research questions asked: To what extent is a concrete problem and its context addressed and acts like the goal of these projects? How do the projects show the theory?

In relation to the first research question, three of the projects appeared to have a problem as a goal of the project while the two others started explaining that some mathematical theory exists and they then later found a case to apply the theory. On the other hand, writing a project report is a long process where chapters are edited multiple times. Since the students knew that they are studying within a PBL curriculum, it is also possible that all the projects started with theory, then later found a case and explained the context of this, a kind of PBL archaeology digging down to find what might have been a good initiating problem. Nevertheless, the fact that three of the group chose to present their project in a way that fitting the AAU PBL principle, shows that at least they know what PBL is and they are able to make it fit a project in linear algebra.

Regarding the second research question, the projects covered the eight mathematical competencies in various degrees which was also the case with the curriculum. Theory played a central role in the learning objectives and the theoretical chapters took up a larger part even though some of the reports had less mathematics thinking than others. A question could be, why have the theory section? If the problem is truly the point of departure and guide for the project, is it then not enough that students within a few lines refer to existing theory and then go directly on to apply the theory to their case? From a "pure" PBL principle, one may argue that having theory section disrupts the structure of the report and these sections are not necessary for the student to apply the theory. However, given that this is also an *education* in mathematics, and that pure mathematics is an essential part of mathematics, one can argue that it needs to be there.

In terms of the exemplarity principle, only three projects were truly exemplary as they began with a problem, while the two others began with theory. Nevertheless, even these two projects still applied the theory to a concrete case. Given that the learning objectives do not insist on problems being the guide of the projects, the students fulfilled these learning objectives. One may also argue that since all projects applied theory to a real case, they indeed learned to apply theory, which is therefore exemplary. One might also argue that the AAU PBL Principles 1 and 5 to some extent are contradictory as in most jobs, even though a task takes an outset in a problem, it is not always the employee's problem, but the employer's problem that the employee is asked to solve. Principle 1 and the general principle about student centred learning stipulates that the students should find a problem that motives them, but this is not usually how the work market functions.

The projects clearly all fulfil the criteria set up in the curriculum, but a critique might be that the curriculum itself does not explicitly state that the projects should take a point of departure in a problem. However it is clear that the projects should have some part of concrete application. The paper started by asking the question if mathematics fit a PBL curriculum, particularly real mathematics. Based on the finding it appears that a study of linear algebra that aims at developing the students' abilities in all the eight mathematical competencies are in fact able to do so provided that they take care of leaving a good amount of the report to theoretical chapters. However, a study of mathematics also includes course in mathematical analysis where an application to the real world is less obvious. One solution might be to only have pure mathematics in the courses, but another solution could be to regard the real world as also including the abstract world, which in fact according to Plato *is* the real world.

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Sources of mathematics self-efficacy and their influence on students' academic achievement in problem-based learning

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Abstract

Self-efficacy is the belief in one's capabilities to organise and complete a task successfully. Many studies have shown that there is a positive relationship between efficacy beliefs and academic achievements. However, there is a dearth of literature in exploring the influences of mathematics self-efficacy on academic achievement in a problem-based learning (PBL) environment. Hence, this study aims to (a) investigate the sources of mathematics self-efficacy in a PBL classroom, (b) examine if there are any correlations between the sources of self-efficacy and mathematics achievement scores, and (c) predict the main source of self-efficacy that significantly affects mathematics achievement. A 23-item survey on mathematics self-efficacy was administered to 161 Year 1 students studying Mathematics using problem-based learning in a polytechnic in Singapore. The collected data from the questionnaire was subjected to an Exploratory Factor Analysis (EFA), which yielded three sources of mathematics self-efficacy, namely, (a) personal experience, (b) vicarious experience, and (c) psychological state. These sources of mathematics self-efficacy showed positive and significant correlations with one another, and also with mathematics achievement scores. In addition, personal experience was found to be the main predictor for mathematics achievement. The study findings have important practical implications for lecturers / curriculum designers to regulate self-efficacy level of students by providing tailored learning experience for students learning mathematics to build their confidence and improve academic achievements.

Keywords: Self-efficacy, mathematics, problem-based learning, academic achievement

Type of contribution: Research paper

1 Introduction

Bandura defined self-efficacy as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3). He posited that self-efficacy was developed from four main sources, namely, mastery experience, vicarious experience, social persuasion and psychological states. Mastery experience refers to how one judges his competence according to his previous achievement on a similar task. Vicarious experience refers to how one observes the action of the others so as to gauge and compare with his or her own capability. Social persuasion refers to the feedback and appraisals received from significant others when one is engaged in a task. Lastly, psychological states refer to emotional arousal such as anxiety, fatigue, mood and stress that one experiences while performing a particular task.

There are various factor analytic outcomes derived by different researchers in their studies of mathematics self-efficacy. In particular, Matsui et al. (1990) identified a three-factor model, namely vicarious experience, social persuasion and psychological states for his studies. Mastery experience was not established. This finding was unexpected as mastery experience was established by Bandura (1997) to be the dominant influence of one's self-efficacy. On the other hand, Lent, Lopez, Brown, and Gore (1996) found a spectrum of factor solutions, from a two-factor (personal experience and vicarious experience factors) to a five-factor (vicarious experience was further divided into peers and adults influence) solution, when exploring the sources of mathematics self-efficacy in a research on career relevant activities for high school and college students using confirmatory factor analysis. Loo and Choy (2013) conducted a similar study on investigating the sources of mathematics self-efficacy for 178 third year engineering students in a polytechnic in Singapore and found four sources of mathematics self-efficacy as hypothesised by Bandura (1997).

There are different instruments developed to measure self-efficacy. Lopez and Lent (1992) developed a 40-item instrument, Mathematics Self-efficacy Scale (MSES), to examine the sources of mathematics self-efficacy for high school students, which is equivalent to pre-tertiary schools in our local context. Loo and Choy (2013) had adapted the MSES in their research study. On the other hand, Usher and Pajares (2009) created the Sources of Self-Efficacy for Middle School Students (SSEMSS) to investigate the mathematics efficacy level of middle school students, equivalent to secondary school in the local context. This scale was developed in respondence to the observation that the assessment of students' mastery experience in the area of mastery experience in MSES did not align with that defined by Bandura. Also, Usher and Pajares (2009) advocated the need to segregate the vicarious experience aspect into peer and adult influences as these influences offer different degree of impact on the middle school students. In our current study, the questionnaire is adapted from the work done by Usher and Pajares (2009).

Research studies in the academic settings have shown that there is a positive and significant correlation between self-efficacy with academic achievements (Bandura, 1997; Jones, Paretti, Hein, & Knott, 2010; Liem, Lau, & Nie, 2008; Lodewyk & Winne, 2005; Louis & Mistele, 2011; Purzer, 2011). These studies have shown that regardless of age, gender, domains, disciplines and countries, a student with higher sense of self-efficacy will achieve better academic performance. In the context of Singapore junior college, Amil (2000), through investigating self-efficacy and self-regulated abilities of students taking Economics at 'A' level, found that there was a significant, positive correlation between self-efficacy with academic performance, and self-efficacy with self-regulated learning. Loo and Choy (2009), who conducted their research in a polytechnic in Singapore, also found that there is a positive correlation between the sources of self-efficacy with academic achievements.

According to many research studies, mastery experience has been found to be the main influence of student's academic achievement in mathematics (Lent, Lopez, & Bieschke, 1991; Loo & Choy, 2013; Lopez & Lent, 1992; Usher & Pajares, 2009). In addition, vicarious experience was found in studies (Lent, Lopez, Brown, & Gore, 1996; Matsui, Matsui, & Ohnishi, 1990) to be a construct that was difficult to be captured consistently. Loo and Choy (2013), who conducted research in a polytechnic in Singapore, also found that the sources of self-efficacy were correlated with mathematics achievement scores and cumulative grade point average. In addition, results indicated that mastery experience was the main predictor of mathematics achievement scores and related engineering modules. Notably, the research subjects were students in their final year of diploma studies and were specialised in the engineering field. Hence, it might be not surprising that mastery experience was the main factor that attributed to the students' sources of mathematics self-efficacy as the students have built up their domain knowledge in engineering throughout their three years of study.

2 Research Questions

Based on the above literature review, the following research questions were formulated and guided the data analysis in the study:

1. What are the sources of mathematics self-efficacy in a PBL classroom for Year 1 students?
2. Are there any relationships between the sources of mathematics self-efficacy and mathematics achievement scores?
3. What are the sources of mathematics self-efficacy that predict students' overall mathematics achievement scores?

3 Problem-based Learning in the Polytechnic

Since its inception in 2002, the polytechnic has leveraged Problem-based Learning (PBL) as a deliberate instructional approach for all its Diploma Programmes. PBL was adopted to help students construct an extensive and flexible knowledge base; develop effective problem-solving skills; cultivate self-directed, and lifelong learning skills; as well as become effective collaborators, in keeping with the demands of a knowledge-based economy.

From 2011 onwards, to complement the use of PBL, and to cater to the varied demands of different disciplines, the polytechnic expanded its use of instructional strategies to include other learner-centred, inquiry-based strategies such as Cognitive Apprenticeship (CA), Interactive Seminar (IS), and Project-based Learning (PjBL). These strategies are used as they are grounded in social constructivism, in that they provide opportunities for learners to share, debate, make sense of, and build on their learning collaboratively.

A typical PBL classroom in the polytechnic consists of 3 Learning Phases with 2 intervening breaks. The lecturer-to-student ratio is 1:25 and students work in small groups of 5 each.

1. Learning Phase 1 (60 minutes): Problem is released to the students and it serves as a trigger to simulate students' learning. Students work on a heuristic tool – Problem definition template (PDT), where they synthesise their thought process by putting in "what they know", "what they don't know" and "what they need to find out".

2. Learning Phase 2 (90 minutes): Students engage with the learning resources such as worksheets provided to them. They work and collaborate with each other in their team to solve the problem statement. Lecturers facilitate their learning and bridge their learning gaps.

3. Learning Phase 3 (120 minutes): Each team is given an opportunity to present their solution to the class. Teams critique the solutions and also provide feedback to each other. Finally, there are lecturer summary slides that show the concepts for the day and a possible solution to the problem statement. Students are expected to write a reflection journal on their learning by the end of the day and also submit quiz, peer and self-evaluations.

4 Methodology

4.1 Sample

The sample for this study consisted of 161 Year 1 Semester 2 students studying mathematics module in a polytechnic in Singapore. Out of the total students who participated in the study, 91 (57%) were males and 70 (43%) were females. Students were informed that their participation will be kept anonymous and that they can refuse or discontinue participation at any time without penalty. All the students have signed an informed consent form that allows the author to use their responses of the survey as well as to extract their academic grades from the database.

4.2 Instrument

A 23-item questionnaire adapted from the work done by Usher and Pajares (2009) was used in the study to investigate the sources of mathematics self-efficacy of students. It was decided that the SSMESS, developed by Usher and Pajares, is the most appropriate scale to be adapted for this research as the research subjects have just completed their secondary school education. Even though the sample data is enrolled in the polytechnic, their age group is comparable to those in the secondary school as they are still in Year 1. For the SSMESS, some of the questions were modified to use terminologies that the students would be familiar with. This was done in consultation with math content experts and to suit the local context of the study. Terms like, 'teachers' were changed to 'facilitators' and 'mathematics courses' to 'mathematics modules'. Students responded by indicating their level of agreement with each statement on a 5-point Likert scale.

4.3 Ethics

Ethics approval for the research was sought from, and granted by the Polytechnic Ethics Review Committee. Students participating in the survey were assured of anonymity and all individual data were de-identified in the data set for analysis.

5 Results and Discussions

Statistical Packages for Social Sciences (SPSS) version 23.0 was used to analyse the collated quantitative data. Descriptive statistics consisting of mean and standard deviation for the individual items in the administered questionnaire is shown in Table 1. The mean ratings of all items ranged between 2.59 and 3.73 and the standard deviation (SD) ranged between .87 and 1.25.

Table 1: Descriptive Statistics of the questionnaire items

Items	M	SD
1. I have excellent grades for my math tests.	3.28	.96
2. I have always been successful with math.	3.08	1.09
3*. Even when I study very hard, I do poorly in math.	3.43	1.12
4. I do well on math assignments.	3.54	.87
5. I do well on even the most difficult math assignments.	2.86	.93
6. Seeing my friends do well in math pushes me to do better.	3.31	.94
7. When I see how my math lecturer solves a problem, I can picture myself solving the problem in the same way.	2.84	1.19
8. When I see how another student solves a math problem, I can see myself solving the problem in the same way.	3.03	1.20
9. I imagine myself working through challenging math problems successfully.	3.11	1.12
10. I compete with myself in math.	3.01	1.08
11. My lecturer has said that I am good at learning math.	3.73	.96
12. People have told me that I have a talent for math.	3.44	.99
13. I have been praised for my ability in math.	3.51	.88
14. Other students have told me that I'm good at learning math.	3.57	.89
15. My classmates like to work with me in math because they think I'm good at it.	3.67	.92
16*. Just being in math class makes me feel stressed and nervous.	3.18	1.25
17*. Doing math work takes all of my energy.	2.59	1.16
18*. I start to feel stressed-out as soon as I begin my math work.	3.12	1.18
19*. My mind goes blank when I am doing math work.	3.30	1.15
20*. I am unable to think clearly when doing math work.	3.42	1.10

21*. I get depressed when I think about learning math.	3.49	1.24
22*. My whole body becomes tense when I have to do math.	3.57	1.14
23. I feel good when I am doing math.	3.36	1.09

*Items 3, 16-22 are reverse-coded items

Using Cronbach's alpha, the items in the questionnaire were subjected to an overall internal consistency examination. The questionnaire items were deemed to have demonstrated good internal consistency with $\alpha = .93$. Besides that, inter-item and item-total correlations were analysed. Generally, inter-item correlations were satisfactory with values ranging from .04 to .83. In addition, all item-total correlations satisfied $r > .40$ requirements, with correlation values ranging from .47 to .71. Skewness and kurtosis of the terms ranged from –1.00 to .52, within one standard deviation from the mean as recommended by Lin and Hsieh, 2010.

The questionnaire items were then subjected to an Exploratory Factor Analysis (EFA). A Principal Components Factor Analysis of the 20 items using Varimax Rotation, with Kaiser Normalization was conducted. Three items were removed from the original data set, namely "Even when I study very hard, I do poorly in math", "I compete with myself in math" and "I feel good when I am doing math". The Kaiser-Meyer-Olkin measure of sampling adequacy was .89, above the recommended value of .60, and Bartlett's test of sphericity was significant ($\chi 2$ (190) = 2362.66, $p<.01$), confirmed the factorability of the data.

The result of the factor analysis yielded three factors which explained 67.37% of the total variance. As hypothesised by Bandura (1997), the sources of math self-efficacy are namely mastery experience, vicarious experience, social persuasion and psychological states. However, for this study 3 sources of math self-efficacy were derived, namely, personal experience, vicarious experience and psychological state. It is noted that personal experience is an amalgamation of mastery experience and social persuasion. In the PBL context, learners are presented with a problem in order to activate their prior knowledge. This prior knowledge is then built upon further as the learners collaborate with each other in small groups to construct a theory or propose mental model to explain the problem in terms of its underlying causal structure. Thus, the prior knowledge and the collaborative skills come together and play an important part to influence the self-efficacy and are categorised as personal experience.

Descriptive statistics and reliabilities of the three factors are shown in Table 2. Cronbach's alphas of the three factors were found to be ranging between .76 and .92, indicating high internal consistency reliabilities.

Table 2: Descriptive statistics and reliabilities of study variables (N= 161)

	Factors	Descriptive Statistics		Cronbach's Alpha
		M	SD	
(1)	Personal experience (PE)	3.12	.86	.94
(2)	Vicarious experience (VE)	3.56	.71	.76
(3)	Psychological state (PS)	3.24	.97	.92

Table 3 shows the correlations among the 3 identified sources of mathematics self-efficacy and mathematics achievement scores. It is noted that all the sources are statistically significantly correlated with each other and with the mathematics achievement scores.

Table 3: Correlations among study variables (N= 161)

	Factors	Correlation			
		(1)	(2)	(3)	(4)
(1)	Personal experience (PE)	–	.66**	.30**	.41**
(2)	Vicarious experience (VE)		–	.36**	.35**
(3)	Psychological state (PS)			–	.34**
(4)	Mathematics achievement score				–

Note: ** $p < .01$.

In order to determine which factors predict the students' mathematics achievement score, a multiple regression was performed using students' mathematics score as a dependent variable and the three self-efficacy factors as independent variables (see Table 4). The results of the regression indicated that the three predictors explained 66.0% of the variance ($F(3, 157) = 15.07$, $p<.001$). The result also suggests that personal experience was the strongest predictor when predicting the academic achievements of mathematics modules. This implies when a student has a strong and positive personal experience in mathematics, he/she may achieve good grades in the subject.

Table 4: Results of multiple regression analysis (N= 161)

	Dependent variable: Mathematics Achievement Score				
Independent variables	**B**	**SE**	***B***	***t*-value**	**Sig.**
Personal experience (PE)	.39	.12	.30	3.15**	.00
Vicarious experience (VE)	.12	.15	.07	.76	.45
Psychological state (PS)	.27	.09	.23	3.00**	.00
R^2	.22				
Adjusted R^2	.21				

Note: ***p*<.01

6 Conclusion

This study is an attempt to investigate the sources of students' mathematics self-efficacy and to determine the source that contributes the most to the academic achievement of polytechnic students in a PBL classroom. Three factors were identified, namely personal experience, vicarious experience and psychological state. The results of the present study showed that the self-efficacy sources were significantly correlated with mathematics achievement. More importantly, personal experience was found to be the main predictor for academic achievements of mathematics.

The study findings provided important practical implications for school educators and curriculum developers that tapping of student's prior knowledge and experience are critical in mathematics modules. Based on the findings of the study, the following are some key recommendations that could enhance polytechnic student learning mathematics in a PBL classroom:

(a) During the process of developing mathematics curriculum, curriculum developers should plan activities that could help students to reinforce their prior knowledge and to instil positive experience of accomplishing mathematics tasks in class. These activities should involve collaboration among students. For example, curriculum developers could design activities to help students relate which of their background knowledge can be applied to solve their current mathematics problem and work in small teams. This could allow students to recognise that they have the ability to solve what may seem to be initially difficult.

(b) Curriculum developers can design smaller tasks to allow students to have more confidence in completing math tasks. Tasks should be given progressively and gradually so as to develop strong students' efficacious beliefs. As long as students start to build up significant level of confidence in mathematics, they would do well in the subject.

Although the findings of this study cannot be generalised and may only apply to mathematics, they can be used to provide insight for the development of similar study in future. At the same time, since the data collected for the current study is from Year 1 students, a future study may be conducted to compare between Year 1 and Year 3 students' self-efficacy results in order to investigate if the PBL environment has a significant impact.

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Teaching reform and practice of PBL model in basic mathematics courses

---Research and enlightenment for PBL teaching model of Aalborg University in Denmark

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Abstract

PBL model has significant effects in stimulating learning initiative, cultivating analytical thinking, guiding to construct knowledge, and deep learning and are affirmed in training ability of strong adaptation, teamwork, organization and management, and innovation. Teaching of basic mathematics course is indispensable in the process of achieving the goal of college education. Teachers should continue to reform, improve and practice teaching in order to meet the needs of social development. On the basis of traditional teaching model, it is a good idea for teaching reform that PBL model is introduced in basic mathematics course. Mathematics emphasizes the cultivation of students' ability to innovate and apply. PBL model can effectively cultivate the students' comprehensive competence. Therefore, exploring PBL model has a positive effect on the reform of teaching strategies. In this paper, basic information, gains, reflection, enlightenment and reference in Aalborg University are summarized, focusing on in-depth analysis and summary about PBL model and further analysis of its teaching idea and related contents. By using the methods of literature review, quantitative and qualitative analysis, interviews, and empirical data analysis, we study the transformation of the teaching model, introduction of the PBL model in teaching design and strengthen of process evaluation. The purpose of this study is to complete teaching reform of the PBL model in basic mathematics courses and practice, and to promote the students' coordinated development in knowledge, skill and comprehensive competence. Finally, through the case study of PBL teaching design in single courses and cross courses for statistics, the conclusion that interdisciplinary teaching design is an effective strategy to promote cognition, cooperation and content learning is drawn and PBL teaching model not only helps to cultivate students' professional identity and sense of responsibility, but also improves their learning motivation and makes their learning process more meaningful.

Keywords: (maximum of 5): PBL teaching model; Basic mathematics course; Teaching reform; Educational idea; Teaching strategy

Type of contribution: **Research paper.**

1 Introduction

In the present era of knowledge economy and challenges, the development of higher education only can be invincible for a long time by keeping in step with the times and training high-quality talents to adapt to the new situation (Du *et al.*, 2013). Therefore, the training of essential competencies has become the focus of university education and improving the essential competencies of college students has become the mainstream of higher education reform (Spliid, 2016). Mathematics has an irreplaceable role in promoting social progress, human civilization, the development of students and social harmony (Wu, 2014). The teaching and learning of basic mathematics courses is an indispensable part of realizing the goal of college education and it requires teachers to reform and improve the classroom teaching to meet the needs of social development (Lu, 2003).

Calculus, Linear Algebra and Probability Theory and Mathematical statistics are compulsory mathematics courses for non mathematics majors in the science and engineering university. These courses have laid the necessary mathematical foundation for the study of subsequent courses, and are very important for improving students' ability in abstract thinking, logical reasoning and self-study. In recent years, with the development of higher education, there have been problems of uneven quality of students and the outstanding individual needs of students (Liu, 2003, 2008; Li & Yang, 2007). In addition, the traditional teaching mode of college mathematics curriculum is centred on the classroom, teachers occupy the dominant position, and the theory teaching is carried out from the concept, the interaction between teachers and students is difficult to carry out, and the students are lacking of learning enthusiasm, many students feel that mathematics is abstract and boring, and it doesn't seem to be useful enough, which lead to poor teaching effect. The main reason is that the teaching process of is too theoretical and not close to practice. Furthermore, the choice of the teaching method of basic mathematics courses will greatly influence the teaching effect and the long-term development of the students. Therefore, the reform of teaching mode for basic mathematics courses has become a topic of increasing concern (Wedelin & Adawi, 2015).

PBL teaching mode originated from medical education in 1950s (Du *et al.*, 2013; Marra *et al.*, 2014). Now it has become a very popular teaching method in the world (Guerra *et al.*, 2017). PBL is an important research model of self-directed learning, problem solving, team cooperation and interpersonal communication (Kolmos, 1996, 2002, 2010). It is to set up learning in a complex and meaningful problem situation, by allowing learners to cooperate to solve the problem of authenticity, to learn the scientific knowledge hidden behind the problem, to form the skills to solve the problem, and to form the ability of autonomous learning. Different PBL practices are mainly based on the same learning theory -Dewey, Kolb and Schon theory. Graaff and Kolmos (2003, 2007) summed up PBL learning principles in three aspects: cognitive learning, cooperative learning and learning content. From the point of view of cognitive science, psychology and sociology, the essence of PBL is embodied in the three aspects of the interaction: method, the content and the sociality. Aalborg University in Denmark is founded in 1974 and the PBL teaching mode is launched at the beginning. After 40 years of development, it has become an important example in this field, and has attracted wide attention (Kolmos *et al.*, 2004; Spliid, 2011; Holgaard *et al.*, 2017). The PBL teaching model of Aalborg University has also been recognized and respected by UNESCO, and the PBL research centre in Aalborg University provides strategic advisory services to the world.

Many researches show that the implementation of PBL teaching mode in higher mathematics is helpful to stimulate students' enthusiasm and initiative in learning (Soto & Ayesta, 2009). It enables students to participate in the mathematics teaching, change inherent learning methods, change passivity into initiative and turn weariness into desire, guide students to form more rigorous and meticulous logical thinking while teaching mathematical knowledge and ideas, to exercise independent thinking, to apply the knowledge and theory flexibly, to enhance the ability to use the knowledge to analyze and deal with the actual problems, to enhance their self-confidence, to cultivate the teamwork spirit and the sense of collective honour.

Although many documents have affirmed the effect of PBL teaching model in higher mathematics teaching, there are many problems and many challenges, such as the students need more energy and time to find information and complete the PPT presentation, which may affect the teaching progress, and more professional knowledge of teachers is required, some students' self-learning ability is limited, some students like the traditional teaching mode. These problems will be further explored.

In this paper, we will carry out research and practice on the reform of PBL teaching model in basic mathematics courses and through the implementation of the PBL teaching model, students can not only have a solid foundation of mathematical theory, but also have corresponding skills in technical application, exercise and develop the essential competencies, expand the autonomous learning space and channels. The purpose is to promote the coordinated development of knowledge, skills and competencies of students. With the corresponding higher mathematics knowledge as the carrier and through the learning of knowledge, the students can accept the logical thinking training imperceptibly and improve the ability of logical reasoning and abstract thinking. To increase the integration of mathematical modelling ideas, improve the application of basic knowledge in real life, such as the combination of mathematical knowledge and computer. To promote the students' ability to grasp the mathematical knowledge, so that they can better improve their rational thinking ability and benefit them in their work and life in the future.

2 Background

Changing the teaching ideas is the premise for doing well the teaching and learning, and the transformation of teaching mode and the choice of teaching contents are the key to teaching reform. For a long time, the basic mathematics courses are based on the traditional classroom teaching mode. Although the means of teaching reform have come out in an endless stream in recent years, the results of these methods are not very obvious. This is mainly because the teachers act as the main body of the teaching process in the traditional classroom teaching. They tend to pay too much attention to the logic and systematises of the strict mathematics, as well as the proof of the theorems, the derivation of the formulas and the exercises of the problem solving. It is little known what kind of practical application of mathematical knowledge is put forward and how to use mathematical knowledge to practical applications. The direct result is that the students' main position, the cultivation of students' creative spirit and creativity are neglected, there students only accept knowledge passively as an "object". So it is very important and urgent to explore a new teaching model to meet the needs of the development and reform of basic mathematics course teaching and to improve the quality of teaching and learning. Therefore, teaching reform and innovation for basic mathematic courses is of practical value and significance.

The introduction of a new teaching method, PBL teaching model, is a good way of teaching reform based on the traditional teaching model. From 2017.08 to 2018.01, the authors had attended a research project of Higher Education and Teaching Method in Aalborg University, Denmark. Through teaching arrangement, we participated in the experience and perception of knowledge construction and project running model under the advocacy of PBL model with problem oriented, student centred and team cooperation. PBL is parallel to traditional classroom learning and can improve the teaching methods of teachers, change the simple form of written examination, give the initiative to students, encourage them to cooperate, use knowledge to find and solve problems. It champions integrating professional knowledge into classroom teaching. Students can find and handle the corresponding contents according to the needs of solving problems. In the form of group assisted research, students' coordination and cooperation ability and social interaction ability are tempered. Otherwise PBL model also improves students' ability of organization and management. Under the guidance of the teachers, the students' ability is gradually exercised and improved to adapt, operate, plan and solve the problem.

3 Research contents

Firstly, the teaching model will be changed from teacher centred into both teacher and student. In the student centred teaching model, students are the main body of information processing, the active constructor of knowledge meaning and connotation and teachers are the organizer and instructor of the classroom teaching, the helper and facilitator of the students. We should pay more attention to the subjective, practical and innovative ability of the students in learning activities, and the meaningful construction of the students in the face of specific situations. The choice of teaching methods should follow the principle of “Teaching has its method, and it is not fixed yet”.

Secondly, in order to cultivate students' mathematical thinking and application ability, we need to explore the application and practice of PBL teaching model in basic mathematics courses and design the teaching process of PBL teaching model in calculus, linear algebra, probability theory and mathematical statistics reasonably. The process includes: (1) Teachers put forward questions, not specific subjects but the real problem in the major or in a certain field; (2) Teachers give students the necessary support and help, including the software and hardware facilities; (3) Cooperation, communication and group discussion sublimate the deep understanding of basic knowledge of mathematics, and make students feel the practical application of basic knowledge of mathematics in its major or a specific field; (4) Students present the results publicly and enhance language expression ability and self-confidence through team presentation. The teacher summarizes and explains the discussion and differences of the team, and gives the relevant hints and guidance.

Thirdly, the formative evaluation will be strengthened in our teaching reform. Formative evaluation is to emphasize the evaluation of students' learning behaviour, including the learning objective, the way of learning, the process of learning, the effect of learning and so on. Student's learning behaviour is a continuous process, so the formative evaluation should also be a systematic, continuous and dynamic process. Teachers should be clear about the purpose and significance formative evaluation of learning, especially pay attention to the evaluation of students' development level, organization capability, process cooperation and problem diagnosis.

4 Research questions

Q1: How to change teachers and students’ understanding of teaching and learning.

Q2: How to link PBL with the actual situation of own school students.

5 Research methods

5.1 Interview, questionnaire, and empirical data collection

To design interview outline, including two levels, teachers and students. Teachers involve probation teachers of mathematics, related courses in mathematics, as well as headmaster and dean of teaching and learning in school, etc. Students involve students who are learning and who have learned mathematics. In view of the questionnaire and index of the students, the subjects of investigation are mainly for the students of sophomores, senior and the graduating who are learning and who have learned higher mathematics in the department of science and engineering. On the basis of the application of Higher Mathematics in each major and each school, the PBL teaching experiment is carried out among the students, and the results of the final examination and the learning effect are compared and analyzed.

5.2 Quantitative and qualitative data analysis

Data of this research is mainly about two types: qualitative and quantitative data, they are mutual support mixed. It is to analyze the quantitative characteristics, quantitative relations and quantitative changes of social phenomena. It includes content and statistical analysis method. For example, what problems students have in learning mathematics can be obtained by qualitative analysis, the degree of lack of ability is needed to analyzed quantitatively by statistical analysis method and the specific data are given.

6 The case study

6.1 Methodology

PBL's ideas and methods could be introduced in the reform and innovation of the curriculum teaching design. The implementation of PBL can be carried out in a single course level within a small range, such a part of the traditional time of teaching can be re-planned to be used for the project. Also, it can be implemented in the large scope of several across courses or universities and faculty. This section is to list the different strategies for different levels of – single course level, across course level and universities and faculty level- the implementation of PBL.

6.1.1 PBL implementation in single course

In general, traditional teaching is based on a series of independent courses, and students can get credits through the examination of these courses. The basic teaching activities include classroom teaching, reading and writing alone, homework finished by own, and taking part in written examination individually. In comparison， the activities of PBL teaching and learning in single course include classroom teaching, group work, solving problem together, collaborative research and writing, and specific test. Using PBL in a single course, it involves only one teacher. The reconstruction of the curriculum needs consider

Objective. Clear the teaching goals that you expect to achieve.

Assessment and evaluation. Are the customary methods of assessment applicable to the detection of PBL learning? Is it necessary to improve the weight of the students' project work and the learning process in the assessment? And how?

Learning method. Group work - How many students are in each group? Is the group work free combination of students or assigned by teachers? Topic selection - In a limited framework, do students define a problem by themselves, or teachers choose the problem? If the latter, is it an open question, or a specific question?

Content Selection. In particular, it is necessary to consider what needs to be taught in the classroom, which needs to be inquired and explored by the students themselves. Remember in the process of PBL teaching, the teacher needs to compress the time of teaching, or the students will not have enough time to finish the project.

Student. Students have previous experience in project work or not. What extent do you need to introduce this new method to students? How to introduce?

Teacher. Does the teacher involved in the reform have the knowledge and skills to organize PBL teaching? How to develop related knowledge and skills?

Guidance and supports. How to give students support and guidance in the process of project work?

6.1.2 PBL implementation in across course

Higher demands of reform are required to cross the existing curriculum threshold, and at the same time, the interdisciplinary approach is also needed. Firstly, a group of colleagues who are interested in the reform course and are willing to attend the reform. Many colleges and universities will encounter resistance in this first step. Secondly, colleagues need to develop teamwork spirit, support each other, and carefully design curriculum plans together because this project needs to design the knowledge category of different subjects. The design of interdisciplinary PBL courses needs to be paid attention to

Objective. How to deal with problems involved in interdisciplinary? What is the desired goal of teaching and learning? In this case, more abstract goals are usually set, and the aim is to prompt and guide students to choose learning methods based on their learning goals, rather than setting a target that has been specifically defined by the using method.

Assessment and evaluation. Are the customary methods of assessment applicable to the detection of PBL learning? Is it necessary to improve the weight of the students' project work and the learning process in the assessment? And how?

Learning method. Group work - How many students are in each group? Is the group work free combination of students or assigned by teachers?

Organization. Across curriculum creates better conditions for students to solve open problems and students will also actively participate in the problems they own build. In such a case, in order to better organize the learning process, it is necessary to set a theme according to the overall goal. Under this framework, students can build a problem more clearly.

Content Selection. In particular, it is necessary to consider the contents and needs that need to be presented in the classroom. The students themselves explore the contents of the discovery. The teaching time must be compressed or the students do not have enough time to carry out the project activities.

Students. Students have previous experience in project work or not. What extent do you need to introduce this new method to students? How to introduce?

Teachers. Does the teacher involved in the reform have the knowledge and skills to organize PBL teaching? How to develop related knowledge and skills?

Guidance and supports. How to give students support and guidance in the process of project work?

6.2 PBL teaching design

Calculus is one of the core courses set up by the Ministry of education in non mathematics major in China university. For example, it is an important basic compulsory course for statistics major, and the basis of other mathematics courses such as Mathematical Statistics, which are an important tool for learning the theory of statistics. Calculus is an essential basic knowledge and basic tool for mastering modern scientific knowledge that is the basic course of the subsequent course, such as Social Statistics, Introductory Econometrics, etc. As 1 year and 2 semester course, teaching principle is an understanding in the field of basic knowledge and background for students with certain mathematical foundation, to lay a solid foundation for professional courses further study, to play its unique and irreplaceable role in cultivating high-quality talents in statistics.

Through this course, make students master the basic knowledge, theory and methods of limits, continuity, derivative, integral and differential equation, master a thorough understanding of the basic concepts, theorems, calculation method in calculus. On the one hand, provide students the necessary basic mathematics knowledge and frequently-used mathematic methods for learning subsequent courses to solve practical problems; On the other hand, through every teaching section to cultivate students to have more skilled operation skills, correct and skilled computing skills, mathematical ideas and methods and skills, self-learning ability, spatial imagination ability, generalizations and abstract thinking ability, logical reasoning ability, creative thinking ability, and the ability of using the knowledge to analyze and solve problems, to improve the students' mathematical quality.

6.2.1 In single course

The PBL teaching design in Calculus can be taught in lectures for 11 sessions, 2 times each session, 2 hours each time. This assignment for other three sessions is carried out by group work. First, each student will be selected as a team member (He or she will be decided the team in a week ahead of time), and the team will select the topic teacher put forward by using mathematical methods you learned in these three session – The teacher will help team to select one. In other words, three small projects are done in the form of a group. The topic of three projects are the methods of calculating function limit, how to make a function image, and application of the differential mean value theorem, respectively. During this week, the group members work together to read and write, and discuss the knowledge gained in teaching and reading. Then, each team member will present their results at the presentation session and teacher or other students will give your team comments. The presentation is a team work, so you must learn and collaborate with your team. The project result is more or less 5 pages report. This small project report needs to be delivered within 5 days after the former lecture. The assessment of the students is based on the group. In the assessment, the students are required to oral defence on the written materials they have submitted. On the basis of reports and oral defence, each student is scored individually, with a full score of 10 (3 projects, full score of 10 each project, accounting for 30% of the final exam results).

In this teaching design, cognitive and collaborative learning will be strengthened as a result of comprehensive group learning, participant oriented problem building and cooperative writing. In addition, students actively choose, discuss, and integrate the knowledge gained in teaching to solve specific problems. The process of small projects jointly completed by the group provides a good platform for students to discuss. In this process, the team will decide what kinds of mathematical methods you will use, and strategize the analysis process including analyzing, derivation, calculating and interpreting. This is difficult to achieve in traditional teaching designs that only emphasize personal learning. However, since the small projects only involve in only one course Calculus and have not been closely integrated with the technical and practical courses, it has a limited role in cultivating students' professional identity and does not provide the knowledge of cross discipline. Therefore, it is difficult to find the meaning of learning this course for students.

6.2.2 In across course

This design aims at the undergraduates of statistics in 3rd semester. Before this semester, they have learned some basic courses, such as probablitity theory, linear algebra, and introduction of statistics. They have some experience by social practice and social survey and can use professional software to collectand analyze data. The weakness is inability of defining question and absence of comumunicating effectively. This is across course design, including 3 courses and 1 project. The 3 courses are Calculus, Introductory Econometrics and Social Statistics. The project provides a comprehensive training for statistical data analysis. The students should achieve professional foundation, master practical skill and have comprehensive competence to solve the specific problems. From the overall design of the curriculum system, we integrate into the PBL element, that is, we set up three main courses in one semester: basic compulsory courses-Calculus, professional compulsory course- Introductory Econometrics and professional elective course- Social Statistics, and a statistical data analysis project. The credit ratio is 3.5 : 4 : 4 : 3 and the class time ratio is: 56 : 64 : 64 : 120. In particular, the statistical data analysis project will begin at the beginning of the semester, and the project work, which is different from the domestic university, is not started until the end of the semester. At the beginning of the semester, the teacher team provide for students a series of project proposals to choose and reference, but the student group need to construct their own final selection. The project is around a problem, and the topic can be empirical analysis of the relationship between carbon emission and economic growth in China, empirical study of the population aging and economic growth in China, and analysis of the measurement in urban estate bubble and its influencing factors, *etc.* The student group need to apply integratedly the theoretical knowledge involved in the 3 courses to complete the project. The result is a 50 page project report, which is completed by each team member. Each group will make oral defense by submitting the report in two weeks. The defense committee consists of 2-3 judges (usually the project's supervisor and 3 substitute teachers). The process of evaluation is as follows: firstly, students make a comprehensive statement of the project according to the written report, then explain, discuss about the questions proposed by judges, and reflect on the learning experience of the project. The denfense is about 2-3 hours, depending on the number of member. The defense committee, based on the level of the report, the performance in defense, and the knowledge of the different disciplines involved in the project they master, make a comprehensive evaluation for each group member, and then discusses the potential and something need to be improved with the members after the end of the defense, thus creating further opportunity to reflect and learn.

In this across course of PBL teaching design, the learning of cognition, cooperation and content have been greatly strengthened, because it emphasizes the principle of longer group cooperation, active learning principle, interdisciplinary learning and theory connection practice. Interdisciplinary knowledge makes the problem solving process more close to the complex statistics problems in real life. By combining statistics professional courses with Calculus, students can realize the necessity of considering specific situations, the close connection of technology, humanities and society, which not only improves the students' ability to integrate social and environmental factors, professional identity and sense of responsibility, but also improves students' learning motivation.

6.3 Characteristics and innovation

In combination with the actual situation of undergraduates' learning of basic mathematics courses in own university, the application of PBL teaching model can Innovatively solve the problem of students' weak ability in analyzing and solving problems. Change the former teaching model from theory to homework, and form the starting point of problem based learning. All the learning content is based on the problem. Feedback is adopted to complete the integration of formative assessment and summative assessment. The PBL can help students to improve learning motivation and cultivate professional identity.

6.4 Teaching goal

From 2018 level, we will start the point teaching in some major which have basic mathematics courses, and start the formal teaching in all major which have basic mathematics courses from 2019 level.

After the reform and practice of a series of PBL teaching models based on basic mathematical courses, students are expected to achieve: (1) master the ability to study, analyze and solve problems, and can be fully applied to practical work to solve all kinds of problems in the career and in the society; (2) Enhance communication skills and have good teamwork spirit.

7 Conclusion and perspectives

Teaching and learning is the most fundamental and core problem in pedagogy and also most likely to be despised or misunderstood and recognized. It needs to be understood the relationship between teaching and learning and change teachers and students' understanding of teaching and learning. There are differences for the basic mathematics courses in the theoretical basis, cultural background, and teaching knowledge and class characteristics of different majors in different colleges, which will lead to the difference in the adaptation of the PBL teaching model. Therefore, implementing PBL teaching model should relate to the actual situation. Formative evaluation will be considered to bring timeliness feedback evaluation.

In the next years, a stable teaching team will be formed to carry out the teaching reform and design PBL model for basic mathematics courses in Shanxi University. We will track senior students and students after graduation, carry out quantitative analysis and feedback on teaching model, contents and effects after the implementation of the reform. The improvement of teaching quality and effectiveness of PBL teaching reform will be presented in some research papers.

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Teaching design of PBL principles on college physics in larger scale class

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Abstract

The college physics is an importance basic science course in higher education and is usually taught in larger scale class, but the learning motivation of the students is fairly limited and the learning outcome of students is not satisfactory as expected. The Problem Based Learning (PBL) model has significant effects in stimulating learning initiative, training ability of adaptation, cultivating analytical thinking, guiding to construct knowledge, innovation and deep learning. For the teaching of college physics, teachers should continue to reform, improve and practice teaching in order to meet the needs of social and educational development. On the basis of traditional teaching model, it is a good idea for teaching reform that PBL model is introduced in college physics. In this paper, the questionnaire was conducted to identify the major problem in learning motivation of the students. The negative factors and the positive factors of influencing students' learning situation, including students' learning goals, self-efficacy, learning strategies and perception of science learning values, were investigated to find out the function of motivation in the learning process and 870 samples were collected. The results showed that, the students would like to compete with other students and get attention from the teacher rather than believe in their own ability to perform well in college physics learning, which is a new character to the learning motivations of students in the second-tier universities; performance goal, active learning strategies and science learning value are also mainly functions to motivate learning. The teaching design of college physics was developed with PBL principle to motive students' learning interest, in which the Kolb Cycle and the student-centered learning were considered. The advantages and inadequacies of the teaching design were evaluated. Students can cultivate their habits of scientific thinking and enhance their ability to analyze and solve problems scientifically by implementing the teaching design.

Keywords: PBL teaching model; Teaching reform; Learning motivation; College physics; Larger scale class

Type of contribution: **Research paper.**

1 Introduction

For the college students of science and engineering, fundamental courses are usually arranged in the first four semesters. They are the concrete foundation of all the engineering subjects and rather helpful in training the comprehensive competence. The fundamental science courses are considered as the courses with considerable contents, but they are significant difficulties for students. The college physics is a fundamental science course and taught in the 2nd and 3rd semester, which includes five parts (Shi, 2010): mechanics, thermotics, optics, electromagnetism and modern physics, and so on. Each part involves lots of concepts, theorems and formulas all of which are hard to be understood and applied in the practice.

Due to the expansion of enrollments in China universities, the problems of students-to-faculty ratio and insufficient teaching resources (including experimental equipment and financial supports) emerge. Teaching in the form of larger scale class containing more than one hundred students could well solve the imbalance between students and insufficient teaching resources. However, one should be aware of the following shortages of larger scale class (Hayes, 1997). Firstly, the communications between teacher and every student are reduced. Secondly, some special teaching strategies and activities such as discussions in the form of small group are restricted to implement. Thirdly, it is difficult to administrate the learning process for each student. The learning motivation of the students is fairly limited and the learning outcome of students is not satisfactory as expected. An authentic problem is that the learning outcome has not achieved the expected value. This paper attempts to propose some strategies and suggestions to motivate the learners to learn college physics.

2 Current situation

Many students feel bored and lack of motivation when learning the college physics since they think it is hard to master considerable theories in the textbooks. Some of them even lost the confidence to learn the college physics. Taking college physics as an example, in the light of accumulated teaching experiences, a solid foundation of advanced mathematics should be established before embarking the learning of college physics. Actually, any course beforehand will be serving the subsequent courses. If a solid foundation of advanced mathematics is not established, it is uneasy to learn the college physics well.

In the larger scale class, many students have no desire (or are not brave enough) to give feedback to teachers. Although this is not an exclusive problem for the case of college physics in larger scale class, it is necessary to mention the issue here because, for students, the college physics learning could indirectly influence the learning of the future specialized courses as pointed out earlier. Question and answer (Q&A) hours after lectures have been allocated for the feedback from students to teachers in China universities. Unfortunately, very few students utilize the Q&A hours to reflect the questions encountered in the learning process and further solve these questions with the help of teachers. If insufficient feedbacks from students are collected, the teachers are unclear about the extent that the students master the knowledge in the learning process. Probably, the following points are the reasons why the students have no desire (or are not brave enough) to give feedback.

Firstly, the students who have the strong competence of knowledge acceptance and understanding believe that they can analyze and solve the problems encountered in the learning process. These students seldom utilize the Q&A hours to communicate with teachers unless the complicated question is encountered and they prefer individual learning and are usually defined as top students. However, the communication, collaboration and coordination are, probably, the weakness for these top students.

Secondly, the students who think college physics are difficult and boring are always unwilling to resort to the teachers with questions because they do not know what to ask and how to define questions. These students always have no confidence and always think they are unable to answer any question in college physics. In fact, they have never experienced the sense of achievement if an authentic scientific question is well answered. Therefore, rebuilding a solid foundation would be helpful to wake up the feedback from students to teachers.

Thirdly, some students do have the desire to resort to the teachers with the encountered questions. However, they are not brave enough to communicate with teachers since they always worry about whether the presented question is stupid or even a joke. It is suggested that these students should be encouraged to ask questions no matter the problem is simple or complicated.

3 Research questions

The problem in the teaching design is students learning motivation for college physics of large classes should be triggered, that is, what means can be adopted to improve students' interest in learning.

4 Learning motivation survey

4.1 Questionnaire

The important domains of students' science learning motivation involve students' learning goals (Lee & Brophy, 1996), self-efficacy (Hynd et al., 2000; Lee & Brophy 1996; Nolen & Haladyna 1990), learning strategies (Nolen & Haladyna, 1990) and perception of science learning values (Pintrich & Blumenfeld, 1985; Urdan & Maehr, 1995), and so on. In order to find out the function of motivation for the college physics learning, a questionnaire were designed including the negative factors and the positive factors of influencing students' learning situation.

The factors in the questionnaire were defined in six aspects (Tuan et al., 2005):

(1) Self-efficacy. Students believe in their own ability to perform well in course learning;

(2) Learning strategies. Students can use strategies to construct new knowledge;

(3) Learning value. Students acquire problem-solving competency, experience the inquiry activity and stimulate their own thinking and can perceive important learning value;

(4) Performance goal. Performance goals of student in science learning are to compete with other students and get attention from the teacher;

(5) Achievement goal. Students feel satisfaction for their achievement;

(6) Learning environment. Learning environment stimulation influenced students' motivation in course learning.

The items were constituted using five-point scales: 5 = strongly agree; 4 = agree; 3 = no opinion; 2 = disagree; 1 = strongly disagree. There are 35 topics for the six scales in the questionnaire. We put the questionnaire on website, https://www.wjx.cn/jq/18805207.aspx (in Chinese). Some students, who were third-year or forth-year students and had learned college physics are surveyed. These students came from Xi'an University of Tcechnology, Xi'an Petroleum University, Xi'an University of Science and Technology, Xi'an Polytechnic University and Xi'an University of Architecture and Technology. 870 samples were collected in a week. The questionnaire (in English) and the survey results (in Chinese) can be seen in the APPENDIX I and II in our project report (Nan et al., 2018).

4.2 Results

The survey results were analysed by using the principal component analysis (PCA). PCA is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. It is mostly used as a tool in exploratory data analysis and for making predictive models. It's often used to visualize genetic distance and relatedness between populations. PCA can be done by eigenvalue decomposition of a data covariance (or correlation) matrix or singular value decomposition of a data matrix, usually after mean centering (and normalizing or using Z-scores) the data matrix for each attribute (Abdi & Williams, 2010). The results of a PCA are usually discussed in terms of component scores, sometimes called factor scores and loadings. The common factor variance are shown in Figure 1 for the six aspects. Based on the survey result, the mean, standard deviation and Cronbach alpha reliability coefficient for each scale are calculated and shown in Table 1.

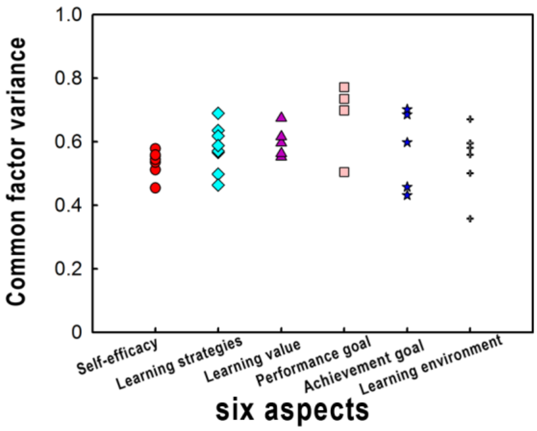

Figure 1: The principal component analysis for each scale.

Table 1: Internal consistency and individual ability for the questionnaire (n = 870).

Scale	Item number	Mean	Standard deviation	Cronbach alpha
Performance goal	4	11.50	4.66	0.784
Achievement goal	5	18.59	5.25	0.781
Self-efficacy	7	19.93	8.27	0.364
Learning strategies	8	31.72	7.66	0.890
Learning environment	6	18.79	6.74	0.818
Learning value	5	17.42	5.69	0.823

In Table 1, Cronbach alpha reliability coefficient for each scale, using an individual student as the unit of analysis, ranged between 0.890 and 0.781 for the performance goal, achievement goal, learning strategies, learning environment and learning value. But it is small for the self-efficacy. The internal consistency of the six scales was estimated by the Cronbach alpha coefficient. It was suggested that this questionnaire was satisfied with for checking the students' learning motivations of college physics in larger scale class.

In Figure 1, the results showed the minimum common factor variance at 0.358 and the maximum at 0.772, which confirmed the six scales designed in the questionnaire. The common factor variance of topics indicate the students would like to compete with other students and get attention from the teacher rather than believe in their own ability to perform well in college physics learning. It is a new character to the learning motivations of students in the second-tier universities.

The analysis results suggested that the student's learning motivation of college physics has been affect by performance goal and learning strategies significantly while by self-efficacy slightly. Performance goal, active learning strategies and science learning value are mainly functions to motivate learning. The learning motivation is a important problem for the teaching study and some research methods and concepts (Mazur, 1997; Hake, 1998; Hernandez et al., 2011) had really inspired us. We will documented and analyzed our survey results in another paper.

4.3 Strategies

Motivation is a prerequisite and co-requisite for the construction of knowledge. In order to enhance student motivation, the full range of motivation strategies should be adopted and utilized. Teachers should try to promote as many positive motivational beliefs as possible. For instance, teachers should use novel experiences and fantasy to arouse students' curiosity, give students a moderate difficulty tasks for regularly experiencing success, allow students to be active participants in the lesson, allow students to work individually or collaboratively, provide assessment feedback and rewards and be supportive, reassuring, and attentive to the students.

Research suggests that, during the crucial middle school and high school years, there is a strong downturn in student motivation during middle school (Anderman & Maehr, 1994), particularly in science (Butler, 1999; Tobin, Tippins, & Gallard, 1994). But in universities, some students may still be motivated even if teachers do not utilize any strategies. Such students may already have high individual interest or welldeveloped learning goals. In order to optimize the motivation of all students, there is a range of motivation strategies that could be integrated into classrooms. The following section will give examine some models of constructivist-informed teaching and will determine the extent to which these types of strategies have been included in them.

5 The case study

5.1 Methodology

Based on the above analysis, all evidence shows that student-centered teaching and learning can improve the students' motivation most (Marra et al., 2014; De Graaf & Kolmos, 2003). PBL (Kolmos, 1996; Kolmos & De Graaff, 2014) and conceiving, design, implementation and operation (CDIO) (Dutson et al., 1997; Zha, 2008) are popular teaching models which are the student-centered teaching and learning. Kolb (Kolb, 1995) believed that one cannot conduct both variables on a single axis at the same time (e.g. thinking and feeling) and proposed Kolb's learning styles (McLeod, 2013). Each learning style is a combination of two behaviors, one of which is from every continuum. The matrix in Table 2 showed Kolb's terminology for the four learning styles. Assimilating learning style and converging learning style are very important for the science and engineering students and thinking is the vital for the college physics learning based on watching and doing.

Table 2: Kolb's learning styles (McLeod, 2013).

	Active Experimentation (AE)	Reflective Observation(RO)
Concrete Experience (CE)	Accommodating	Diverging
Abstract Conceptualization (AC)	Converging	Assimilating

PBL, a systematic project, whose core is student-centered teaching and learning, concerns the four learning styles in the Kolb' cycle and is able to facilitate the effective learning. Based on the theory of constructive alignment theory (Biggs, 1996), the systematic project includes teaching designs of teaching objectives, teaching expectations, teaching environment, teaching resources, teaching activities, teaching methods by multi-dimension and multi-angle.

5.2 Teaching design

The college physics is a fundamental science course and the student numbers are about between 90 and 120 in a larger scale class. We adopted the PBL for epistemological competence model. The teaching design would be made up of lectures which consume 2/3 teaching time, problems for every chapter and a mini project. The teaching design of PBL principles on college physics in larger scale class lies in the following aspects:

Content: Teaching content should be designed under the frame of Kolb's theory. According to analysis of Kolb's learning styles, for the college physics teaching in larger scale class, thinking would be paid more attention to than watching and doing.

Preview: During the learning process, individual learning, peer learning and group learning are the main Teaching Learning Activities (TLAs) in student-centered teaching and learning.

Experience: The relevant phenomena or activities what students have experienced should be introduced to students to arise their concrete experience, for example, by real experience or by visual aid. The concrete experience could motivate the students want to ask how, what and why.

Discussion: When some results could not reach consensus, teachers can conduct group discussion for students. There are some other TLAs related to assessment.

Flipped class: In the teaching and learning process, the flipped class would be adopted. Some lecture would be given by students themselves.

Problem and mini project: The problem and mini project would be introduced for the whole student in larger scale class, which would have certain result since the Intended Learning Outcomes (ILOs) is to help students grasp the basic knowledge. Students can be motivated by introducing and solving the problems and mini project. And by problem solving and project finished, students can learn more by individual, peer, group and intergroup learning.

Abstract conceptualization: Some new methods or theories would be introduced to solve the problem. The phenomena or movements are explained with the help of the existed knowledge and the new introduced methods. Students have constructed their new knowledge based on their existed knowledge.

Assessment: According to ILOs and TLAs, both the summative assessment and the formative assessment would be used in this teaching design. Usually the formative assessment could help students learn more. To motivate students' learning, assessment for learning should be adopted in the process of TLAs of student-centered teaching and learning. But the assessment of learning cannot be discarded.

5.3 Evaluation

The evaluation principles of teaching design achievements include the teaching design integrity, normativity, feasibility, innovation and resource support. The formative evaluation of teaching design results usually includes six stages: self-evaluation, expert evaluation, one-on-one evaluation, group evaluation, field test and on-going evaluation. Using scientific evaluation theory system (Fletcher, 2000), we have developed a set of evaluation mechanism. Teaching evaluation diagram shown in Figure 2.

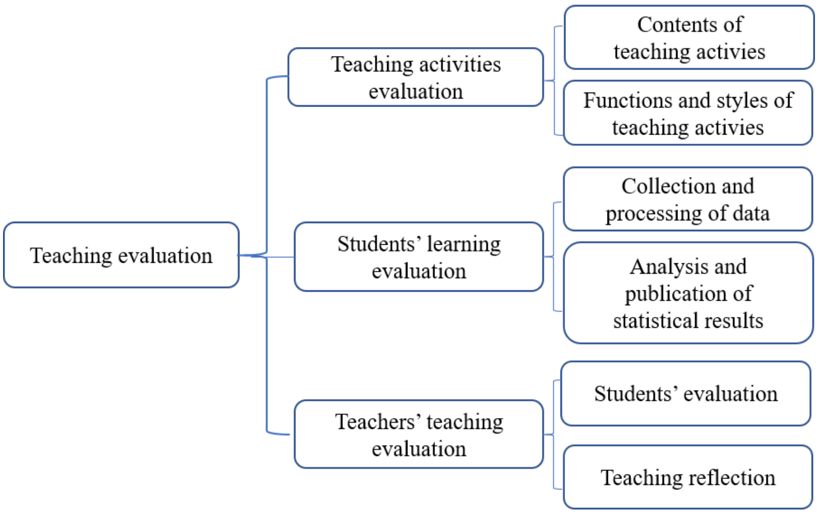

Figure 2: Diagram of teaching evaluation.

For the PBL teaching implementation and evaluation of college physics in large classes, the design of the teaching model has the following characteristics:

(1) Student-centered in the teaching activities;

(2) Define and express class goals clearly;

(3) Key and difficult points in teaching are strengthened;

(4) The evaluation for students' academic.

There are still some inadequacies in the design teaching activities, implementation and teaching evaluation of teaching design: Because the college physics is abstract, how to choose an appropriate and useful contextual example is quite a difficult problem in teaching design. There is no individualized instruction for students in the teaching design to the large numbers of students in the class.

6 Discussion

The previous teaching reform stressed on too much how wonderful and how complete the presentation is. These reforms ignored that the students have the potentials to construct knowledge by themselves and should participate in the teaching activities. The teaching design and assess should be focused on the student-centered. The roles of a university teacher are the guider, facilitator and co-operator in teaching activities. Teachers need to provide students with appropriate learning environment. The whole teaching should encourage students to participate in the teaching activities, so as to nurture students to develop certain high-level abilities like analytical, problem-solving and communication skills (Shiu-sing, 2005).

In the previous guidance of curriculum-centered and the feature of the large class, teachers only need to complete the teaching task in accordance with the requirements of the syllabus. This teaching design is completed by the front-line teachers of college physics with an average of 5 years of rich teaching experience. The team members used the analytical tools such as brainstorming and problem tree to raise questions, analyze the problems by discussing together, and confirm the problems through questionnaires and surveys with the students and teachers. According to the teaching situations and the characteristics of educational objects, teacher can determine reasonable teaching objectives, and then select the appropriate teaching methods and effective teaching strategies. At the same time, teacher can create a good teaching environment and carry out a set of evaluation schemes to ensure the smooth progress of teaching activities.

The teaching problems of large classes lie in their large numbers of students (Gibbs & Jenkins, 1992) and the formulates and theories are relatively boring and difficult to learn. Different from professional courses, the content structure of college physics is basic and simple, but it does not directly link with the real application, which will lead to some students' poor interests in learning (Prince & Felder, 2006). In this teaching design, some teaching forms of PBL are conducive to changing the shortcomings of the traditional teaching. For example, in motivating students to learn college physics, the teacher breaks down the total teaching goals into unit-based teaching objectives and more specific enabling goals, and then formulates strategies according to each specific goal. Through application of teaching design, students can cultivate their habits of scientific thinking and enhance their ability to analyze and solve problems scientifically.

7 Conclusion and suggestions

This teaching design adopted the principle of combining theory with practice. The teaching concepts was student-centered and create appropriate teaching activities to trigger students' learning motivation, which was conformed to the theory of constructivism and Kolb's cognitive theory. The proposed problem of the teaching design was built on the questionnaires and surveys with the students and teachers and solved in the teaching design. In the teaching design, the teaching activities are based on the level of students' intelligence, students' psychological and physiological characteristics and the teachers should summarize their teaching experience, pay more attention to discover new teaching and learning problems, and put forward new ideas and new methods to solve the problems.

During the process of teaching design execution, the teacher may encounter some challenges coming from their students, their college's institutions and even teachers themselves. For the new teaching design, students might be unwilling to participate and interact with teacher. Students may more accustomed to construct knowledge by teacher and do not want to discuss with their classmates. Without sufficient support, teachers could not finish the expected teaching goals. In summary, when teachers faced the above challenges during the process of implementation teaching design, our suggestions are that teachers should have enough confidence firstly, actively find ways to explain and exchange ideas to support. At the same time, the teaching design need to be improved yet.

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Learning through experience in engineering teaching

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Abstract

This paper presents the authors' best practice in learning through experience. The idea of this direction in education was introduced at the Faculty of Machines and Transport (FMT), Poznan University of Technology, Poland, several years ago. It started as a short educational innovation project. The aim was to improve the quality of students' knowledge and relations with the industry. Moreover, international teams have been invited to the project. As a result "International Summer School of solving technical problems in mechanics, material sciences and transportation" was created. The participants were students from different countries, employees of companies and teaching staff from the university. Its success was an inspiration to go one step further, i.e. to improve the quality of the educational program at the FMT. Taking into consideration the increasing role of engineers in the society, in times of oposing needs for resources and preserving the natural environment, a change in the education paradigm was expected. The new specialization, opened for students from different countries, was opened. The international cooperation is its main force and wide range of students' experiences, as well. At master level, the students get an opportunity to develop knowledge and skills in the field of life cycle-oriented technical objects design and management, with a strong quality approach. Overview of past activities and experiences from the introduction of international workshops and the new specialization in education process at FMT are presented in the paper.

Keywords: Experiential Learning Model, Annual Workshop, International Specialization

Type of contribution: best practice paper

1 Introduction

Learning through experience has a special meaning in engineering education. A great number of courses delivered at technical universities have a practical character. This situation can also be observed at the Faculty of Machines and Transport, Poznan University of Technology, Poland.

Today, within the FMT one can distinguish between Institute of Machines and Motor Vehicles, Institute of Internal Combustion Engines and Transportation, Chair of Thermal Engineering, Chair of Basics of Machine Design and Chair of Virtual Engineering. This structure is reflected in research and educational activities.

One of the FMT's main pillars, except for teaching and research, is the cooperation with companies. The role of the university is to solve practical problems using the knowledge and experience of both sides. The lecturers share this practice with students. It strengthens the methodological background, makes lectures more interesting and invites students to participate actively. This part of teaching is very important for companies, as well. Their expectations regarding future employees are clearly defined. Knowledge, experience and the ability to solve problems in a creative way play a very important role.

The aim of this paper is to present shortly the path of engineering teaching at the FMT, its current state and future directions. The authors would also like to present two cases pertaining to their experience regarding annual international workshops organized at the FMT, and the specialization which is opening a new area of practical experience. Both initiatives are also a great opportunity to share a novel way of thinking and problem solving.

The paper is composed of four sections. The first one is a short description of the FMT and authors' didactical experience at the faculty. The stress is put on the cooperation with the industry, and students' expectations as beneficiaries of the teaching process.

In the second section, the literature review on learning through experience has been presented. The stress has been put on practical experience at different universities.

Information presented in the third section includes a short description of the university, FMT and the initiatives carried out in teaching and research, leading to the best practice of learning through experience, as well as practical examples.

The last part of the paper is devoted to the conclusions. Strengths and weakness of the FMT's initiatives are presented. A further step of the learning through experience is also described. This part of the paper is extended with the list of references.

2 Methodological Background

The use of practical experience in teaching has become the subject of discussion among many researchers. Some of them agree that this is one of the best ways to develop knowledge (Felicia, 2011). There are also opponents, who show the examples of biases, such as: disregard for negative information, the tendency to use confirmatory evidence, which does not improve the student's judgment of experience (Brehmer, 1980). However, based on the authors' teaching practice in engineering education, it is hard to disagree with the theory "that helps explain how experience is transformed into learning and reliable knowledge" (Kolb, 2014). This idea is based on Experiential Learning Model (ELM) presented by David A. Kolb in 1984 (Kolb, 1984). It is composed of four main stages, namely: concrete experience, reflective observation, abstract conceptualization and active experimentation. According to this model, learning is the process where knowledge is created on the transformed experience. Thus, starting from a new situation or existing experience, one can reflect on that. It leads to the general conclusions, which are tested in the future situations. Finally, these new situations result in the new experience and the Kolb's cycle goes round.

G. Hills and D. Tedford (Hills & Tedford, 2003) emphasise the role of learning, which is an active process, tested in action. The authors pay attention to motivation in education, which can be seen as a personal benefit or a group success.

S. El-Raghy (El-Raghy, 1999) states that learning by doing and interacting with experts is one of three of the most important quality engineering education skills. The author, as well as M.J.

Riemer (Riemer, 2002), shows the importance of foreign language skills for the practicing, "global" engineer. According to authors the students should speak at least one.

Current studies within engineering teaching show that many universities in different countries, e.g. Poland (Avsec & Szewczyk-Zakrzewska, 2018) or Indonesia (Setiadi & Suparmin, 2018), face the problem of creativity. This is one of the most important factors having an influence on innovative thinking which is highly appreciated by companies. Their role in the engineering teaching process is significant, as well. Creativity is dependent on engineering experiences (Klukken et al., 2013). It also influences the level of motivation. Thus, for many years now, there has been growing number of teaching methods and their variations in engineering education, such as: project methods (Knoll, 1997), active learning (Prince, 2004), case studies (Herreid & Schiller, 2013), microteaching (Herrera et al., 2017) etc. The new methods are tested, and final conclusions and recommendations are given.

Problem-based learning (PBL) was originally designed to respond to the criticism that traditional teaching and learning methods fail to prepare students for solving practical problems. Instead of requiring that students study content knowledge and then practice context-free problems, PBL procedure embeds students' learning processes in real-life problems (Hung et al., 2008). Academics and engineering professionals are more familiar with the concepts of projects in their practice than with the concepts of problem-based learning. Most case based learning strategies use cases as a means for testing one's understanding. A case is presented after the topic is covered in order to help test understanding and support synthesis. In contrast, in PBL, all of the learning arises out of consideration of the problem. From the start, learning is synthesized and organized in the context of a problem (Savery & Duffy, 1995). During the problem solving process, students construct content knowledge and develop problem-solving skills as well as self-directed learning skills while working toward a solution of the problem (Hung et al., 2008).

There are at least two key issues that go to the heart of all of these approaches to learning through problem solving. First, all the approaches emphasize that learners actively construct knowledge in collaborative groups. Second, the roles of the student and teacher are transformed. The teacher is no longer considered the main repository of knowledge; he/she is the facilitator of collaborative learning (Hmelo-Silver, 2004).

Professional problem-solving skills in engineering require the ability to reach a solution using data that is usually incomplete, whilst attempting to satisfy demands from clients, government and the general public that will usually be in conflict with each other, minimising the impacts of any solution on the social and physical environment and doing all of this at the least cost possible (Mills & Treagust, 2003).

Engineers need more than just factual technical knowledge to be successful in an ill-structured and complex environment, so problem-based learning seems well suited to prepare future engineers. Problem-based learning in engineering is a natural fit since it espouses developing students' ability to solve ill-defined problems, increasing critical thinking skills, and broadening their communication skills (Yadav et al., 2011).

As presented in a paper by Williams & Williams (Williams & Williams 1997), PBL and engineering have much in common, e.g.: starting with an identified problem or situation which directs the students' area or context of study, large number of phases or stages of the project, students' need to develop motivation and organisation skills, effective use over a longer time frame, as is usually associated with technology projects. Hence it would appear to be a logical extension of design education in engineering to implement problem-based learning (Mills & Treagust, 2003).

At Polish engineering universities, the growing interest in different teaching methods is also observed, including the above-mentioned and the following: brainstorming, didactic games, simulations, case studies, audio-visual methods (Grabara, 2014) and e-learning (Rosak-Szyrocka & Blaskova, 2016). The didactical offer becomes more interesting for students. It makes higher technical education more competitive and it attracts industry. This situation affects Faculty of Machines and Transport (FMT), Poznan University of Technology, where we always look for new teaching methods. Some of them are presented in the next section.

3 Best Practice on Learning Through Experience at FMT

Poznan University of Technology is located in Poznan, Poland and is one of the oldest universities in the city, established in 1919. Today, there are ten faculties, with some 20 000 students. The former Mechanical Faculty was the basis of the current Faculty of Machines and Transport. The field of FMT's research is always evolving. It is also affects the three core fields of studies: mechanical engineering, transport, and aerospace engineering.

Apart from the growing number of fields of teaching, the number of specializations within mechanics and mechanical engineering is getting wider, too. Today, the following specializations are offered at the FMT:

- within mechanical engineering: aircraft engines, cars and tractors, food industry machines and equipment, internal combustion engines, mass transportation vehicles, mechatronics, thermal engineering, virtual design engineering, and working machines,
- within transport: air transport, ecology in transportation, food transport, pipeline engineering, railroad transport, road transport, and transportation logistics,
- within aerospace engineering: aircraft engines and airplanes, air transport, aviation security and management, piloting of aircraft.

There are four main reasons of the above-mentioned diversity. The first one is students' growing interest of new trends in mechanical engineering and transport, encompassing: ecology, logistics, transportation means, and new mechanical solutions. The second reason are the companies' expectations and needs regarding the students' qualifications as potential employees. The third aspect is connected with the large number of public and private universities in the region, which raises the level of competitiveness. The last important issue is general development of research, technical solutions and new forms of teaching.

To meet all these requirements at the highest level and to make FMT more attractive for students and companies, a variety of activities were devised, including the following initiatives:

- Mechatronics Design Seminar,
- Academic Working Group in Mechanics,
- International Summer School of solving technical problems in mechanics, material sciences and transportation,

– Product Engineering – new specialization within area of mechanical engineering.

The last two of the above mentioned activities are dedicated to Polish and foreign students. These events have the same main goal, i.e. to share experience and to learn through experience.

3.1 International Summer School

The International Summer School (ISS) of solving technical problems in mechanics, material sciences and transportation was initiated 18 years ago. This is an annual workshop, which lasts 5 days. There are usually 30 - 35 students from different universities in Poland and other countries like: Czechia, Portugal, Germany, Hungary, Slovakia, Slovenia. The main objective is to provide the solutions to the real-world problems submited by enterprises.

The ISS is focused on cooperation between students and different companies from Poland. It is a particular mixture of theory and practice, leading towards quality improvement of different areas within those companies. Moreover, students – engineers, defined as future "problem solvers" (Hills & Tedford, 2003), have an opportunity to solve complex problems using their knowledge and working capabilities.

This workshop is organized in the middle of September. The companies represent different branches of industry and service sector. Some of them, such as a producer of household equipment or a producer of precise measurement devices, take part in this exercise since its beginning. The problems they present are always real and up-to-date.

The organization of the workshop starts at the beginning of the calendar year. It is the time when an organizing committee is formed, including students. The invitation letters are prepared, sent to companies and to the scientific committee members. Then the information about the workshop is distributed to students, also in form of posters and leaflets. Participants can visit ISS website with detailed information about the International Summer School, where they can also register.

The workshop itself always starts on a Monday with the students' registration. The participants receive a work package including a detailed schedule of the ISS, technical drawings, companies' promotional materials, description of the problem to solve and other information. After the registration, the opening ceremony begins, including the introductory lecture. Then the representatives of companies present problems to students. Problems are related to the major fields of the workshop, i.e. mechanics, materials engineering and transport.

Students are divided into groups of 3 – 4 persons. Each problem is solved by two teams that compete with each other. This is the time for discussions. Groups of students can of course cooperate each other, but the proposed solutions must be different and unique. It is also possible that one group is working on more than one solution to a problem, indicating advantages and disadvantages of each.

In the following days students visit companies (usually on a Tuesday), learning more about them and their major problems. Students can also consult their ideas with PUT scientists. Not only companies and students are participants of this undertaking. An important role is played by professors, who are supervisors in finding the best solutions to submited problems.

Students can consult their ideas from Tuesday until Thursday. Thursday is also the last day of their work. In the evening they are obliged to deliver a short report to the Organizing Committee. This is a formal document which goes to the companies.

In the last day of the workshop, i.e. Friday, students present the results of their projects. The time for each presentation is limited to 15-20 minutes with 5 minutes for discussion. The number of presenters and the form of presentation is not defined. Each project is judged by a jury, i.e. the representatives of companies and the university. One of the most important features is its objectiveness (Osiecka, 1996). The members of the jury are not directly engaged in projects. After all presentations, the jury meets and notes for each group are given. The marking scheme goes beyond simply marking a presentation. Similarly as in the case presented by T.D. Short, J.A. Garside and E. Appleton (Short et al., 2003) the factors that are taken into account are as follows: creativity (initiative and ideas), effort undertaken, understanding the problem and the level and advancement of project realization. The maximum note a group can receive equals 10 points. The quality of the presentation itself is also marked and the notes are as follows: -1, 0 and 1. All those marks are collected in a form and the final opinion is delivered.

The final notes are presented during the closing ceremony. The most advanced and interesting solutions are rewarded. All students also receive certificates of participation. Now the students have the possibility to discuss freely with representatives of companies about the details of their proposals, and from the other side, representatives of companies have the chance to try to encourage the most distinguished students to join their staff. The closing ceremony finishes the official part of the workshop. All the concluding remarks are taken into account during the organization of the ISS next year.

3.2 New Specialization

The second initiative taken at the FMT is a new specialization – Product Engineering. It was launched more than 5 years ago. The main idea was to open the FMT's door to the students from various sides of the world and share the experience. Thus, this specialization is dedicated not only to Polish, but to foreign students with bachelor degree, as well. Each year, students from different continents, like Europe, Asia, South America and Africa, apply, undergo a recruitment process, and start their master's degree program. The lectures are delivered in English, which plays a significant role for today's engineers facing globalization.

Students of Product Engineering have an opportunity to develop knowledge and skills in the field of life cycle-oriented technical product design and management. It is a chance for them to become a specialist for whom there will be a growing demand in the market - an engineer for fulfilment of future needs of industry and economy. Today, one of the main issues on the market is the "product". It is defined as an item that ideally satisfies a market's wants or needs or is described as a deliverable or set of deliverables that contribute to a business solution. In economics and commerce, products belong to a broader category including mainly goods but also services.

Product Engineering is focused on the area of sustainable environmental management and application of Life Cycle Assessment methodology in relation to technical objects and connected services (Product Engineering, 2018). Some of the delivered lectures are based on the application of problem-based learning. This attitude to lectures strengthens their clarity and makes them more interesting. Students are equipped with theoretical knowledge and practice. An integral part of the specialization is an internship. It is implemented in the companies operating in the area of product engineering. It usually finishes with solving the company's problem, which is a significant part of the students' master thesis. They have also an opportunity to learn more about cultural differences, various points of view and they share their research background and experience.

Product engineering refers mainly to the process of designing and developing a device, assembly, service or a system, so that it can be offered as an item for sale. Product engineering usually entails activity dealing with issues of cost, quality, performance, reliability, serviceability and user features. These product characteristics are generally all sought in the attempt to make the resulting product attractive in its intended market and a successful contributor to the business of the organization that intends to offer the product on that market. It includes design, development and transitioning to manufacturing of the product. The term encompasses developing a concept of the product and a design and development of its mechanical, electronics and software components. In its broadest sense, product engineering comprises of the process of innovating, designing, developing, testing and deploying a product.

Product engineering (PE) is a master cycle course spanning over 930 hours of lectures, desk and laboratory exercises, project sessions and seminars. Most of it is concentrated in the first two semesters, while the third, last semester is devoted mainly to the preparation of students' master theses, where the future product engineer shows that he or she is familiar with all phases of the product development cycle and able to keep up with the latest technologies.

The first semester starts with an introduction to marketing aspects of product management, showing students the complex process of preparing, executing and communicating the value to potential customers. This lecture is also important as an entry point for quality management, stressing the importance of proper customer requirements analysis. Foundations of innovation explain the central role of innovation process in developing new products and services. Two subjects: Ecotechnologies and Ecological Evaluation Tools address the environmental aspect of sustainable development, the latter being conducted as a course to teach theory and practice of Life Cycle Assessment (LCA). Students learn how to provide ecological evaluation using chosen software suites. Computer aided realization of mechanics and flow issues are also performed during various other classes: Programming Languages, Technical Thermodynamics, Strength of Mechanical Constructions and Surface Engineering. The education during the first semester of PE is complemented with analytical mechanics, applied mathematics and a review of the newest achievements in physics.

The second semester introduces Life Cycle Management (LCM), a practical implementation of sustainable development issues on a product level, presenting an integrated concept of product management. Service Engineering extends students' knowledge on how to manage the market outcomes of the 'tertiary sector of industry', nowadays accounting for about 70% of GDP in most developed economies. Ecodesign, Machine Technology, Modern Engineering Materials and Fluid Mechanics are all subjects introduced into the PE program for extending qualifications of students in their major – Mechanics and Mechanical Engineering. Quality Engineering introduces important aspects of products' conformance to customer and/or user requirements, while Intellectual Property and Customer Protection explains the role of legal aspects of product development and manufacturer's responsibilities.

Subjects taught during the last semester of the PE program focus on the implementation of gained knowledge in everyday business practice. Modern Management Systems presents how and why various system-based management frameworks (quality, environment, health & safety) should be introduced and how they contribute to product management. Project Management puts students' expertise of New Product Development process into practice, while Corporate Culture and Communication explains how the information and knowledge disseminate in companies. There is also a complementary course on Life Cycle Costing methodology, useful for students who want to base their thesis on LCM of chosen product. During the third semester vocational lectures can also be chosen. In previous PE editions these covered for example the tribology, fuels and lubricants. Finally, there is the diploma seminar, which helps the master level candidates refine their scientific writing skills.

After four editions of PE (as of summer of 2018) it can be safely assumed that students find the program and courses interesting and useful for their future careers. They don't seem to have major problems with strictly technical subjects (mechanics, design, and thermodynamics) and they seem to grasp the life cycle thinking and its practical approach (LCM, LCA, ecodesign etc.) very well.

Popular diploma topics among PE students include LCA of selected objects for the need of setting ecodesign criteria, use of quality-oriented tools and methodologies for product development and in some cases students' own propositions coming from own interests' or previous education (first cycle studies).

Specializations provided in English are not popular at technical universities in Poland, and Poznan University of Technology is no exception. Introduced as a novelty, Product Engineering at the FMT has an innovative character. The growing interest in this form of studies among students and companies presents one of the future trends in technical education. Moreover, the offered courses are becoming more and more popular among the foreign students coming to Poznan within Erasmus+ program.

What link the initiatives described above is learning through real-world examples, practical experiences and common language. Thanks to these activities students can concentrate on solving problems, improving quality of different areas of the companies involved in the educational process. Graduates with these interdisciplinary qualifications are appreciated in industry.

4 Conclusions

The FMT's initiatives in learning through experience are ongoing. International Summer School of solving technical problems in mechanics, material sciences and transportation, and Product Engineering – a new specialization within mechanical engineering - attract both students and companies. These initiatives are a challenge for the university staff, which is also the base of their success. Thanks to them students can familiarize with practical problems and gain experience. They can also test their creativity and strengthen the motivation for future challenges, i.e. new projects, sometimes bachelor and master thesis, new jobs. Psychological aspects are significant, too. Both initiatives are grounded in communication, usually in English, international cooperation and competence training. They create a chance for students to work for the companies taking part in these events.

The advantages for the companies are also important. They have a chance of finding interesting individuals among the students participating in solving their problems during the workshop or the internships. The solutions are very creative and rational, as well. This close relation with the university is very often a base for future cooperation.

Last but not least, these initiatives are significant for the university. Their success creates a competitive advantage amongst technical universities. The attractiveness of such innovations means that there is a need of such initiatives and that pure theoretical knowledge is not enough in the education process.

However, there are some minor drawbacks, such as:

- short length of the International Summer School, which affects the final solutions to the problems; some of them need more time to be dealt with appropriate precision,
- wide variety of backgrounds of new specialization students, causing some trouble and misunderstandings, at least at the beginning.

The number of benefits significantly exceeds disadvantages. Students, university staff and companies are looking for this type of cooperation, where both theoretical and practical aspects are considered. Learning through experience attracts students, focuses their attention, and strengthens students' creativity and motivation. It also constitutes the future direction of quality improvement of educational program at the FMT.

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PBL in international STEM - Lab teams

Cooperation between Chinese und German students and teachers

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Abstract

Universities educate students for a global labour market and students benefit from international universities to be able to apply successfully worldwide. This paper addresses how problem-based learning (PBL) can be adapted to facilitate international teamwork amongst students.

At the Kaiserslautern University of Applied Sciences, Campus Pirmasens, PBL is combined with project-orientated learning for logistics students in a STEM - Lab. The experiments enclose mathematics, informatics and technology and are carried out by a specific 10 step method. This method offers students the possibility to improve their competencies and to recognise problems in a practice - orientated situation.

With the cooperation of two Chinese universities, Shanghai DianJi University and Changshu Institute of Technology, exchange students are enrolled for a year to become a significant part in the teams of the STEM - Lab. The PBL approach is unusual for the Chinese students, requiring working as a self-organized team, sharing, solving problems and making decisions by contributing independently along with their fellow students. The behavior of the lecturer as a coach is also very unfamiliar.

Since PBL is a western developed concept, it is unknown if the Chinese students, who tend to be calm and reticent, will be able to implement PBL method.

PBL as a learning method has been highlighted significantly; however, it requires further discussion at the international level.

A new adopted concept in the STEM - Lab has been developed and will be introduced in the paper. The students are supervised by an international team of teachers in this STEM - Lab. The PBL approach and the 10-Step-Method are introduced to the Chinese students so that they can understand its philosophy and integrate it in to their own behavior.

Keywords: Problem-based learning, STEM - Lab, international teamwork, learning and teaching transfer

Type of contribution: best practice paper

1 Internationalization at Universities

Universities compete globally for national and international students and are therefore challenged to adapt their research and educational strategies.

In 2012, 47 countries signed on to adopt a mobility strategy for the European Higher Education Area by the year 2020. As a result, universities in Germany developed a joint strategy for university internationalization. Therefore, internationalization is a multidisciplinary task and an important aspect of quality assurance. In order to make universities internationally attractive and competitive, the contents and methods of teaching and studies should be structured accordingly. Intercultural sensitivity is necessary for both teachers and students (KMK, 2013).

In this context, the questions arise as to what extent universities respond in the curricula with regards to the increasing accessibility to international students and to which degree competencies required for the global labor market are anchored in the curricula. Notwithstanding the internationalization of research and education, students increasingly represent a heterogeneous group, which creates both opportunities and challenges for teachers and students. In 2015, foreign students accounted for 11.9% of all students at German universities (DAAD, 2016).

While the discourse on diversity management emphasizes equality and anti-discrimination, the effects of internationalization and its potential implications are less of a topic. Contrary to developments in the USA, Germany often approaches diversity based on gender equality policies developed for women. Since the 1980s, the advancement of women in Germany has been firmly established in institutions. As a result, the term Diversity Management is often coupled with measures tailored toward women (Ehmsen, 2010).

If the intention at universities is internationalization and the strategies and teaching are to be changed, it remains unclear as to what extent these processes will be evaluated and supervised. Moreover, how should the academic success of international students be measured?

The following article is an example of best practice which examines Chinese students working in teams for a STEM - Lab. The students work in internationally diverse teams within the methodology of problem based learning. Feedback from German students and evaluations from teachers led to the realization that Chinese students are not familiar with problem based learning and working with teams. This in turn led to questions as to the depth of research in this area and the necessity for change with accordance to this methodology. The assumption is that revisions will be made with regards to integrating Chinese students in the PBL approach. The paper shows exemplarily how cultural differences, with the focus on PBL, affect teaching and learning methods.

2 Chinese students at the Kaiserslautern University of Applied Sciences

A partnership has existed between Dianji University and the Kaiserslautern University of Applied Sciences since 2004. This partnership was extended to include the Changshu Institute of Technology in 2014. A reciprocal exchange program exists for both students and teachers. Since 2010, students majoring in German studies from China have attended the University in Kaiserslautern at the Campus Pirmasens for a length of one year. These students accounted for

64.5% of the students enrolled in the Technical Logistics program in the winter semester of 2017/18. A steady increase in the number of students and Chinese exchange students can be expected which will continue through the close cooperation between the universities.

Students from China favor Germany for their studies over other countries, such as the US for example, because there are no tuition fees. Germany has become the first choice by reason of a relatively strong international image, low costs of living in comparison with the US and a high level of safety in contrast with most other countries. Moreover, the mentality of the Germans appeals to Chinese students. The time spent abroad is considered pragmatically with an emphasis placed on the benefits for the future career. Since financing is ensured by the parents for the duration of the student’s stay before arrival, it is also of high importance to satisfy them. In other words, the students strive to be successful by fulfilling the required benchmarks (Zeilinger, 2006).

At the Kaiserslautern University of Applied Sciences, Campus Pirmasens, Chinese exchange students attend compulsory modules and modules that are specifically adapted to them to attain the required 40 ECTS points within two semesters. The STEM - Lab is included under the compulsory modules. Faculty decided to include the Chinese students in the STEM - Lab due to the necessary language requirements corresponding to the abilities of the students as well as the chance to expose students to a new learning method. The inclusion of the Chinese students in a STEM - Lab is also substantiated by their generally sound school education in mathematics and the natural sciences. The introduction to mathematics already occurs during preschool. In the 11th grade, the students can choose a concentration in either the natural sciences or the social sciences. Examinations for acceptance at the University level emphasize Mathematics, Chinese and a foreign language (Chen et al, 2010).

3 The Structure of the STEM - Lab

Students of the logistics programs Logistics - Diagnostics and Design (LDD), Chemical- and Pharmaceutical Logistics and Technical Logistics attend the STEM - Lab during their first year of the study. Herein the students are placed into teams and required to complete various experiments within a given deadline. Six experiments are designed from the fields of mathematics, ICT, physics, engineering, and logistics. These experiments are projects which simulate the work performed in companies. Logisticians work under time constraints to find the correct solution to a given problem. The problems defined by the customers, however, are not always the same as those identified by the logistician. Often, students are unable to assess whether the measures decided upon solve the actual problem which leads to wasted time (Wölker et al, 2016). Through the STEM – Lab, diverse teams are trained to deal with this issue.

The STEM - Lab teams, working with problem- and project-based learning, establish a project plan and work is conducted largely independently and autonomously. Each team is responsible for the distribution of work in each experiment, and this distribution builds the basis for the grades. The 7-Step-Method was extended to a 10-Step-Method and specifically adapted for the STEM - Lab as part of a student project which was implemented during the winter semester 2017/18 (Daggett et al, 2017). With the extended method, the team members are able to engage more thoroughly with the problem. Typically, the teams consist of three German-speaking students and one Chinese exchange student. The experiments are completed within a two week period with the 10-Step-Method, which is part of the problem-based learning. During a lecture and under the supervision of the instructor, the students work through the first 6 steps within their teams. Regular, well documented meetings take place and work is conducted under time constraints. Throughout the entirety of the STEM - Lab, students are guided by a professional, interdisciplinary team. This team consists of the professor responsible for the module, a technician, an assistant with a background in the social sciences and a Chinese assistant who is both a logistician and trained in PBL.

4 International Teams in the STEM - Lab

During the winter semester of 2017/18 the STEM - Lab consisted of 18 teams, each comprising of 2 Chinese students and 2 German-speaking students. The instructors assembled the teams according to the following criteria: gender, work experience and education. These criteria were to be represented in each team. The purpose of this combination was to create a balance that can better manage the experiments both theoretically and practically. With the help of the Chinese assistant, an assessment regarding the Chinese students and their competencies could be generated to assist in the suitable formation of teams.

5 PBL Philosophy in the STEM - Lab

PBL is a method that identifies and solves problems in a practical way. This occurs mainly in teams that together recognize, evaluate and solve problems using the 10-Step-Method. In addition to achieving technical competence, the STEM - Lab trains students in teamwork and completing projects. Teamwork means not only presenting one's knowledge and assessment during the analyses and solving of a problem, but also recognizing and learning to solve conflicts within the team. To train competence in writing, an emphasis is placed on the writing of an experiment protocol (Wölker et al, 2017).

The STEM - Lab is based on a self-determined and independent learning process founded on western values. While students from Europe are encouraged to act independently and with confidence, this behavior is not observed in the Chinese students. This raises the question as to whether schools and universities in China characterize these traits as desirable. During their stay at the Kaiserslautern University, the reservation of the Chinese students at times that require active involvement is notable, especially during discussions and problem solving.

Unlike conventional methods used in labs, the teaching and learning method in the STEM - Labs is "student-centered" (Barrow & Tamblyn 1980) and not defined by working through given instructions for corresponding experiments. The self-directed learning process forms the basis of the STEM - Lab: „The student does not listen, observe, write, memorize; instead he is asked to perform, think, get involved, commit himself, and learn by trial and error“(Barrows and Tamblyn 1980). This requires a higher level of competence in areas such as independent research, associative thinking and the ability to change perspective in correlation with the "thinking about thought" at the metacognitive level (Flavell 1979; Daggett et al, 2017).

Presumably, students at school and university in China are taught self-control, discipline and good performance as academic standards. The all-day schooling, which is organized and structured, leaves little room for other experiences with their peers outside of the classroom. This means that discipline and self-control are learned within the group which is reinforced by the teacher, who functions as an authority figure. Learning content is focused on the preparation for exams, which require the recall of fact based knowledge (Guan, 2007). The ability to solve problems is neglected as students' performance is largely assessed through written examinations that are not designed to test the ability to solve practical problems within a team. Chinese students may also lack the creativity for new ideas while solving problems. When Chinese students arrive at Western universities for the first time, they are faced with other learning styles and approaches (Chan, 1999). This makes the behavior of the Chinese students comprehensible and explainable; however, it stands in contradiction to the learned behaviors of western students who have been taught self-reflection and to be individuals with self-confidence. Western teaching and learning styles, especially PBL, are practice-oriented, discursive and require the active participation of students (Guan, 2007).

This philosophy, based on the teachings of Socrates and Plato, encourages students to think critically and inquire (Tavakol/Dennick, 2009). The active learning style of Western students is a process of critical thinking, active learning and making conclusions by way of one's own realizations. However, even if this is a myth or an over- generalization, there could be a need for deeper consideration regarding the internationality of students and the influence of the PBL approach. One might also argue that PBL or small group discussion, in which students collaboratively solve problems and reflect on their experiences, is not culturally suited for Asian students (Tran, 2013).

It is here between these conflicting ideas that the STEM - Lab finds itself, and this must be withstood by both lecturers and learners. For problem and solution oriented thinking, especially during teamwork, there is an opportunity to promote mutual creativity and success. Essentially, diverse teams offer the possibility to work more creatively than homogeneous groups and to find viable solutions together (Klammer/Ganseuer, 2013). The high number of Chinese students at the University of Applied Sciences Kaiserslautern, Campus Pirmasens, has created exactly this dynamic, however in practice it has yet to yield the desired results.

6 Previous experiences with Chinese students in STEM - Lab teams

According to research, PBL is known in China as a learning method for medical studies (Che et al, 2010), while according to the exchange students the philosophy of problem-based learning is unknown and foreign to them. Since the introduction of the STEM - Lab in the winter semester 2012/13, the following statements from German-speaking students have been made repeatedly:

- Chinese students do not participate in team discussions
- Chinese students do not understand the technical language of the experiments
- Explanations in the team are given in English, not in German
- Difficulties during the development of solutions for the experiments are not discursively formulated by the Chinese students
- Restraint among Chinese students affects teamwork
- Equal work percentages, which serve as a basis for the grading, are assigned to all team members of the teams, although the Chinese students contributed less to it

Teamwork during the STEM - Lab was primarily the responsibility of the German students.

Due to a limited knowledge of the German language, the writing that was done by the Chinese students did not meet the expectations and requirements of the lecturer. However, according to feedback, the Chinese students are good at arithmetic. So far, the teams have been able to use this skill. The friendliness and politeness of the Chinese students made a significant contribution in creating a positive team atmosphere. Unfortunately, no statements by Chinese students were made that allow a differentiated assessment.

During the implementation of the 10-Step-Method (Daggett et al, 2017) in the STEM - Lab, the following points become evident:

- Problems are not discussed equally in the team, especially if problems include questions which need to be appropriately formulated (Step 2).
- When the team forms the working hypothesis from a brainstorming session (Step 3), ideas presented to systematically examine the problem are structured and ordered, the Chinese students have limited involvement and the overall process of teamwork is slowed down.
- The formulation of results is limited due to language skills as the assignments go beyond a conventional experimental protocol (numbers, facts) (Step 9).

These assertions are based on subjective statements, but the frequency prompted a rethinking and questioning with regard to the success of PBL and its methods, especially due to the high number of Chinese students in the winter semester of 2017/18. In the following chapter, improvements will be presented in Tables 1 and 2.

7 Improvements to the STEM - Lab

Based on discussions and subjective observations within the LDD program, methodological changes were made without changing the main elements of the STEM - Lab. A focus was put on improving communication and the understanding of social relationships. This procedure was chosen because it made the process of getting acquainted easier before the start of the STEM - Lab. This was directly implemented when the students first arrived as well as in certain modules where international team- and project work was considered. The following changes have been made:

Table 1 Promotion of intercultural competence

Subject	Method	Outcome
Promoting intercultural communication	Lecture by the Chinese assistant on cultural aspects for German-speaking students	Promoting understanding for international students
International Teamwork	Theory and practical exercises in the module Teamwork and Conflict Management for German-speaking students	Learn to understand particularities of international behavior
Arriving at University	Getting acquainted at the beginning of the semester; communication, non-verbal games, informal meeting and establishing contact for Chinese and German-speaking students	Stress-free pre-semester contact

International Projects	Theory and practical exercises on international projects in the module Project Management	Understanding and reflecting on international projects

Due to lack of teamwork and a resulting frustration from not achieving successful results for the experiments together, it was necessary to rethink the methodology of teamwork. The need to improve the 10-Step-Method was also recognized. The following steps have been implemented:

Table 2 Restructuring of the STEM - Lab with international teams

Theme	Procedure	Outcome
Improving Teamwork	From the start teams sit at group tables	Communication and work habits are trained, intercultural teamwork is introduced
Improvement of the working methods	Establishment of a weekly Jour-fixe	Familiarization with structured, goal-oriented work
Definition of collective team rules	Establishing and writing down team rules creating a basis for team coaching in the case of team conflicts	Practicing team commitment and social behavior in international teams
Rules of lecturers	Punctuality, German as the language of lectures	Getting accustomed to a foreign situation, testing the demands of work life
Coaching during the first experiment	Each STEM - Lab LDD team begins the first experiment with the 10-Step-Method under the observation of a coach	Learning to debate, adhering to the 10-Step-Method, working in an international team
Improvement to the 10-Step-Method	Lecturer visualizes the first 6 Steps with time specifications and teams work together to complete them, strict adherence to the 10-Step-Method	Learning to work under time constraints, language support through visualization, practicing a method
Evaluating the competences of all students	Filling out an English and German competence questionnaire at the beginning and end of the semester	Awareness of the competence profile and gaining competence in the STEM - Lab

Due to the formation of the teams from the very beginning of the STEM - Lab, there was no segmentation of the Chinese and German-speaking students. The visualization of the 10-Step-Method allowed Chinese students a better understanding to facilitate a linguistic comprehension. The competences of the Chinese students to observe and follow rules and to achieve learning success through practice could be used for further development of the 10-Step-Method, which requires strict adherence. The learning that occurs through the repetition of structured process also proved to be advantageous.

As part of the further development of the STEM - Lab, the STEM teams worked closely together with the teaching staff. The cooperation of a Chinese assistant trained in PBL within the LDD program, was shown to be beneficial. In addition to this work, she is an important resource and acts as a mediator in reaching the Chinese students.

8 Survey of the Chinese students

As little is known about opinions and acceptance regarding teamwork and PBL from the Chinese students, a questionnaire addressing these topics was developed and 32 students in total were interviewed. The German and Chinese assistants were present and each of the students completed the questionnaire individually and anonymously. The answers could be given in German or English and students made use of both. Open questions were used as a qualitative survey and were answered in a differentiated manner.

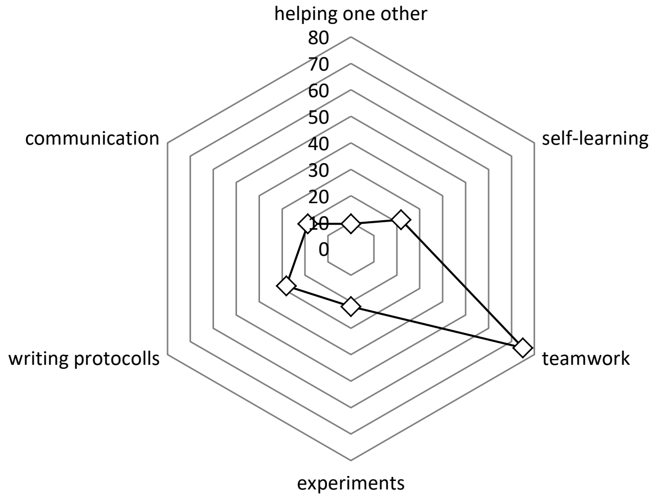

Figure 1: Unknown and new to Chinese students in STEM - Lab

When asked about their knowledge of teamwork, Chinese students mentioned that they had never worked in a team. As to how they felt about teamwork, the answers differed widely. Responses ranged from “very positive”, “valuable”, to “a discussion occurred”

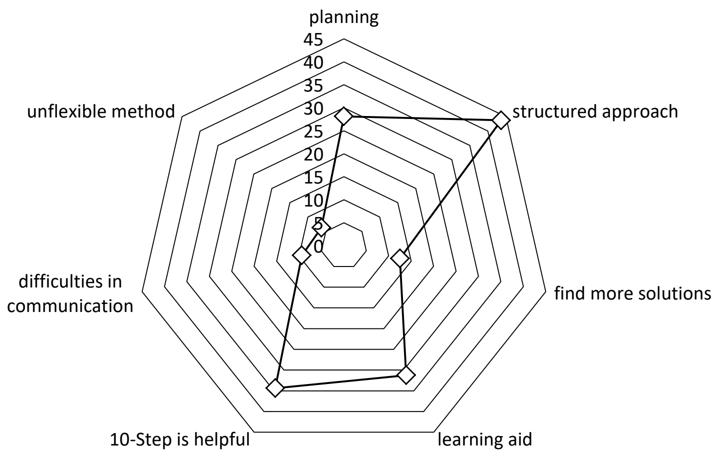

Figure 2: View of PBL and 10-Step-Method

The assessment regarding PBL and the 10-Step-Method was differentiated. The positive stance towards the method is clear. The benefits of PBL and the method used gave students a structured way of working and supported a better understanding of the problem at hand.

8 Conclusion

"The student does not play much of a role in China", according to a quote from a Chinese student's questionnaire. Teamwork was a new experience in the STEM - Lab. The success through the restructuring of the teams is that they became more satisfied working together. Surveys of the teams show that the Chinese students are more involved in the preparation of the experiments which enhances communication and leads to a sense of accomplishment.

Chinese students are well equipped to work under pressure and the structured approach of the 10-Step-Method is not difficult for them, because they are familiar with such work. When asked what the students thought about the 10-Step-Method and problem-based learning, students answered that they could plan better and that it promoted thinking clearly. Also, students claimed that through the 10-Step-Method they learned to understand the experiment. One student noted that with PBL they were able to find the solution to a problem independent of the teachers, and with use of the 10-Step-Method the experiment was better understood.

Friendships that are created through teamwork facilitate integration into the German society. The language skills of Chinese students improve, and international contacts are established between students that have the potential to continue beyond the STEM - Lab.

Intercultural competences and the close examination of problem-based learning by teachers in an international context have a positive effect on teaching and learning. This is a prerequisite of the further development of PBL with a focus put on internationality. An international team of teachers encourages research and constructive dialogues.

PBL in international teams can work successfully if communication occurs before teamwork begins. The constant support of a team of teachers is possible which means transferability to other models is also possible. Within the framework of research based learning, intensive case studies with the approach of problem based learning are currently being developed.

9 Recommendations

Teaching and learning with international teams call for additional review. The chosen approach of “learning by doing” is time - consuming and often only after a reflected consideration can a change be implemented. PBL is a cogent approach for preparing the students for a global market; however the following aspects require further evaluation:

- Further research on the impact of internationalization in PBL
- An interdisciplinary and internationally composed team of lecturers is recommended
- Influencing the positive development of international teamwork through direct oversight
- Creating social learning and communication opportunities
- Encourage discussions with teachers and students about which competence profile of students with different cultural backgrounds can be utilized
- More empirical research on internationality and PBL
- Further training of teachers in intercultural competences

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The International Young Physicists' Tournament Incorporated with PBL Elements in Chinese Higher Education

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Abstract

The committee of the International Young Physicists' Tournament (IYPT) release the open problems every year, which need contestants to solve by group work. Students present their solutions and discuss their solutions with other teams. Finally, reporter, opponent and reviewer are graded by a jury consisting of international experts for the international stage. Before the international stage, there are different level, such as campus, province and national level. This tournament has the apparent feature of Problem/Project Based Learning (PBL) elements, including the open problems, team work, supervisor, student-centred teaching and learning, presentation, discussion, instant feedback, summative and formative assessment. This paper would introduce Aalborg University (AAU) PBL model into the organization and implementation of different level IYPT in order to achieve a better performance in the series competitions. When PBL elements are considered, the contract for project used in AAU model, which has a significant meaning for the final project, would be suggested for the contestants groups. After every stage competition, process analysis would also be suggested for students to provide to analyse the reason of success and failure for their project or problems. At the same time, a main difference between the AAU model and the IYPT PBL model, which is the number of the problem and project, would be addressed. When PBL elements are introduced to IYPT, the communication skills, the collaborative abilities, the discussion and the presentation skills of students would be improved. It would benefit the students for their employment after their graduation.

Keywords: the International Young Physicist' Tournament (IYPT), Problem/Project Based Learning (PBL), Aalborg University (AAU), contract, process analysis

Type of contribution: best practice paper.

1 Introduction

International Young Physicists' Tournament (IYPT) (Plesch et al., 2017) is a world-wide competition for secondary school students. Its former competition, Young Physicists' Tournament, was founded at the Physics Faculty of Moscow State University in 1979. It became an international competition from 1988 and took place only in Russia until 1993. Since 1994, it takes place in different countries every year. The organization form of IYPT and the problems released by IYPT are adopted by the Chinese college physics competition in recent years, named as China Undergraduate Physics Tournament (CUPT).

In IYPT or CUPT (for convenience, IYPT would be used only), every five students form a group on their own will and work together to solve the open problems released by the IYPT committee before contests at almost one year ago. Discussions and presentations take place between groups at different competition levels. Supervisors give the students comments and suggestions according to their daily work and competition behavior. Besides, IPYT can help students to develop the communication, collaboration, management and creation abilities during their team work (Marra et al., 2014). For more information about IYPT, readers could find related introductions and discussions in (Vanovskiy, 2014) and (Hömöstrei & Beregi, 2015). Allinson (Allinson, 2014) discussed IYPT and the inquiry-based science education, which is a constructivist learning environment. Besides, he mentioned Problem/Project Based Learning (PBL) in his paper, which is the first paper mentioned IYPT and PBL at the same time.

Obviously, IYPT has the inherent feature of PBL elements (De Graaf & Kolmos, 2003), including the open problems, team work, supervisor, student-centred teaching and learning, presentation, discussion, instant feedback, summative and formative assessment. Especially, PBL has the instinctive feature of team work and has the teaching achievements (Kolmos & De Graaff, 2014), especially for the skills development, as IYPT does (Nadolny, 2002). Whereas, there is no a contract, as PBL model in Aalborg University (AAU) does (Barge, 2010), to constraint the behavior of the group members and to guarantee the accomplishment of the ongoing competitions. Besides, for IYPT, there is no a process analysis, which provides the detailed explanation about how and why the project/problem has been tackled, whereas, the AAU PBL model has. Hereafter, the process analysis would benefit the students' following projects in AAU PBL model.

Therefore, the application of PBL model in IYPT is proposed and discussed. Especially, the contract for team work and the process analysis for project conducting or problem solving in AAU PBL model are introduced into the daily training of IYPT. The contract would help the contestants to communicate, collaborate and work more easily and more fluently. At the same time, the process analysis would help the contestants and supervisors to figure out the pros and cons of their problem solving.

2 The Connections between IYPT and PBL

2.1 The Brief Description of IYPT

All of the different competition levels of IYPT in China, including the campus, provincial, national level and even the international level, obey the official guidelines for correct behaviors and organizations during the tournament.

The committee of IYPT release the open problems every year, which need contestants to solve by group work before the competition for almost half a year. Every group consists of 5 students. Teams would act as reporter, opponent and reviewer team alternately. Reporter team presents their solutions and discusses their solutions with their opponent team. Finally, reporter, opponent and reviewer teams are graded by a jury consisting of physics experts. There are many skills or dos and don'ts at the presentation stage for the competition. But they would not be the key point in this paper. If students cannot obtain the final solving strategies for the problems by their group work before their presentation, they would have few materials for presentation. Therefore, the key point is how to analyse these problems and solve them.

2.2 What's AAU PBL Model?

AAU PBL model (Du & Kolmos, 2009) is a systematic project, whose core is student-centred teaching and learning. Based on the theory of constructive alignment theory (Biggs, 1996), the systematic project includes teaching designs of teaching objectives, teaching expectations, teaching environment, teaching resources, teaching activities, teaching methods by multi-dimension and multi-angle (Barge, 2010). Especially different with the current curriculum design in our country, the project proposals are based on 3-4 courses of a semester and provided by these courses teachers through discussion in PBL model (Kolmos &

de Graaff, 2014). The proposal might likely be an ill problem without a certain solution and should include at least one curriculum or 2-3 curricula better.

At the beginning of each semester, student groups (5-7 students for one group) choose the topics and their supervisors firstly. The lectures are given by these teachers in their courses, normally in the first two months of the semester. Problems related to courses and their project are discussed in the formed group frequently. Exams follow after these lectures. Afterwards, student groups complete the project by taking advantage of what they have learned in this semester and under the guidance of their supervisors, using all available resources, which could be provided. The students' ability of solving the real problems are trained, and also the ability of communication and cooperation. After the project are finished, the process analysis report and project report are demanded to train their scientific writing ability (Barge, 2010).

At the third semester, students would have grasped the basic operational processes of PBL, which is very similar to the working environment provided by his/her employers in business after their graduation. The employers need little training and the students could take his/her actual work status after their graduation.

Hence, the graduates could be admired by European companies and enterprises (Fink, 2002) and (Spliid, 2016). At the same time, during the process of PBL, the thoughts and motivations of further innovation are provided by open problems released by supervisors. Then, the thoughts and motivations could promote the scientific research and the scientific application in daily life, which could drive the development of the other aspects in turn. All these aspects could contribute to the development of AAU's engineering, which has been ranked at the first in Europe although the young university was established in 1974.

2.3 How to Establish the Connection between IYPT and PBL?

As for the problems or project, the problems in IYPT and the project in AAU PBL model have the same characteristic, which is the open-ended problem. The difference between them is the supported subjects. Problems in IYPT mainly cover the categories in physics and there are 17 comprehensive problems for one competition. Whereas, the project in AAU PBL model should be normally supported by 3-4 courses. Several projects would be released for students in one class, but one group would choose only one project in one semester. It is noted that it's not enough to fulfill the task of the IYPT only by the knowledge and skills learned in physics (Fösel & Mathelitsch, 2017). Although regardless of the presentation skills and strategies, the other aspects, including the model establishment, the supported theory confirmation, the experimentation design, the experimental data processing and expression and the related software usage would cover wide fields. Therefore, the problems in IYPT can be treated as one project for the contestants.

Another important thing is the organization form in daily teaching and learning process. Both of them adopt the group work as the main teaching and learning activities (TLAs), even for the assessment, which is the presentations and discussions in the competition and in the final oral exam, respectively. Hence, it is possible for the teacher and the contestants to adopt PBL model for preparing IYPT.

During the learning process, both the IYPT problems and the PBL project need the fundamental knowledge of related subjects. For the PBL project, students have already learned some basic concepts, theorems, laws and solving methods for the project related to the supported courses. For the IYPT problems, contestants have also learned the basic requirement knowledges and skills in their daily learning process. The same characteristic for solving IYPT problems and finishing PBL project is to learn the related knowledge for the problems and project by students themselves. They can use all the possible means of resources, including library, Internet and consulting the related specialists and their supervisor. That is to say, both the IYPT problems and the PBL project induce students to learn by themselves. It reflects the idea of student-centred learning (Wright, 2011).

For the supervisors, they should help students to think over and fulfill the problems of IYPT and related to their PBL project, respectively. The function of the supervisors is to guide students when students are lost in the decision branches and is to give them advices and suggestions during the implementation of the problem solving and project execution. Therefore, the teachers act as the facilitators during the teaching process. Thus, it reflects the idea of student-centered teaching.

At the same time, both the IYPT problems and PBL project could help students to train their capabilities and skills in communication, collaboration, discussion and presentation.

From the view of the time and space resources, students of completing PBL project have the same curriculum schedule and they also have their group room as their common work, meeting and discussion place. Whereas, for the students of IYPT, if they come from the same class, they would only have the problem of place for team work. Usually, teacher would help them to apply the group room. But if they come from different class or major, the common time for them is a hard nut to crack. They should arrange their time carefully and seek the common time intervals to work together.

According to the analysis above, there are intimate connections between IYPT competition and PBL model, including the research target, teaching and learning organization form, the central idea of teaching and learning, the capabilities and skills training and the limitation of time and space resources. It is possible to adopt PBL model in IYPT training. Whereas, there still exists the improvement possibility for IYPT.

3 The Function of Contract and Process Analysis Introduced from PBL

3.1 The Brief Introduction of Contract and Process Analysis in PBL

The contract in AAU PBL model is set to constraint the team members and their supervisor. It's the behavior guidelines for all team members in one group and is obtained after discussion and agreement by all team members. According to the contract, some group even could kick some one out for his/her usual absence for their group activities in AAU. The agreement on the contract means the burden of the responsibilities. It makes the PBL project as formal as which the students would meet after their graduation.

For the process analysis, it mainly provides the reason of success and failure for themselves, for their supervisor and for the potential readers. Besides, the reason of success and failure should be supported by their daily discussion and meeting records. Hence, it is a reflective process for all team members and it will help them to do better in the next project.

3.2 The Application of Contract and Process Analysis in IYPT

Since there are common characteristics for the solving of IYPT problems and the implementation of PBL project, the contract and process analysis in AAU model could be introduced into IYPT. According to the effect produced in AAU model, the contract and process analysis would help the contestants to burden their research task and to conclude about the gain and lose for the past level competitions.

As for the contract, if contestants have no such experience, they should read some examples to draw up their own contract. But if they have difficulty to accomplish their contract, the supervisor could help and induce them to draw up one. The contract mainly covers the place and time of group meeting, the interval of group meeting, the time arrangement for the whole competition problems, the basic behavior guidelines for collaboration, the means of cooperation for supervisor and contestants and even the kicking out conditions. With the development and deep-going of their cooperation, they can modify the contract according to their requirement. The existence of the contract could help the contestants to cooperate more easily and provide a known common criterion for all participants.

The process analysis would be demanded after their accomplishment of a certain level competition. This is the distinct difference from the requirement of AAU model. In AAU model, the process analysis is demanded before the final presentation of their project. This changing is due to two reasons. One is that IYPT contestants should concentrate on the competition and that there is no relevant checking while competition by the contest committee. The other is that the skills and experiences on the competition are very important for the IYPT contestants and that the process analysis would be more useful for their next competition and the next year contestants if the process analysis could cover related thing on competition.

In brief, supervisors and their contestants could benefit from the introduction of the contract and process analysis of AAU model.

4 Discussions

According to the above analysis, due to the PBL characteristics of IYPT, supervisors and contestants should be easier to conduct PBL model in their preparations of IYPT, even some of them did not know what PBL is. As for the author's experience, before my visiting study at AAU, the cooperation between the contestants and I has already had some distinct PBL features. The obvious feature is team work, which is demanded by the rules of the competition. But if the supervisor could find the relationship between IYPT and PBL model and adopt the PBL principles in their training, PBL model would help them to improve their performance. Especially, the contract makes the contestants more responsible. The process analysis would help the contestants to analyse their mistake and fault in the past level competition. It would help them to notice these aspects and to make the correction.

However, at the beginning of the introduction of contract and process analysis to the IYPT students, they thought that both of them were useless for them and wasted their time. At the same time, they might think both of them are only formalities. But after the usage of them during one round or one level competition, the students think the organization form in virtue of PBL model is much better than the spontaneous organization form for preparing IYPT.

But the supervisor should notice that the introduction of PBL model into IYPT is not the final aim. The core target is to help their students to have the abilities of analyzing problems and solving problems by team work, then to acclimatize themselves to cooperate and communicate with the team members, finally to hope to acquire good score and performance in their competitions and to have the abilities to tackle the new problems in other subjects and daily life later. As for the students, they need to know only some basic knowledge about PBL, but need not to learn much PBL theories as supervisor does. The supervisor should permeate the PBL theories and knowledge in the daily training for competition.

At the same time, the application of PBL model in other related competition is arising. Up till now, the author has adopted PBL model in the students' training of IYPT and the national college students' contest on energy saving and emission reduction. Actually, any contests by the organization form of team work could utilize PBL model for preparing the related competition. But the PBL model is unfit for the individual contest preparing, for example, the Olympic physics contest.

Another important point that should be addressed is the survey to assess the implementation effect. However, it is unfortunate to have only 3 times CUPT, adopted from IYPT as mentioned in Introduction section, in Shaanxi Province of China since 2016. The author took part in the first CUPT of Shaanxi Province as the supervisor in 2016. The author did not know what PBL is in 2016. Till Aug. 2017, the author had the opportunity to visit AAU for half a year to study how to apply PBL in Chinese higher education and lost the chance to tutor students to join CUPT 2017. As the competition should be prepared for almost one year, for example, supervisors and students should start preparing for CUPT 2018 in Sep. or Oct. 2017, the author still lost the chance to tutor students with PBL principles for CUPT 2018. After the author came back to China in Jan. 2018, the only thing that the author could do is to help and suggest students and the other supervisors to manage the competition with PBL principles. Based on the experience, the author is preparing to tutor students for CUPT 2019 with PBL principles. Thus, it is hopeful that the reliable survey could be conducted for the fully PBL planted CUPT after CUPT 2019. That's the reason why the author could not provide a survey to support his statement and only describe and conclude the students' feedback.

5 Conclusions

IYPT has distinct PBL features, especially the team work, which is demanded by the rules of the competition. Based on the discussion of the relationship between IYPT competition and PBL model, including the research target, teaching and learning organization form, the central idea of teaching and learning, the capbilities and skills training and the limitation of time and space resources, the contract and process analysis of AAU PBL model are introduced into the students' training of IYPT. According to the existed practice, the introduction of PBL elements into IYPT could help students to realize and burden the responsibility and to reflect on their behavior in the last competition. By doing this, the PBL elements could help the students to improve their performance.

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Failing to Learn: Practical techniques for using failure as an active learning trigger for science and engineering education (IRSPBL 2018)

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Abstract

In a typical instructor-led hands-on science or engineering experiment session, students begin experimentation only after a preceding lecture on concepts and procedures. This form of instruction eschews the benefits of PBL (Problem-Based Learning) by prescribing the scope of the exploration and presenting the student with an unearned expectation of success. By flipping this process and giving students an opportunity to perform active, hands-on exploration before the "reveal" of applicable concepts, we challenge students to explore the scope of the problem, call upon their prior learning and experiences, and bring to the surface their previously held beliefs and (mis)understandings. In this best-practice paper we discuss the benefits and challenges of a hands-on active-learning method for science and engineering that triggers student self-motivated learning by exposing students to repeated failures as they attempt to solve the presented problem. This method presents even greater benefits (and also challenges) when used in a team-based learning environment. Students in small teams encountering initial and repeated failures are able to develop their team-working skills beyond simple task division and assignment. We will share what we have learned regarding activity design and instructor guidance that creates an environment where the learner maintains a manageable cognitive load during inquiry and avoids learner disengagement.

Keywords: problem-based learning 1, team-based learning 2, active learning 3, inquiry process 4, K-12 science 5

Type of contribution: best practice paper.

1 Introduction

One of the key practical challenges of implementing student-led, inquiry-based learning in science is that students frequently do the “wrong” things or do things in the “wrong” way in the course of their inquiry. While methods have been suggested in the literature on various ways to minimize this “problem” by bounding or guiding the inquiry process, in effect reducing the solution space for the student, less attention has been paid to the value of allowing students to do the “wrong” thing as they explore the solution space on their own. On closer examination, however, it might be argued that it is only when students apply the wrong methods and concepts during their inquiry that the greatest value of the inquiry-based method of learning is realized.

In this paper, we reflect on what goes on during the student's inquiry process and how the mistakes students make during their inquiry are at the very root of what makes inquiry-based learning effective. We will discuss the challenges faced by both students and instructors during the inquiry process and describe some of the things we've done in terms of course design, class preparation and instructor training in order to create a more effective science inquiry.

2 Brief Description of Instructional Setting

Our students range from 1st to 8th grade and classes are grouped according to age levels. We typically have 12 to 18 students per class, split into student teams of 3, with a lead instructor and one or more assistant instructors who help lead small team discussions. Our curriculum covers a range of topics across physical sciences and engineering, but departs from the typical school science curriculum. Instead of separating across Physics, Chemistry, Biology, we take a PBL approach and explore different "topics" in science where students' investigation often spans physics, chemistry and biology. Each topic is explored for a period of 8 weeks (a school quarter) cumulating with a design project. Some topics we have covered includes: flight (physics), microbes (biology, physics), colours (physics, chemistry, biology), materials (chemistry, physics), electricity (physics, chemistry). Each session of our course runs for 3 hours with a roughly 40-40-20 split between hands-on experimentation, analysis & discussion, and lecturing, respectively.

3 The Value of Being Wrong

With the heavy emphasis on standardized testing in most educational settings, it is not surprising that both teacher and students have been led to perceive that the objective of learning is to get to the "right" answer (Tsai *et al.*, 2011). This is particularly problematic when it comes to science education where memorizing lists of isolated scientific "facts" does little to help students recognize science in its natural context (Bell *et al.*, 2010) It might be argued that in developing a deep understanding of core science concepts, it is as important to realize why alternate explanations fail as opposed to just confirming that the explanation in the text succeeds. This is particularly true of physical processes that don't conform to a simple direct causal relationship and often results in students having robust misconceptions (Chi 2005) that are difficult for students to overcome.

With inquiry-based, problem-based learning, we have the opportunity to present science to students in a rich context (Schwab, 1958). But as students undertake inquiry, we also need to empower students by re-framing the standard meaning of wrong or right, good or bad. The inquiry should not be viewed as a process of validating or assessing some existing knowledge, but rather as a process of exploration. This is true for both students and instructors. As the students work through the inquiry, they should expect that, given their incomplete understanding, some (or all) of their predictions might match very poorly with their experimental outcomes. Those outcomes should not be considered "bad" or "wrong" or reflect negatively on the student. Rather, this creates the opportunity for the student to reflect on the knowledge and reasoning that produced the mismatched predictions and create an opening for new ideas (Schmidt, 1983).

Authentic science inquiry is also particularly well adapted to cultivating a better student understanding of the nature of science (Hume *et al.*, 2010), as is the goal of current national science standards. Instead of seeing science as a fixed body of knowledge, students come to realize that the nature of science is one of continuous re-examination of our understanding as new situations are presented (Schwartz *et al.*, 2002). Instead of passively learning about a conceptual nature of science, students experience the nature of science for themselves as they refine their knowledge and understanding through repeated cycles of inquiry and progressively work towards solving their inquiry challenges. They discover that scientific phenomena often exists in a rich context and require critical thinking in order to identify different factors that come into play during experimentation. Just as important as understanding the underlying science concepts, students come to appreciate the process by which humanity's understanding of science is expanded.

Allowing students to move forward with science inquiry based on erroneous ideas is also supported by the constructivist concept of how a students build understanding (Ackermann, 2001). By making use of their existing knowledge and experience during experimentation, students reveal the gaps and flaws in their understanding. This useful for the students to identify where her previous scientific ideas, often formed through previous informal learning, are actually incomplete or incorrect when examined rigorously. The instructor is also able to identify specific student misconceptions of science concepts and give students the opportunity to closely examine these misconceptions and revise them as needed. This is closely related to the idea that passive learning tends to create "inert knowledge" (Whitehead, 1959). In science learning, this is particularly problematic when science concepts taught in class appear to the student as conflicted with their personal experience through informal learning. If these misconceptions are not addressed and resolved, many students tend to view formally learned science concepts as divorced from reality and are only useful for formal assessments (homework & quizzes).

It is also important to make a distinction between science inquiry and the more general problem solving method of "trial and error". During science inquiry, students are encouraged to make "best effort" attempts to explain scientific phenomena, predict likely outcomes, or perform active investigations. At each step, students should put to use any existing knowledge and concepts that they can apply to the situation. In that way, students are "invested" in the inquiry and feel that they have a stake in the outcome. As they progress through the inquiry, they find that their additional learning is allowing them to make progress, either towards their goal or at least in reducing the solution space. With simple trial and error, however, students are not invested in the outcome of each trial. “If it doesn’t work, we’ll just try something else.” This weakens the opportunity for learning and also creates a misconception regarding the nature of science inquiry as just an undirected search. When students become invested in the inquiry, they tap into their own intrinsic motivation to make progress. Instead of passively waiting on each “reveal” from the instructor, they seek for additional information, ideas, or concepts that they feel can be applied to their current challenge. A well structured science inquiry should leverage each failed attempt or misprediction by the students to push them into their zone of proximal learning where their understanding can be extended.

4 The Right Way to Get to Wrong

Creating the right situation during science inquiry where the students are willing to invest themselves into their inquiry poses a number of challenges in the design and flow of the course. Students take a significant emotional risk in order to “failing forward” towards their inquiry goals and a suitable emotional environment must be established both with the student teams and between students and instructors.

We set the expectation up front with students that many of their initial predictions and attempts would fail and that failure would in no way reflect negatively on themselves or their teams. We do this by starting the inquiry before any background science is presented by the instructor. A typical inquiry trigger problem would be to either explain an unexpected scientific phenomenon or to tackle a difficult scientific challenge (Tobias, 1994). Students new to this style of inquiry often feel shocked that they are expected to make predictions and undertake experimentation before the instructor provides a thorough explanation and step-by-step instructions. This is particularly true for students who have previously experienced Level 1 types of confirmation inquiry instruction style (Banchi *et al.*, 2008). By basing their first round of inquiry on only per-existing or even non-existing knowledge, students feel much less pressure on the correctness of their initial predictions and attempts. This is supported by research into productive failures (Kapur 2008, Kapur 2016) where early failed attempts by students can actually, given the right environment, encourage improved retention and transferability of the student’s scientific learning.

Helping students set the right expectation for their inquiry also requires us to set an appropriate lower bound of expectations. We need to encourage students to be deliberate about their inquiry even if they anticipate that their predictions would be wrong or their attempts would fail. We do this by having students make predictions and justifications before starting each iteration of their hands-on experimentation. Typical queries include: “What do you think will happen?”, “Why do you think it will happen that way?”, “What will change this time and why do you think it will have an effect?” Even when we anticipate that students have not achieved an understanding of the science, we encourage them to make a best-effort guess (Bereiter *et al.*, 1985).

“I don’t know why” or “let’s just try it” are not accepted as valid predictions or explanations. Instead, we have the student teams brainstorm based on their previous experience and observations from outside the formal learning context. This is especially effective in a team-based inquiry environment since students need to present arguments to each other within their small teams in order to set their team predictions and justifications. Only after the instructor signs off on a team’s consensus predictions and justifications is the team allowed to begin their hands-on experimentation. In this case, what the instructor needs to determine is that the team is being deliberate in their inquiry. Whether the team’s ideas are scientifically correct is not at issue.

During the actual hands-on experimentation phase of the inquiry, students are required to record their observations. An important part of these observations is to record how their predictions match up to their experiment results. For students new to this type of inquiry learning, we often times observe the tendency to want to “correct” their predictions when they see actual results. At those times, it is important for instructors to not just deter the changing of predictions but to reinforce to the students that wrong predictions should not reflect negatively on either the science inquiry or their own performance.

After each iteration of experimentation, instructors guides each student team to discuss their findings amongst themselves. One objective of this discussion is to evaluate which predictions appear to be born out by observations and which predictions did not match. During this discussion, it is important that mispredictions are not simply dismissed. Instead, students should spend the time to consider the justification for the prediction and attempt to explain the mismatch. Hands-on science inquiry in a small group setting provides ample opportunities to make use of the ICAP framework (Chi *et al.,* 2004) to guide students on a rigorous evaluation of their findings. The instructor should make clear that the purpose of the discussion is not to find fault or assign blame. Rather it gives the student team an opportunity to challenge their earlier justifications and consider whether or not an alternate explanation might be called for. Another challenge for the instructor is that students might mistaken matching predictions as “proof” that their explanations were correct. Students should be encouraged to view concurring results as making their explanations more plausible but at the same time consider alternative explanations.

The class-level discussion following the small-teams discussion is a great time for the instructor to incrementally present more of the ideas and concepts underlying the scientific phenomenon the class is exploring. Students might be given a chance to utilize reading materials to gain additional ideas to use on their next iteration through the inquiry. Alternatively, the instructor may also allow teams to present their findings and explanations, with the instructor providing any necessary assistance in tying different partial explanations into a more cohesive whole. If the instructor sees the need to present ideas or concepts wholly different from that given by students, we have found it more effective to present these new ideas as suggestions or possibilities to the students instead of established “known facts” (Roessingh *et al.*, 2011). This helps to avoid creating an educational “moral hazard” where students anticipate that instructors will eventually present a complete explanation and become disincentivised from venturing their own predictions and justifications.

5 Reflections and Challenges

We have witnessed a very high level of student engagement with this method of science inquiry. Student actively participate during both discussions and hands-on experimentation as they feel much more personally invested in the activities. We have also collected plentiful anecdotal evidence from parents and other teachers that students are taking their science findings and critical thinking habits beyond our science classroom. For instance, we have parents share with us student assignments in composition classes where they routinely write about their experiences doing science inquiry.

But this form of instruction also has its challenges. Students are naturally adverse to being wrong or in failing at a task. We find that this tendency very markedly increases for students in progressively higher grades, very probably due to the reinforcement of years of focus on test results. At the extremes, we sometimes observe behaviour that might be attributable to fear of failure due to cognitive dissonance. Students make predictions or justifications that they themselves strongly doubt in order to avoid making a commitment to the inquiry. But we also find that these tendencies can be effectively mitigated through creating an emotionally safe environment for inquiry.

Another challenge that instructors will face with using this method is the constant need to manage the cognitive load on the students. Having students repeatedly fail on their attempts or repeatedly make wrong predictions generates a significant pressure on the instructor to prematurely reveal the science instead of giving the students a chance to struggle through on their own (Kang, 2008, Seeley, 2009). There is a bit of experience needed on the part of both the instructor and the also the students to find the right balance of constructive struggling. Too early a reveal or too simple a challenge risks diminishing student interest. On the other hand, too much cognitive load risks having students disengage out of frustration.

Allowing students to construct their understanding through repeated iterations through inquiry means allocating significantly more time that a more traditional Level 1 confirmation inquiry. Much of the team-based, problem-based science inquiry process relies on discussions both within the small student teams and with the class collectively But discussions also tend to consume significant amounts of time. It is tempting to truncate discussions due to time pressure, but the student reflection during the discussions is where most of the actual constructive learning is happening. While we strongly believe that this method of learning largely overcomes the “inert knowledge” problem and nurtures a much stronger interest in science, available science assessments are not designed to accurately evaluate these gains.

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Introducing a Low-Cost, Early Engineering Concept among Malaysian Native Pupils using Robotics

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Abstract

This paper presents an innovative project called MySTEMRobotic in introducing early engineering concept using robotics. Biomechanics are the core concepts that the project aims to deliver and robotic serve as a tool of teaching and learning delivery methods. Introducing pupils to cross-discipline science activities, as devoted in MySTEMRobotic project addresses the declining trend in our nation's science, engineer, mathematics and technology workforce. The robotics activities are tailored mainly toward hands-on, minds-on activities and highly manipulative to optimize pupil's ability in designing articulated robotic hands to demonstrate biomechanics concept acquisition. The key is not simply to test for understanding but to examine the science, technology, engineering, and mathematics (STEM) thinking of each participating pupil. The target group of this project is native pupils (Semai tribe) in the age of 7 until 12-year and the school is located in a remote, northern Malaysia peninsular.

Keywords: biomechanics; articulated hands; robotics; Malaysian native pupils

Type of contribution: Best practice paper

1. Introduction

This article reports on a project called MySTEMRobotic to introduce primary-level native pupils on engineering concepts of biomechanics using robotics. In introducing engineering concept via robotics, the literature suggest several manipulative materials such as Lego Block, Lego Mindstorm programmable brick (Martin et al, 2000) and ROBOLAB programming language (Portsmore, 1999). Native pupils are required to design an articulated hand—from ordinary drinking straws and some other basic, cheap and easily available materials. The researchers would like to demonstrate that introducing robotics in a project doesn't necessarily require expensive hi-tech equipment. MySTEMRobotic project uses low cost, everyday item to deliver engineering concept related to biomechanics. The project invites pupils to venture into hands-on, minds-on learning process. Robotics is not necessary came in the form of metal-bodied of square- or barrel-shaped walking trashcan. This project isn't mechanized or electronic, and there are no fancy or expensive materials required. Instead, MySTEMRobotic project guides pupils acquire biomechanics concepts by constructing their own articulated human hand, human feet, birds wing and earthworms out of drinking straw. However, for the purpose of this paper, it will be only the articulated robotic hands that will explain further as a starting point for building those structure and function using ordinary drinking straws. MySTEMRobotic are revolves pupil-centred learning process whereby they need to first determine what kind of articulated robotic hand they want to make and *why*. To initiate the project, pupils were inspired by the following inquiry:

What will be the tasks the hand will do?
In performing those tasks, what is needed?

Answering these questions will help pupils develop a blueprint for the project that will help guide them through development, testing, and refining the articulated robotic hand they constructed. In an articulated robotic hand with multiple joints, the string-based tendons allow bending and refined articulation and movement. This kind of precision and attention to detail—specifically to detail that supports the ultimate goal and function of the robotic part—is key in working on robotics projects. Once pupil created a "hand," they can experiment with many task articulated hands can do, for example pinching, grasping, lifting, and other movements in which multiple fingers work together. By executing this process, the pupils is expected to grasp the biomechanics concept on how the human hands articulated to perform tasks.

2. What is MySTEMRobotic?

MySTEMRobotic is a community-based, local university community program aimed at enhancing Science, Technology, Engineering and Mathematics (STEM) among native (aborigine) primary school pupils. From the statistics of Malaysia general examination for primary schools pupil, it is prevalent that native pupils consistently underperformed other pupils in their achievements. Therefore, this project is dedicated to native pupils with the hope to alleviate their performance in science and mathematics-related subjects.

MySTEMRobotic hails from National Blue Ocean Strategy (NBOS), a government-level initiative that accelerate the sharing of expertise and exchange experience between university (university students) and community (native pupils). MySTEMRobotic is an initiative to innovate the delivery of STEM contents in a way that one fun, exciting, and gamified. The content and focus up MySTEMRobotic program is across discipline and goes beyond school curriculums. Pupils are exposed to activity enriched with the integration of Science, Technology, Engineering, and Mathematics (STEM). The university student acts as facilitators to facilitate native pupils, constructing their articulated robotic hands, encouraging creative and critical thinking skills and inculcate innovative engineering design process. Every two or three native pupils are assigned to a facilitator during the project period of two days.

2.1 Human Hand Anatomy

The human hand has five fingers, each with multiple bones and joints. The three bones in each finger and two bones in each thumb are called phalanges. The phalanges connect to the metacarpals which are the five bones in the palm of the hand. Joints are controlled by muscles and tendons—the muscles pull on the tendons, which pull on the joints and make them bend. The human hand has so many different joints, which makes it very flexible and versatile and easily adaptable to a wide variety of different tasks. However, fingers are special because there are no muscles in the fingers. Instead, the muscles that control fingers are located in the palm and forearm. The muscles move the tendons of the fingers, and it’s the tendons that make fingers move. The tendons slide through a tendon sheath, which is connected to finger bones.

Within MySTEMRobotic Project, the pupils will learn with the facilitation of their university counterpart (facilitator) on how to construct the articulated robotic hands, hone their reasoning skills and grasp the biomechanics concepts along the process of constructing and presenting their articulated robotic hands. Activity-based teaching and learning process as devoted in MySTEMRobotic project is deemed appropriate for native pupils since they are lack of reading skills but well-verse in manipulation skills. Therefore, this project highlight their skills and utilized it to achieve scientific concepts.

3. Syllabus Content Related to Early Engineering Concept

In the Malaysia Primary School Curriculum Standards, the early engineering concept, is started to introduce since Standard 1 (7 years old) in Basic Construction concept. Basic shape such as triangle, square, pyramid, sphere, cuboid, cylinder, prism and cone serve as stimulus for pupils to develop construction model including robot based on paper, pencil and playdoh. During Standard 2 (8 years old), early engineering concept is spelled-out in called Unit 10Technology whereby pupil is provided with Lego-like construction kit to develop scalable model such as helicopter, ship, crane, tree and yatch. In one of the activities, pupils playing their role as Little Engineer that encourage them to create their own unique model. In Standard 3 (9 years old) and Standard 4 (10 years old), the curriculum content is focusing on application of engineering principle in daily life, for example simple machine (lever, pulley, wheel and axle, incline plane, and wedge). In Standard 5 (11 years old), the engineering concept is enhanced through structure sturdiness and stability. Pupil is expected to explore sturdy and strength of an object. In Standard 6 (12 years old), simple machine concept learned during Standard 3 and Standard 4 are extended using complex machine concept. Pupils will complete a simple engineering design project that converge simple and complex machine concept, use of sustainable resources in engineering design and STEM concept.

4. Implemention of MySTEMRobotic Project

The project was design around biomechanics concept whereby the pupils are required to develop and construct robotic functional human hands (palm and fingers). In constructing robotic hands, there are only 3 basic items provided to them which are drinking straw, thread or yarn and cello fan tape. Since the school is located at the remote area, the science teaching and learning facility (e.g. models, laboratory apparatus, figures, charts and etc.) is minimal, broken or poorly maintained. Those three basic items are easily available and we would like to prove that despite the basic items, the pupils should not be left behind and they have all the rights to learn about science and mathematics. Since this is an engineering design process activity, there is no specific formula to follow in building the hand. Designs can be very different, and there is no "right" or "wrong" way to make it. Some designs might be better at performing different functions. MySTEMRobotic project provides pupils with general instruction on how to develop a robotic articulated hads as following:

a) Use scissors to carefully cut a small triangular notch in the middle of a drinking straw. Make sure not cut the whole way through the straw. This notch is the "joint" of the finger.

b) Tie one end of the string through the eye of the needle and carefully puncture the straw with the needle, just above the notch. The puncture should be on the same side of the cut out notch, not on the back side.

c) Push the needle all the way into the straw past the notch and thread it out the bottom of the straw. Hold the straw vertically and shake it, to let the needle fall down.

d) Keep pulling the needle through until about 15 centimeters of string comes out the bottom of the straw. This string will act like a "tendon" that helps the finger bend.

e) Cut the other end of the string, leaving enough extra length to tie off a knot. Please ensure the knot is large enough that it cannot be pulled through the hole punctured. Cut off the string from the eye of the needle. Tie the bottom end of the string to a paper clip.

f) Hold the base of the straw with one hand. Pull on the paper clip with your other hand. This should cause the straw to bend at the notch, similar to a finger bending at a joint.

g) Repeat the above steps to make the rest of the fingers. You can also decide whether each finger has multiple joints or just one. If a finger does have multiple joints, you can use a single string to control all of them (by tying it off above the last joint) or individual strings to control each one (by threading multiple strings through the straw above each joint).

h) Play around and controlling them by pulling on the strings. Adjusting the finger changing the position and orientation of the fingers relative to one another.

i) Now try using your hand to pick up some small objects. Keep in mind that your hand is made of straws so it is not very strong, so you should only use it to pick up lightweight objects (for example, empty plastic bottles, not ones full of liquid).

Throughout the constructing process, pupils are challenge by their facilitator on variety aspect of design manipulative. For example, those inquiry are thrown to them by facilitator to trigger their manipulative skills in engineering design process:

- How to increase the gripping power so that the hand can picked up objects?
- What tasks do you want your hand to manage?
- What kind of hand will enable the completion of those tasks successfully?
- How many fingers would the hand need?
- How big should the hand be to perform those tasks?
- How would the fingers be sized in relation to each other?
- Is your hand better at picking up certain objects than others?
- How to design a hand that is specifically designed to snatch certain objects?
- What changes that can be made with articulated robotic hands to improve the performance?

5. Discussions and Conclusion

For pupils whom are interested in robotics and engineering, creating a robotic and articulated hand can be an exciting venture that blends physiology, anatomy and design as part of the process of building a hand that can perform certain functions. A robot's anatomy doesn't have to mirror human anatomy, however, which is where things get even more creative and interesting. But by better understanding the way a human hand works, how the fingers bend, and how the "wiring" goes, pupils will have a better sense of how to modify or improve upon hand design with a robotic model. The MySTEMRobotic project provides a fundamental design of robotic hand to pupils and they are expected to extend the design based on their own creativity and manipulative skills.

Most of the pupils are able to build a robotic, articulated hand that can pick up light objects, such as ping-pong balls, paper balls, paper sheets, empty plastic bottles or small stuffed animals. To be able to grasp a wider and larger object, pupils arrange extra short straw in between the fingers to increase grasp width.

However, this innovation is not necessarily successful if the surface area of finger is relatively small. During the construction, our standard guideline calls for two straw to be joined together to form a finger. They can always add more two straws to form a finger to increase the surface area of the finger. Another hand tasks that require them to manipulate the design are the ability of the hand to hold object and to transfer the object from one point to another. Both tasks require the finger to possess good ability of grip. To improve finger's grip ability, pupils line the finger with rubber band and as a result, the finger can hold the object longer and able to transfer it from one point to another. These are some of the examples of design innovation that the pupils can come out with. Through robotics in MySTEMRobotic does not involve any mechanical, machine-assisted devices, pupils learn about flexibility that deal with quality of bending easily without breaking, the ability to be modified, or willingness to change or be compromised. Flexibility is important because without flexibility, our fingers, limbs, and other non-bodily related objects such as plastic would incapable of bending.

We use flexibility in out lives today in any and every action. When picking up objects using our hand, one uses flexibility to clutch the object and raise it. Flexibility is applicable to nearly every bodily task preformed. Another important concept is force that defines as strength or energy as an attribute of physical action or movement. Force is important because it helps things to move. When getting up out of a chair, applied force propels your body out of the chair into a standing position and prevents you from falling back into the chair. Force in any form is important because it is the principle that gives objects movement. Within an engineering design process-oriented as devoted in MySTEMRobotic project, the pupils inculcate their and hone their manipulative and creative skills and as results, they innovate the articulated robotic hands according to the tasks that they desire.

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Implementing PBL in Qatar - Civil Engineering students' views on their first experiences from a perspective of constructive alignment

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Abstract

The current study investigated how students in Qatar experienced the transition to PBL and their views on the PBL pedagogy and alternative assessment in a constructively aligned civil engineering design course. Following PBL principles and constructive alignment framework, data were generated and analyzed drawing on classroom observation, interviews with the instructors and 30 students. Findings showed that most of the students reported acceptance of and positive attitudes to the PBL implementation and the group-based assessment, nevertheless group function situation made a difference on students' first experiences of PBL. Several challenges have been identified including their difficulty in seeking for the correct answers, management of time stress, and feeling insecure about grades. The results suggest that while practicing PBL, students held beliefs about learning and assessment associated with the lecture-based curriculum and their prior experiences. The way they interpreted their learning outcomes still followed summative approach to grading. Outcomes of the study suggests that it takes longer time than expected for the students to go through the transformation. To successfully implement PBL for the long-term benefit of student learning, it is essential to provide supporting activities at an initial stage for motivation, needed learning skills and readiness for the transition.

Keywords: PBL for engineering design, constructive alignment, group function, students' views on assessment, Qatar

Type of contribution: research paper

1. Introduction

Project/problem-based learning has been implemented in higher education worldwide for a few decades. Nevertheless, in the Middle Eastern context, although Problem Based Learning has been practiced in a few medical schools, project-based learning (PBL) remains a new phenomenon, in particular, in engineering education. There have been only few engineering schools using it. For example, over the past few years, Australian College of Kuwait has implemented PBL in their engineering curriculum with reported positive experiences from students' points of view (Al Mughrabi & Jaeger, 2017; Jaeger & Adair, 2014). Further educational and research attention is needed on implementing PBL in the Middle Eastern context.

The state of Qatar, in its transformation into a knowledge-producing economy (General Secretariat for Development Planning, 2008), has investigated advancement in the fields of science and technology education (Dagher & BouJaoude, 2011). Being the country's foremost institution for higher education, Qatar University (QU) is the flagship in educational innovation in Qatar. In its strategic plan for 2018–2022, the leadership of QU has initiated "Educational excellence framework of learner- centric, experiential, research-informed, digitally enriched and entrepreneurial education" (QU, 2018, p20). Following this initiative, beginning of 2018, the College of Engineering encouraged instructors to implement PBL within the current curriculum. The second author was one of few instructors who conducted pilot experiments in spring semester 2018.

Research on general university instructional practices in Qatar remains sparse. To develop feasible change strategies for long-term success and sustainable educational innovation, it is necessary to document initial change strategies and practices (Sabah & Du, 2018). Internationally, substantial studies have been reported on the benefits of PBL on student perceptions, motivation and learning outcomes; however, evidence on student beliefs is limited. Previous research has also called for attention for impact of assessment in PBL (Zhao, Zhang & Du, 2018), in particular, from the perspective of constructive alignment (Biggs & Tang, 2011) to examine how PBL activities and assessment methods are designed to support overall learning goals. Therefore, the purpose of this study is to explore engineering students' perceptions and views of learning and assessment at an initial stage of implementing PBL. It also aims to fill in the literature gap by extending the knowledge base of PBL into the Middle Eastern context.

2. Literature review

2.1 PBL and constructivism

The conceptual understanding of Problem or Project Based Learning (PBL) takes its departure from the constructivism paradigm, which is based upon the premise that people construct their own understanding of the world they live in via reflecting on experiences (Jarvis, Holford and Griffin, 1998). Thus, learning is a search for meaning, rather than merely memorizing the "right" answers and repeating others' meanings. Learning takes place as a result of experiencing things in the world through solving problems and generating meanings (Dewey, 1938). Cognitive development is intertwined with other people, tools, symbols and processes through engagement in activities and the construction of interactive understanding (Vygotsky, 1978). Definitions of PBL vary; a recent example is "an instructional learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (Savery, 2015, p.7).

Following constructivism belief, this study is based on four premises of PBL. First, learners come to their first class with prior knowledge and experiences of the world in general and of the skills of knowledge acquisition in particular that may contribute to their learning in the current class (Zhao, Zhang & Du, 2017). Second, students learning is about transforming the experiences of living into knowledge, skills, attitudes and beliefs so that individuals might develop (Jarvis, 2003). Third, learning is a process where people participate in activities in different communities of practice and interpret their experiences as meaningful individually and collectively (Wenger, 1998). Fourth, assessments should be aligned to the overall objectives and the teaching and learning activities support student learning instead of merely examining learning outcome at the end (Biggs & Tang, 2011; Kember, Biggs, & Leung, 2004). Therefore, inside the classroom learners negotiate meanings through interaction with their peers, teachers and subjects in a social-cultural environment. In addition, learners should cooperate and participate in meaningful activities related to the real world outside the classroom for further meaning-seeking. Assessment should be used to support learning and as a learning method (Biggs, 2003).

2.2 Constructive Alignment and role of assessment in PBL

The assessment remains an essential concern when implementing teaching and learning innovation (Biggs, 2003). The framework of constructive alignment (Biggs & Tang, 2011) underlines agreement among intended learning outcomes, assessment methods and learning process. Relating this framework to teaching practices, the principles include: 1) developing learning goals and outcomes including student needs, interests, motivation, and context, 2) organizing teaching activities (e.g. PBL) to reach these goals, including adjusting the curriculum and syllabus to address students' prior experience, using problems that are relevant to students, constructing learning around principal concepts, and appreciating students' perspectives, and 3) linking assessment tools to learning goals and student learning activities (PBL for example). The assessment plays a role of mediation between teaching and learning; therefore, design of assessment methods are crucial for facilitating deep and higher-level learning (Biggs, 2003; Biggs & Tang, 2011). Student-centered instructional strategies and practices require a change of assessment methods. Formative assessment, which refers to assessment methods that are intended to generate feedback on learner performance to improve learning, is often used to facilitate self-regulated learning (Nicol & Macfarlane-Dick, 2006).

2.3 Student learning in PBL in Engineering – benefits and challenges

A substantial number of studies have reported the benefits of implementing PBL in engineering education. Previous research efforts have well-documented the benefits of PBL for engineering students. These benefits include helping students not only to construct subject knowledge meaningfully, but also to develop the profession related skills, such as critical thinking, problem solving, communication, management, and collaboration (Bilgin, Karakuyu, & Ay, 2015; Du, Su, & Liu, 2013; Kolmos, Du, Dahms & Qvist., 2008; Lehmann, Christensen, & Thrane, 2008; Steinemann, 2003).

Nevertheless, several challenges were also identified from previous studies substantiating a need for further research. First, implementing PBL in a previously traditional context requires a significant shift in the roles of both teaching and learning (Du et al, 2016). Therefore, both instructors and students shall be prepared for the transformation, which demands individual understanding, motivation, and positive attitude, and institutional supports (Du, Su & Liu; Kolmos, 2012). Second, implementing PBL generates issues and debates of what assessment methods should be appropriate (Savin-Baden, 2004). Third, even alternative assessment practices may not necessarily ensure optimized learning outcomes due to the complexity of contexts (Segers & Dochy, 2001). Therefore, it is crucial to explore both instructors' and students' views and perceptions of PBL, assessment methods, and achieving learning outcomes.

Previous studies have suggested that the implementation of PBL is not unconditional because students' understanding of the rational can be limited and varied, which may influence the results of the implementation (Du et al. 2016; Prosser & Sze, 2014). In particular, the challenges can be critical in the transition process of changing to PBL from lecture-based methods. Increased research efforts are called for to address students' views on the change to PBL, assessment and collaboration embedded in a collective learning process such as PBL groups (Zhao & Zheng, 2014). The present study aims, therefore, to investigate how students experience the transition to PBL and what are their views of the PBL pedagogy in a constructively aligned engineering course, and what are their views of PBL implementation and assessment. Two research questions guided the current study:

(1) how do engineering students perceive the implementation of PBL from a constructive alignment point of view?
(2) What challenges confronted the students in their first PBL experiences?

3. Research methods

3.1 Research context

PBL was implemented in a third/fourth-year engineering design course in the Civil Engineering Program in College of Engineering, Qatar University during Spring semester Feb-May 2018. Drawing on constructivism theories on learning and assessment, the constructively aligned PBL design included the following course objectives. By end of the course through the engineering design project, students were expected to be able to:

1) work in a team to formulate and provide a solution of a real-life problem;
2) analyze and design three different two-way slab systems;
3) analyze and design slender columns;
4) analyze and design continuous beams;
5) analyze and design isolated footings and combined footings;
6) integrate standards and multiple realistic constraints in design;
7) effectively utilize up-to-date technology in the analysis and design tools for reinforced concrete structures;
8) create a professional report and professionally present work outcomes.

Following the expected outcomes, the course instructor designed the overall theme of the project with a designated real-life problem and provided a list of suggested materials on the course platform via Black Board. The course last 16 weeks consisting of three times 50 minutes contact hours per week. During the contact hours, students worked in groups on the project and the instructor and a teaching assistant served as facilitators walking around groups providing advice and discussion with the students. Guided by the principles of constructive alignment (Biggs & Tang, 2011), alternative assessment methods were designed, changing from 100% individual written exams to a method consisting of 60% group project assessment throughout the semester (divided into three stages of project progression), 15% for individual oral presentation and 25% individual written exam at the end of the semester. Rubrics were provided to students to guide their project from the start.

3.2 Participants

This study has been approved by the ethical review committee (IRB) of Qatar University. All the 33 engineering students who attend an engineering design course were invited to participate in this study. Group interviews were conducted with all the six project groups with the participation of 30 students in total. Individual interviews and informal discussions were taken with the students, instructor and the teaching assistant.

3.3 Research design and data generation methods

A qualitative research was designed for data generation including classroom observation and interviews. First, both participant and non-participant observation data (Punch & Oancea, 2014) were generated throughout the course with field notes to gain understanding of the PBL practice, procedures, instructor-student/student-student interactions. Second, individual interviews with the instructor and the teaching assistant were taken at the beginning, mid-term and end of the course, in addition to weekly informal discussions to follow up the implementation of PBL. Third, group interviews were conducted in the late stage of the course, intending to deeply understand participants' experiences, thoughts and feelings (Creswell, 2013). Each group interview lasted 30-50 minutes. Interview questions included student views on project work, their learning experiences through this project. The questions focused on ways with which their learning experiences through the project have been aligned with the overall objectives and assessment methods, strategies they employed for seeking information and managing projects and group work. In addition, there were reflecting questions inviting students to self-evaluate their projects and group work and to identify challenges and future strategies. The three sources of data were collected and analyzed separately, and later triangulated and integrated at the interpretation stage (Punch & Oancea, 2014).

3.4 Data analysis

An integrated approach was employed for the analysis of qualitative data from observation and interview. This approach encompassed a theory-driven deductive content analysis (Marshall & Rossman, 1999) using the constructive alignment framework (Biggs & Tang, 2011) and a thematic inductive approach to interview transcripts using Kvale and Brinkmann's (2009) meaning condensation method. This was used for identifying emerging themes from students' accounts of their experiences and reflections.

4. Findings

The instructor designed the PBL according to PBL principles and prior experiences from the literature. Following constructive alignment (Biggs & Tang, 2011), the PBL activities were designed in alignment with course objectives. In addition, the instructor made efforts to communicate with students and clarify the alignment between objectives, PBL principles and alternative assessment at the start and along the course.

4.1 How do engineering students perceive the implementation of PBL from a constructive alignment point of view?

All the students have experienced project work in groups but more at the level of assigned tasks occupying 15-25% of the overall grade. For them this was the first time they experienced "real" PBL, and four major aspects of differences were pointed out:

1) Types and scope of the projects: The students searched for a real-life problem to solve based on the learning outcomes that are required to be fulfilled. The project was much longer cross the whole semester,
2) students had to search information for the projects on their own instead of getting correct answers from the instructor,
3) different assessments methods were used involving grade based on group projects (60% of the total), innovative way for assessing the 15% individual presentation through recoding, and individual written final exam that covers all course topics, and
4) due to the project scope and grade portion, it demanded all group member contributions and attendance to finalize a high-quality product, which is the project report. As one student said, "This is the first time we work on this kind of project. It is about different topics, lasts the whole semester and takes up a lot of portion of our final grade, so we all have to contribute as much as we can." (A student from Group 3)

In Groups 2,5, and 6, the majority of the students believed that PBL may be a useful method to help them reach the course objectives and expected outcomes. Except one student from each of Groups 2 and 6, students from the four groups believed that they learned more than what they expected through searching information on their own instead of being given by the course teacher; as they traditionally were used to in the lecture-based experiences. They believed that they had developed a certain level of skills that would be useful for their future profession, such as team work, project management and stress management. These skills, in addition to the independent learning, were regarded as major benefits from learning in PBL. Group 1 and 3 reported relatively positive attitude to PBL in general, though different opinions were reflected. Two students from each of these groups expressed their concerns about the level of subject knowledge they reached through their projects, and two from each group mentioned their insecurity from not knowing the "correctness" of components of their projects. Group 4 was rather diverse in the student opinions. Two students were supportive for PBL due to the learning skills they developed through the projects, and two showed worries about their learning outcomes, and one student preferred lectures to cover all needed subject knowledge instead of working on projects.

All the groups mentioned the development of independent learning and group learning through the group projects. Concerning information sources, they reported using lectures and reading materials provided by the instructor on BlackBoard as a major source and additionally they used information from internet such as YouTube and Google as inspiration.

In general, the group projects enforced sufficient amount of time for students to work together. All the groups meet in person 2-4 times a week outside of class meeting time. In addition, they reported meeting a few hours daily via use of social media such as WhatsApp group as a means to organize group meeting. A variation of students' opinions on group work was identified. Group 2, 5 and 6 reported their high level of appreciation of learning from diversity in the group and their projects helped each one to meet their academic levels and preferences of learning. Group 1 and 3 reported "well-managing" group work and showed variation among students' opinions. Most of them showed awareness that team work skills were important to learn to become an engineer. Around half of each group mentioned their concerns about "fairness" in the group project process, in the aspect that how to ensure equal contribution of each member, and how to ensure each member will learn the same things when they produce a shared project report. While a few students showed confidence that they would handle this situation better within the group in their next experiences. Group 4 reported individually different opinions about working in a group project. Two students worried about their grades through the group project, one showed concerns about different expectations of the project outcomes, one student mentioned the issues of equal contribution, and one student showed different understanding of the project overall objectives.

4.2 How do they perceive the alternative assessment practices?

Although the instructor made efforts on designing alternative assessment method to align with the course objectives and PBL activities, students' opinions on the alternative assessment method were varied. Concerning the current semester, 19 out of the interviewed 30 students (mostly from group 2, 3, 4, 5) agreed that 100% group-based grade would be appropriate. Six students (mostly from Group 1) agreed with the current form of 60% group grade +15% individual presentation+ 25% individual exam. Five students (from Groups 3 and 4) believed that only individual written exam should be used for assessment.

Except a couple of students, most of the students supported to continue with PBL. Concerning ideal assessment method for PBL in the future, the responses were also varied. No agreement was reached on a group base. While most of the students agreed it would be important to include assessment for both group-based projects and individual learning, the suggested portion of group grade varied from 15% to 100%. Around half of the students (mostly from group 2, 5 and 6) supported only assessing group project without the need for individual written exams. Because the project would cover all course objectives and expected outcomes, and individual oral presentation would be sufficient to assess individual learning, as one mentioned

> "Additional learning from the project may not be able to be assessed in many forms within the curriculum, such as team building, searching information, solving real life problems, things we do one day as a real engineer" (a student from Group 2).

4.3 What challenges confronted the students in their first PBL experiences?

A few challenges were mentioned by each group such as issues within the group, understanding the problem of the project, writing a long project report in a team. Among them three issues were addressed in common:

First, correct answers: This was mentioned by all groups as uncertainty derived from working on a project. Although students were informed by the instructor that there may not be the only correct way of designing in the project, more than half of the students talked about their feeling insecure, as one said,

> "we know there may be more than one correct answer, but just not sure what is correct or not when we search for information on our own. Sometimes we need to talk to the professor to confirm what is correct." (a student from Group 4)

Second, time pressure: In all groups, students spent many hours on the projects not only during the course time but also in their spare time. While they were motivated and engaged to the project, they also felt pressure from other courses. As one said,

> "We have three courses, each of them has 4-5 exams… so we have deadlines of submission or quizzes nearly every week, this makes it difficult to focus on the project, although we spend lots of our spare time working on the project". (a student from Group 6)

Third, concern about individual exams: Although more than half of the students supported a combination of both group assessment and individual exams, most of them mentioned their concerns about individual exams because they were uncertain about what to prepare, as one mentioned,

> "Before we had lectures and we knew what to prepare for the individual written exams, this time since we spent most of our semester working on projects, we don't know what to prepare and what will be tested in the final written exam…" (a student from Group 1)

5. Discussion and conclusion

The current study explored engineering students' perception of implementing PBL and their views of learning and assessment in relation to PBL in Qatar. An overall acceptance and positive attitudes of students were reported, nevertheless the study also identified variation of students' experiences which are related to their group function. Around half of the students reported clear understanding of PBL intention and expected outcome and demonstrated their awareness of using PBL principles and constructive alignment principles to guide their learning process and interpreted their learning outcomes accordingly. Nevertheless, students' experiences varied by groups, which means they need support to improve collaborative skills from the beginning in order to maximize their project outcomes.

In addition, less than half of the students reported insecurity of the project outcomes and uncertainty concerning whether their learning outcomes were reaching the expected objectives or not. This may be because they still held beliefs of learning that were related to lecture-based curriculum where the instructor was regarded as authority of the knowledge. This result suggests that implementing PBL may change the practice, but it may take longer time to change learners' beliefs, in particular, when they are in the transition process from traditional lecture-based curriculum to PBL (Segers & Dochy, 2001; Zhao, Zhang and Du, 2018).

Biggs and Tang (2011) emphasized the need to change assessment method to be aligned with the change of pedagogical method and objectives. In this study, the instructor adjusted the assessment method with an intention to align with the PBL methodology and the expected learning outcomes. Nevertheless, a gap between students and the instructor was identified regarding their understanding of assessment. The instructor demonstrated a strong will to implement PBL in an ideal way, while the students' reported diverse ways of understanding and accepting the alternative assessment methods. For their first experience of PBL, the students reported variation of views on assessment, which can be related to the complex factors affecting students' learning outcomes (Birenbaum, 2003). Some students in this study were concerned whether they have had reached all the engineering contents required by the curriculum and more than half of them were concerned about their grades. Two factors may explain this gap. Firstly, students' beliefs about assessment is still influenced by the lecture-based curriculum model and their prior experiences, and secondly, following this, the way they interpret their learning outcomes is still associated with the summative approach to grading. This indicated a mismatch between the intended learning environment as planned by the instructor and the actual learning environment as perceived by the students (Segers & Dochy, 2001). This result echoed what Savin-Baden (2004) summarized from previous studies in that students in PBL feel that their learning is unrewarded, working in groups is undervalued, and they were disempowered by complex assessment methods. A dilemma between constructive alignment and choice of assessment is observed in this study in that constructive alignment is an ideal way to structure curricula; however, it can be challenged by how instructors and learners understand assessment. In order to better balance teaching and learning in relation to assessment, it is crucial to clarify and communicate on the role of assessment for learning and as learning from the start of the PBL implementation (Du, Su, & Liu, 2013). To optimize student learning and effect of PBL, it is essential to consider students' concerns and work together with the students to find out ways that help them understand and value their learning process and outcomes.

Outcomes of the study implicates that it is essential to provide students' readiness for PBL, which involves helping them understand PBL, developing beliefs about learning and assessment related to PBL, and developing a list of needed skills for PBL – communication, collaboration, project and time management, and self-reflection and self-evaluation.

The study has a few limitations. Firstly, the results are limited to the number of students that are enrolled in the PBL class. Secondly the social cultural dynamics of the groups may influence the interview findings. Thirdly, the outcomes are tentative due to the initial stage of the PBL implementation and the first experience for all the participants. It is essential to investigate long-term effects of PBL in the middle eastern context employing multiple sources of information in future studies. Further studies on preparing new students for PBL are highly recommended.

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Integrating Courses and Project Work to Support PBL
- a conceptual design for changing curriculum structure

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Abstract

This paper contributes to the discussion on possibilities of changing an institutional semester structure in a PBL-environment which might open up for new ways of integrating courses and student projects. The structuring of individual courses and semester projects are creating the framework for developing both disciplinary knowledge and PBL competences, but integrating and applying the knowledge from course disciplines into a project seems difficult for both students and teachers. A research project "Future Directions for PBL in a digital age" will therefore experiment with how course and project work can become more integrated, this by developing a flipped semester. A conceptual process design for changing the structure at 4.th semester, Mediology to a flipped semester is outlined and concerns and possibilities of expanding and changing a hole semester structure is discussed.

Keywords: PBL, students projects, semester structure, integration of courses and students project

Type of contribution: Conceptual paper

1 Introduction

Internationally, as well as nationally, problem-solving, collaboration and communication are in demand for the 21th century workforce (Voogt & Roblin, 2012). The problem and project-based learning model at Aalborg University (AAU), internationally known as The Aalborg PBL model, is defined in its PBL principles. The PBL principles educate students to solve problems, engage in collaborative relationships and to communicate with different actors in a globalized labour market. Those competences is also known as some of the PBL competences (Holgaard, Ryberg, Stegager, Stentoft & Thomassen, 2014). The AAU model is known for its structure where a strong emphasis is on learning through students' own projects (Kolmos et al 2004, Birch Andreasen et al 2018). Although the AAU PBL-model is a distinctive feature of AAU, the principles have been challenged in recent years. An increased intake of students, problems with the physical environments, as well as a national regulation and standardization have resulted in a significant part of the teaching being conducted as traditional lectures, and the PBL aspects are slipping into the background (Hüttel & Gnauer 2015). However, it is the intention of the AAU PBL-model that students develop the PBL competences during the team-based project work. (Davidsen & Konnerup, 2016; Barret & More 2011). To maintain and support the learning aspects – especially the students development of PBL competencies through students' project work – it is necessary to have focus and time for students project work (deGraff & Kolmos 2017). Traditionally, a semester is equally divided between courses and project work - both running in parallel during a semester. However, managing the segregated workload connected to different courses, and integrating the knowledge

gained in courses with the project work, can be a challenge for both students and teachers (Triantafyllou et al 2016).
In this paper we will discuss the challenges and possibilities for integrating courses an project work. We are focusing on the structural possibilities for integration of courses and projects by studying a semester curriculum where a change is planned. A general question raised in the paper: Is it possible to make an organizational change of the semester structure to support PBL? As structural changes in curriculum is considered to be fairly comprehensive and of a great influence for the involved course teachers (Clark, 2009) we need to establish a semester planning process in which the teachers experiences are very important and in which the teachers are co-creators of a new semester structure. A very important part of the study is how to create a better integration between courses and project work and we will therefore establish a concept of a planning process for a new semester structure. The main question for the planning process is: *How can the courses be integrated in the semester projects, and how could the semester projects integrate the course elements and at the same time- improve efficiency and quality for the teaching, supervision and students learning process?* These questions will be guiding the planning process by analysing and discussing a 4th semester curriculum that will illustrate how the students have to navigate through coursework and project work through a hole semester. As the foundation for discussing the challenges and possibilities of how to structure a semester that integrates courses and students project work, we will present and analyse the semester structure of the 4.th semester of Medialogy AAU Copenhagen where future structural changes is planned to take place.

2 Background

Since 1974 AAU has developed principles and models for Problem Based Learning and group organized project work (PBL). The AAU-PBL embodies the following principles (Askehave, Linnemann Prehn, Pedersen & Thorsø Pedersen, n.d.):

- The problem is the focal point for the students' learning process.
- The project organization provides the framework for problem-based learning
- Courses support the project work
- Collaboration runs a problem-based project-work
- The problem-based project of the groups has to be exemplary
- The students have responsibility for own learning.

Candidates graduated from AAU has been educated to and has got the competences to solve problems, enter into cooperative relations and communicate with different actors in a globalized labor market (Holgaard, Ryberg, Stegeager, Stentoft & Thomassen, 2014). However it is important to distinguish between two sets of competencies: The profession-specific competencies related to the theoretical and methodical mastery of a profession, and the PBL competencies that relate to analyze a problem position critical to be able to apply theories and methods and come up with a possible understanding and problem solution, and to reorganize the ways of thinking and acting (Holgaard et al.)
The AAU principles for problem-based and project-organized work (Aalborg University, 2015) implies a structure for the educational programs at the university where half of a semester is used on courses and half of a semester on student-led project work (semester projects), though there might be differences about the structure in the different programs. The courses have to support the semester projects in which we find a high emphasis of students working problem-based and project-organized. The learning strategies and

pedagogical ideas of active, social and student-centered learning is for both coursework and project work, but there is a tendency that many courses are taking increasing time from project work (Birch Andreasen et al 2018). Therefore, to sustain the PBL competences, it is necessary to maintain the PBL project-work or even improve the possibilities for students to achieve PBL competences. In their project-work students are using more digital tools for communication, data construction, and collaborative writing than earlier (Konnerup & Ryberg 2018), and additionally, there is a tendency that teachers are using digital resources in the courses, especially when using flipped classroom approaches (Triantafyllou et al. 2016, Kristensen et al. 2018).

A new AAU research project; "Future Directions for PBL in a digital age" will be carried out at Aalborg University from 2017 - 2020 with an overall aim to examine, challenges and further development of the PBL model. The fundamental principles of the AAU PBL-model supports a mix of collaboration competences and subject specific competences. Therefore, the overall aim is to investigate how to expand the AAU PBL-model by integrating digital competences to the fundamental principles of PBL (PBL-Future, 2018). The research project has several sub-projects and one of these - "Towards a flipped semester PBL approach" is dealing with possibilities for changing the structure of a semester in order to support both courses and especially the students' work with their PBL project-work.

3 Expanding and creating flexibility in the semester structure

Planning and developing a flipped semester with the aim of creating a more balanced curriculum-structure which facilitates the integration of courses and students project work in a new way, might be a huge challenge for the somehow fixed structure, especially regarding the division between courses and and project-work. But when looking at the conditions, resources and the development of using traditional lectures at AAU at an increasing rate (Hüttel & Gnauer 2015) the Flipped Classroom (FC) approach might be a way to create more flexibility in the courses so time and space can be given for more active learning in the classrooms.

When looking at a semester design like 4th semester at the Bachelor programme of Medialogy 2018 at the Copenhagen campus of AAU, we see how courses, activities related to courses, and exams are spread out during the semester, cf. figure 1.

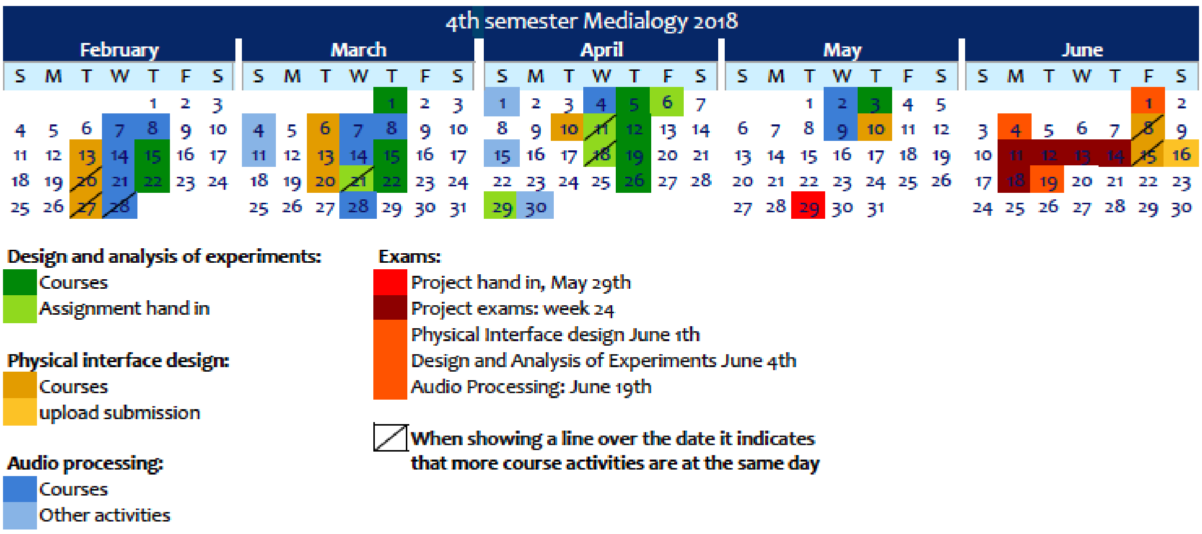

Figure 1: Semester plan activities at at 4th semester Media-technology (Medialogy) at Aalborg University campus Copenhagen.

The study intensity for a semester like the 4th semester Medialogy is 30 ECTS, which is converted to approximately 825 hours of work (1 ECTS = 27.5 hour) (Aalborg Universitet, 2018). The study intensity depends on the length of the semester, and for a semester like 4th semester Medialogy it means that the study intensity of 3 courses (5 ECTS each) sums to 412,5 hours of expected work. The same is applicable for the semester-project i.e. per student. The study intensity spread over the 20 weeks (as scheduled for 4. Semester medialogy) is thereby calculated to be approximately 41 hours a week for both courses and project work. The hours scheduled for lectures in these courses, (spring 2018) sums to 122,75 hours (30% of the hours). Leaving the remaining 289,75 hours (70%) for course-related work (70% of the hours) e.g. preparation for lectures and assignments. In addition, students are expected to work on their semester project in parallel. Thus, not much of the time spend on this semester is thereby available for teachers to interact with the students in the courses. Using the time in courses more efficient therefore becomes more important, and the Flipped Classroom (FC) approach might create opportunities for a more flexible approach to the course teaching.

Initial research of the use of FC at AAU has shown some of the opportunities and concerns when using the FC approach in a PBL environment (Kristensen, 2018). This research has shown concerns about eg. it being very time consuming to produce the FC material and is the approach supporting students reaching a high academic learning level, but the research has also shown that it might be a way of creating more time in the classroom for interaction and active learning using alternative teaching approaches (not using traditional lecturing; Kristensen, 2018). Thereby the FC approach can become a supportive approach to create more flexibility in a semester and expanding the leeway of practising course teaching. This possibility of flexibility and expansion in how to practice courses teaching will be taken into consideration when aiming for designing a more integrated semester.

4 Integrating courses and students project work - towards a “Flipped Semester”

A possibility for more flexible course teaching does not in itself create a better integration of course and project work, but positillities opens for changing practice. Where traditional lectures often focuses on the profession-specific competencies, the expansion and flexibility of FC potentially the opportunity for alternative lectures that is facilitated in a more student centered way, and might be a useful aspect in a balanced integration of courses and projects.

4.1 Methods and theories

The aim of this chapter is to contribute to the question of finding possibilities for a balanced integration of courses and students projects, by letting the students’ projects govern the structure of the semester, which might lead to a concept development for a Flipped Semester.

We are using the curriculum and study plans for one semester (Medialogy, 4th semester AAU Copenhagen) as an example to see how courses and project work is planned and how it could be planned if courses and projects should be integrated using the five steps below: (Dalziel 2015).

1. Important when making a structural and organizational changes of teaching/learning is to know about the institutional attitudes towards the changes.
2. Starting the planning process by collecting data about the framework of the 4th semester (Curriculum, study regulation, semester description, course description.

3. Detailed plan of the planning and developing of a “new” 4th semester
4. Inviting course teachers to be parts of the development and further planning
5. The details of the preliminary plan for the next 4 months (might be changed according to the evolving activities in the plan)

Those 5 steps will be followed in a 4 month process using action research methods (Coghlan & Brannick 2014; McIntyre 2007), combined with observations and interviews (Remenyi 2013; Yin 2008) and ethnographic studies (will be used in the last part of the planning process) and will be integrated in the action research method (Pink 2013).
To use pre-existing knowledge and expertise we will use the semester teachers as experts and co-designers during the planning process (Bovil et al 2016). To support starting a deeper discussion of changing structure, content and pedagogical approaches we will use the learning design methodology in order to develop a common descriptive language to qualify and share teaching activities (Dalziel et al 2013). Furthermore, using learning design is a way to guide individuals through the process of creating new learning activities (Canole & Walter 2008). Learning design can also be applied at different levels of educational practice, e.g. lessons, courses or even curriculum level (Dalziel et al., 2013). Finally, we will use the PBL project methods on the project about planning a flipped semester.

4.2 Staging the planning of a “Flipped Semester”

We have some main actors in the planning process: the course teachers. Later in the process we will add the supervisors and eventually the students in the last part of the planning process. The steps are based on Daziels important planning aspects. (Daziel 2015).

Step one: *Important when making a structural and organizational changes of teaching/learning is to know about the institutional attitudes towards the changes.*
Development of PBL is important in the AAU strategy with an action plan addressing 6 PBL topics as well as financing several research- and developmental projects is a strong support from AAU (Strategi.dk/AAU 2016 - 21). The Faculties of Engineering and Science and of IT and Design has established working groups dealing with different aspects of PBL future aspects of which one is about flipped semester. The head of Architecture, Design & Media Technology Department and the head of medialogy study support a flipped semester approach if it can be developed within the current study regulation, meaning that the theme of the semester and the learning goals have to be followed in a new semester.

Step two: *Starting the planning process by collecting data about the framework of the 4th semester (Curriculum, study regulation, semester description, course description.*
The research team will collect and analyse data from curriculum, study regulation, semester description, course teachers have to be prepared for discussion about courses and projects.

Step three: *Detailed plan for: planning and developing of a new 4th semester.*

Step four: *Inviting course teachers to be parts of the development and further planning*

- Aug. 2018: First meeting with the course teachers:
  1. Short introduction to the process and the planning of a new 4th semester.

2. Discussion of the frame for a new 4th semester.
3. A preliminary analyses of possibilities
4. What to do next?

- Sept 2018: second meeting with the course teachers.
    1. Depending on the first meeting we will chose a future scenario method (Fremtids værksted)
    2. Discussion of making pedagogical experiments
    3. What to do next?

- Oct. 2018: Third meeting with the course teachers.
    1. Scenario method - How could a new ¤th semester be structured?
    2. Presentation of action research and learning design as a methods to develop a course or a semester
    3. Idea generation for the new 4th semester.
    4. What to do next?

- Ultimo Oct. 2018: Fourth meeting with the course teachers.
    1. Depending on results from the third meeting eventually a new shorter future scenario activity. Idea generation - Concretization of ideas. Illustration according the learning design approach.
    2. What to do next?

- Primo Nov. 2018: Fifth meeting with course teachers and project supervisors/facilitators.
    1. Course teachers presenting ideas about the new 4th semester. Eventually a new future activity leading to new concept discussion and clarification.

Step 4: The details of the preliminary plan for the next 4 months (might be changed according to the evolving activities in the plan)

- Ultimo Nov. Primo Dec. 2018 sixth meeting with course teachers and project supervisors/facilitators.
    2. Developing plan for implementation of the new 4th semester 2019.
    3. Producing new material, extra technologies for implementation etc

- Ultimo December: The final concept of the new 4th semester course will be presented for the upcoming 4th semester students.

4.3 From something known to something unknown

Establishing a new 4th semester is a huge change both organizational, pedagogical and technological. Since the start of the Medialogy program 12 years ago, the structure of the semester is more or less as it is today; 3 courses of 5 ECTS and a semester project of 15 ECTS. It takes a lot of effort to change an old structure and at the same time to develop the new structure. It is also a huge change for the students which we have experiences when implementing the flipped classroom (Kristensen et. al. 2018). Otherwise the content of curriculum has undergone massive changes as well as during the 12 year as well as the ICT has become a rather important factor for both teachers and students.

The complex skill or competence of learning to learn together with others using digital media emerges as a new essential for education to be taught as early as possible with the same importance now given to reading, writing and arithmetic (Wegerif p108). There is a tendency that both students and teachers are using different university learning systems or/and social media in their learning environments, and technology-enhanced learning based on collaborative working, creativity, interdisciplinarity, intercultural communication and problem-solving has got an important role (Josefsson 2018). According to Josefsson there is a need to expand existing research, due to the rapid evolution of social media in learning institutions, since it might influence the teaching and learning environment.

5 Summary and reflective remarks

At AAU a research project "Future Directions for PBL in a digital age" is investigating how to support the students development of PBL competences. By researching how to expand and create a more flexible semester structure, the aim is to make space and time for focusing on students project work, where especially the PBL competences are developed. Initiative research projects have shown that the Flipped Classroom approach despite of concerns might create the opportunity to navigate the course teaching in a more flexible way that might support active learning and support an increased interaction between students and teachers. With this opening and possibility for loosening up fixed structures in a semester plan, the subproject "Towards a flipped semester PBL approach" have developed a concept plan and a goal for implementing a flipped semester. It is still an experimental way of creating a "new" semester structure where integration of course and semester project work will be the focus of the initiative. A concept of how to initiate a big change like changing a semester structure is outlined and both action research and learning design will be leading the planning and intervention processes at 4th semester.

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Supporting students' development as self-regulating, life-long learners: a competency-based bachelor programme in biomedical sciences

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Abstract

To meet the needs of contemporary learners as future professionals we transformed the Maastricht University bachelor programme of Biomedical Sciences into a competency-based curriculum. Applying principles of constructive alignment, we designed a longitudinal range of teaching, learning and assessment activities, supporting students to become competent in four domains: biomedical expert (B-competency), communicator and collaborator (C-competency), investigator and scholar (I-competency) and professional and organizer (P-competency). This programme encourages students to discover and follow their personal passion and interests and it supports learners' development into self-regulatory, life-long learners through the use of an e-portfolio and mentoring system. Students upload relevant evidence about learning and competency development to their e-portfolio. A mentor stimulates students to reflect on the feedback and assessment information in the portfolio to develop meaningful learning goals that can be used for their professional development and for career development. The programme is taught in English and aims at creating an international learning and working community through intake of international students and educational staff.

In September 2016, the revised 3-year programme started with 320 students, with roughly 30% from outside the Netherlands. In general, staff feel that the international mix of students has a positive impact on students' motivation and study attitude. First evaluation data show that students highly appreciate the mentorship. A remaining challenge for both students and staff is to make a shift from 'studying for the exam' to self-directed learning and an attitude of continuous performance improvement and competency development.

A detailed evaluation of the new curriculum will follow after the first full run of the programme (2019). In conclusion, first evaluation data suggest that we successfully created a competency-based curriculum with congenial assessment re-design in our large-scale biomedical sciences programme. Implementation, however, is challenging and achieving changes in teaching and assessment culture requires a lot of time.

Keywords: constructive alignment; curriculum revision; e-portfolio; longitudinal assessment

1 Introduction

Panta rhei (all is flowing, changing) was the motto of the ancient Greek philosopher Heraklitos. The flow has not come to a halt, on the contrary changes in society, in technological development and possibilities seem only to speed up. Both current technological and societal changes set (new) challenges for higher education. Technological innovations are a major driving force of the exponential increase of knowledge (Arbesman, 2013). The amount of knowledge in biomedical sciences seems to obey Moore's law. Moore (1965) stated that digital storage capacity grows exponentially. For instance, the number of neurons that can be recorded simultaneously doubles every 7,4 years (Stevenson and Kording, 2011) and the technical capacity to interpret protein sequences doubles yearly (Cox and Mann, 2007). One consequence of this exponential growth in scientific knowledge is, that parts of it become rapidly obsolete. However, more importantly, the knowledge-base of biomedical sciences in general and a bachelor programme in biomedical sciences specifically becomes disputable: what exactly do students have to know when they graduate? Another aspect of technological innovations is the omnipresent availability of all kinds of information. This not only raises the question 'what has to be known (by heart)?', but dramatically affects the way in which we study, collect and use information. In addition, the expectations of society towards academic graduates are changing. The focus no longer lies on academic knowledge *per se*, employers rather expect their employees to be lifelong learners (which fits with the exponential growing base of knowledge), effective communicators and collaborators, and to be empathic to customers (NIBI, 2014; Wagner, 2008).

A third challenge for educators and graduates is globalization. Globalization stimulates and results in increased mobility of students: more often than not, students do not stay at their *alma mater* to follow a master's programme or a PhD-trajectory, but transfer to another university, often in another country. Graduates more frequently seek and find jobs in other countries and cultures, and those that stay 'at home' are confronted with growing numbers of colleagues coming from abroad. Although such culturally diverse settings have many beneficial aspects, they may also interfere with effective cooperation and collaboration and even result in deteriorating performance.

These developments provoke us to reconsider academic education. Currently, academic education strongly focuses on transferring knowledge to younger generations. The aforementioned developments challenge this approach and call for a renewal of education programmes and the way universities facilitate learning of students. Students still have to acquire domain-specific knowledge that enables them to very quickly gain expertise in specific areas of the field, to understand, anticipate and keep up with rapid developments. In addition to this, they have to master skills to deal with omnipresent information and to develop a broad range of competencies beyond those of a biomedical expert.

Maastricht University is known for its Problem-based Learning (PBL) approach. However, PBL is sometimes applied in a robotical manner as a technique or tool. Students then become bored, start using the same procedures in a ritualised way and tend to skip important steps during their learning process (Moust et al., 2005). As a response, educational designers offer additional keywords, providing suggestions for resources along with the problem. This elicits traditional learning behaviour instead of promoting a student-centred learning approach based on the insights on human learning: namely that learning should be constructive, self-directed, collaborative, and contextual (Dolmans and Schmidt, 2010). Therefore, while coping with the above-mentioned challenges, we used the innovations to enhance the principles of contextual learning, constructive learning and collaborative learning. A portfolio and mentor system has been implemented both to support the desired innovations and to counsel students in self-directed learning. The renewed curriculum is outcome-based (i.e. educational outcomes are formulated in terms of competences aligned with the expectations and needs of society and employees), is taught completely in English and offers students ample opportunities to follow personal learning paths. To prepare students for the labour market and to meet expectations of future employers, intended learning outcomes in four competency domains (BioMECS (biomedical education competencies for scientists); inspired by the CanMEDS in medicine (Frank and Danoff, 2007) have been defined and implemented (Communicator-Collaborator, Investigator-Scholar, Professional-

Organizer and Biomedical Expert). To allow the intake of international students, the renewed programme is taught entirely in English. An added benefit is their contribution to a culturally diverse study community. Simultaneously, we learn to deal with the extra challenges posed by this diversity. English as the language of instruction prepares students better for exchange during the minor period or an internship or for master programmes abroad. The exploding and ever-growing amount of knowledge makes it impossible to learn everything within the biomedical sciences. To cope with this fact, we try to provide students instead with a broad base of fundamental biomedical knowledge and, in addition, train them to manage new information available in the future. In this scenario, life-long learning is an essential attitude of students, therefore they will have to learn to learn. Accordingly, we introduced longitudinal learning and assessment trajectories with the focus on learning from feedback rather than learning to pass an exam. These longitudinal trajectories are supported by a mentor and a portfolio system.

2 The new curriculum model: design and implementation

The revised three-year bachelor programme Biomedical Sciences at Maastricht University (BBS@UM) consists of education organised in 4- or 8-weeks courses and in longitudinal learning trajectories running parallel to these courses. During the first three semesters, all students follow the same courses. These courses either introduce basic biomedical topics (organization of life, thriving, moving, sensing and interacting, reproduction, defence mechanisms, growing and ageing) or focus on methodological issues (statistics, information literacy, ethics and philosophy). During semester four, students can choose between various electives, allowing them to explore the depth of several topics. During the fifth semester, students are free to choose a minor of their personal interest either organised at any of the departements of Maastricht University, or at other Dutch or foreign universities. Within BBS@UM three minor trajectories, on respectively drug, nutritional and physical activity interventions are organized. The final semester consists of a skills training course and a short intership resulting in a bachelor's thesis. The courses of the six semesters are typically assessed by summative end-of-course exams; the longitudinal learning trajectories are characterised by multiple moments of formative feedback (low stake) that contribute to a final, high stake pass-or-fail decision. The electives in the fourth semester and the entire education programme of the third year provide students with ample opportunities to define a personal profile (Table 1). The implementation of the competenties as intended learning outcomes, teaching and learning activities and assessment tasks follows the principals of Constructive Alignment (Biggs and Tang, 2007).

Table 1: Overview of the curriculum showing only the courses; longitudinal learning trajectories organised in parallel are not presented. Courses in yellow are identical for all students, electives are orange, the minor period is shown in green and blue represents education that is to a considerable extent individual.

Year 1		Year 2				Year 3	
1.1	The LEGO® bricks of life	2.1	Threats and defence mechanisms			3.1	Minor
1.2	Homeostasis and organ systems	2.2	Cradle to grave: development, ageing and disease			3.2	
1.3	Introduction to statistical methods for data analysis	2.3	Non-invasive techniques in biomedical research			3.3	
1.4	Brain, behaviour and movement	2.4	Elective	A	Human intermediary metabolism	3.4	SoPHiA /practical
				B	Cell signaling		
1.5		2.5	Elective	A	Biorhythms in homeostasis	3.5	Thesis

	Human genetics, reproduction and prenatal development			B	Neuromuscular control of movement		
1.6	Critical Appraisal of a Biomedical Publication	2.6	Elective	A	Integrative systems biology	3.6	
				B	Allometry		
				C	Sensorimotor Behaviour and Neuroplasticity		

2.1 Four competency-domains

All courses and longitudinal learning trajectories contribute to one of the competency-domains that comprise the bachelor programme. Inspired by the CanMEDS, we initially defined seven capabilities, survival skills to prepare graduates adequately for the labour market (Wagner, 2008): biomedical expert, communicator, collaborator, investigator, scholar, professional and organiser. These skills have been clustered into four competency-domains: 'professional and organizer' make up the P-competency, 'communicator and collaborator' form the C-competency, 'investigator and scholar' build the I-competency and 'biomedical expert' is the B-competency. Many of these capabilities were also present in the previous curriculum (e.g. scientific writing, finding and structuring information, presenting, design research), but were not emphasized or assessed separately. The revised programme has been organised around desired, predefined abilities, competencies that all students need to demonstrate upon graduation. We used 'backward-chaining' strategies (Fink, 2013) to design the curriculum. In this process we started defining intended learning outcomes (ILO) for each of the competencies (Table 2); and all teaching and learning activities (TLA) and assessment tasks (AT) have been developed on the basis of these ILOs (Biggs and Tang, 2007).

This approach ensured the programme content was based on the major concepts and intentions and prevented a mismatch between intended curriculum, actual components and final assessment. Accordingly, expliciting the competencies served a feed-up function by clarifying goals and encouraging students to continuously relate their learning and achievements to the expectations at graduation. The P- and C-competencies have been organised in various longitudinal learning trajectories interwoven in the courses and focussing on specific aspects. The C-competency is taught and assessed in trajectories on scientific writing, on presenting science and on communicating and collaborating with peers and supervisors. The P-competency comprises trajectories on organising and documenting laboratory and practical work, identifying personal passions and potential career paths, and developing professional conduct. Competency development is monitored by assignments, and peer or tutor feedback, often directed by rubric forms. Feedback is initially formative but at the end of the trajectory the student's performance on a competency is assessed summatively to determine whether a student scales a predefined competence level. The development of B- and I-competencies is scheduled in courses.

Table 2: Major Intended Learning Outcomes for each of the BioMECS.

Four BBS@UM competency-domains, BioMECS	The BBS@UM graduate as:	Major Intended Learning Outcomes
B-competence	a Biomedical Expert demonstrates and effectively applies knowledge of biomedical sciences	has a broad foundation in biomedical sciences; understands the biological system of the human body in all its aspects and at all levels, from molecules to the complete organism and expanding to the consequences at the population level

I-competence	an Investigator is curious and inquisitive, shows willingness and curiosity to explore and find answers, and has developed critical thinking as well as basic research and problem solving skills.	summarizes and reflects on social, political, international and normative issues in the biomedical sciences
		understands the values of and is able to apply scientific method to obtain academic knowledge, understanding and insight
	a Scholar wants to disseminate knowledge and understands how scientific knowledge is obtained and how it evolves.	critically approach scientific knowledge
		designs and rationalizes a biomedical experiment
C-competence	a Communicator communicates about his work with persons with different backgrounds.	adjusts communication written or oral, to specific global audience/readership and international setting
		communicates professionally with peers and staff originating from diverse cultural and disciplinary backgrounds
	a Collaborator works together in a team with colleagues from various disciplines and with diverse societal and cultural backgrounds.	shows awareness of team roles and takes responsibly her/his position in a diversely composed international team
		works effectively in an international and intercultural team
P-competence	a Professional has a professional attitude to her work and in his relations to others.	demonstrates professional interpersonal behaviour
		appreciates the conventions of scientific integrity and legal and ethical standards and operates accordingly
	an Organizer is organized and can organize her work and research.	takes responsibility for her/his personal and academic development
		organizes his/her work and study well

2.2 International orientation, English taught

The entire bachelor programme is English-taught, enabling an international intake of students and familiarizing students with English as the *lingua franca* of science, and preparing them for international exchange during the minor or thesis period. The international intake is a precondition to create the context that allows students to learn to co-operate in culturally diverse groups. To this end, workshops on intercultural cooperation have been scheduled in years 1 and 2 of the programme. Students are made aware of their cultural diversity and acquire coping strategies for issues arising from this diversity. The emphasis lies on collaboration in a diverse group.

A precondition for an English-taught programme is adequate proficiency of staff and students. To ensure a sufficient level of English proficiency, staff members were invited to undergo a language skills test. A tailor-made language training programme was offered to everyone. The required level for teaching staff is C1 of the Common European Framework of Reference for Languages, for supporting staff B2. Students, who are not native English speakers or who did not finish their secondary education in an EU/EEA country, have to provide evidence of English proficiency by either an IELTS, a TOEFL or a Cambridge test. During the curriculum, learning English is not specifically supported.

2.3 Personal profile

Within the programme, students are encouraged to develop a personal profile. Especially in semesters four, five and six, the second half of the curriculum, students can follow individual tracks: electives in semester four, a free-to-choose minor in semester five, and an individual thesis period in semester six. Assignments to explore the field of biomedical sciences and its conventions are given during the first two years to support students in making career decisions. A series of mini-lectures on diverse BMS-topics is presented and students have to report which topics appealed to them and which did not. Following that, students first interview a biomedical researcher at the university and later an external professional and visit to biomedical company. All these activities result in short individual reports in which students relate these experiences to their own career plans. During the minor in semester five students can either further specialise in any topic in the biomedical science domain, or broaden their scope outside this domain. The minor period allows specific preparation for a future master programme. Students are supported by a mentor and a portfolio system (next paragraph) in selecting courses and personalizing their education.

2.4 Mentor, portfolio and assessment

The programme entails a range of competencies that surmount the mere acquisition of knowledge on biomedical facts, principles, and mechanisms. Development of these competencies requires repeated training and continuous reflection and feedback on performance and behaviour. These processes are supported by a newly implemented portfolio and mentor system in the revised curriculum. Students accumulate products and feedback on performance for each of the competencies as evidence for their development. Typically, the portfolio contains reports on practicals, feedback on lab work and attitude, peer feedback on professional behaviour and communication skills in tutorial and teamwork settings, grades for end-of-course tests, presentations and feedback on presentations. Each student is councelled by a mentor coaching reflection on performance and the setting of new learning goals. Mentor and mentee meet 3-5 times per academic year. Mentees prepare these meeting by writing a short self-reflection on their development and progress in each of the compentencies and by formulating SMART learning goals for the next period. This approach demands a high level of student responsibility, and fosters an active, self-regulating learning style. Thus the portfolio is not only a means to collect evidence to assess whether students achieve the ILOs, but rather to support students to become lifelong, self-regulated learners. In accordance, a considerable part of the assessment in the revised BMS@UM consists of formative feedback, contributing to low stake decisions, especially for the longitudinal learning trajectories. High stake decisions for the trajectories are made at the end of the academic year, stimulating students to repeatedly set and adapt learning goals. The end-of-course exams are summative.

3 First experiences

In September 2016, the revised 3-year BBS@UM programme was launched. The first cohort of students has now finished the second bachelor’s year. In this paragraph we will reflect on the first experiences with the revised programme. We will discuss both the implementation of the revision, results and intended outcomes; the latter for as far as available.

3.1 Competencies

In the revised programme, ILOs are addressed in courses (B- and I-competencies) and in longitudinal trajectories (C- and P-competencies) that are interwoven with the courses. This design incurred a high co-ordination load. Whereas in the old curriculum tuning of content between subsequent courses sufficed, the new design with interwoven longitudinal trajectories demand that TLAs within a course have to meet both the ILOs related to the course (B- or I-competency) and to the longitudinal trajectories (C- and P-competency), increasing the complexity considerably. In addition, this also reduces the autonomy of course co-ordinators, who now have to adjust the course content to externally imposed requirements, namely the ILOs of the longitudinal trajectories. These increased co-ordination and autonomy issues were not optimally addressed in the first run of years 1 and 2. In the second run of year 1 small adjustments, stricter supervision of requirements and improved communication on the relevance of longitudinal trajectories ameliorated the implementation of the programme.

It is too early to conclude whether giving explicit attention to the BioMECS by defining specific ILOs for each competency indeed helped students to become better communicators, investigators and professionals and boosted their self-regulation in learning.

3.2 Internationalization

The revised programme has concurred with an increased number of students and a growing number of nationalities. The former bachelor programme had an average intake of 220 students over the last five years, with decreasing numbers in the years directly preceding the revision. The revised programme started with 327 students in September 2016 and 398 students in September 2017. Influx in the former programme consisted mainly of Dutch students (94%), topped with a small number of Dutch-speaking Belgian and German students. The revised programme welcomed about 37% international students representing 30 countries and 2 continents in 2016 and 39 countries and 5 continents in 2017. German students make up about 30% of the international students. The great majority of students are non-native English speakers.

Accordlingly, we conclude that we achieved the goal of an internationally diverse student population within two years. It is too early to assess whether this culturally more diverse study context contributes to a better preparation for working and collaborating in international settings.

Transforming the programme and its content from Dutch to English did not appear to be a major issue. The majority of staff members is used to communicate and write scientific publications in English. Therefore, writing course books in English was not experienced as a challenge at all. On introducing the revised programme 65% of teaching and 78% of support staff had their proficiency of English tested. 96% of the tested teaching staff reached the required level of proficieny (C1) and 84% of the support staff reached the B2-level.

Programme evaluation questionnaires administered at the end of every course (12 courses evaluated up to now), indicate that all activities in a course were provided in English (score: 4.5 on 5-point scale), that tutors ensured that English was the language of instruction during the meetings (4.5) and that teachers were sufficiently proficient in that language (4.2).

An unforeseen, yet welcomed effect of the increased international diversity is a change in students' attitude with respect to learning; staff reported that the international mix of students has a positive impact on students' motivation and study attitude. Students appear to be more eager to learn and to prepare themselves better for tutorial group meetings. Related to this, we observed that self-reported study time during year 1 of BBS@UM increased by five hours to 29 hours per week compared to the previous curriculum.

3.3 Personalisation

The set-up with electives allowes students to choose twelve different course combinations during the three periods of the fourth semester. Adding the three different minor programmes offered at BBS@UM results in 36 different course patterns that can be chosen. The option to choose minors outside BBS@UM increases this diversity even more. During the first run, each of the twelve possible combinations in the electives period was indeed chosen; the percentage of students choosing a combination varied between 1 and 22%, with 8.3

being the median percentage. 22 of the 230 students currently following year 2 opted for a foreign minor programme. They go to Erasmus partner universities in Australia, Austria, Belgium, Finland, Norway, Romania and the United Kingdom. Six students will follow an educational minor, training them to become a teacher in biology in secondary education. About 10 students found a minor outside the Erasmus exchange framework. The distribution of students choosing one of the three minors at BBS@UM is not yet available.

3.4 Portfolio and its impact on learning

After the first year of the programme, students were asked to evaluate the portfolio and the mentor system. Although students appreciated the coaching by a mentor, they were not convinced about the impact the mentor meetings had on learning and setting goals. The various aspects of the contact with and the usefulness of having a mentor were appreciated with scores between 3.9 and 4.4. on a 5-point scale; the effect of mentoring on their study was rated between 2.5 and 2.9. Students' appreciation of the impact of the portfolio on their progress on the four competence domains was scored as, 2.8 (B-competence), 3.4 (C), 3.1 (I) and 3.4 (P). Students were not enthusiastic about preparing a portfolio and providing peers with feedback, scores on theses questions ranged form 2.8 to 3.4. The software package to manage the portfolio received low scores with respect to user-friendliness (1.9-3.0).

4 Reflection on the revision

In this final paragraph we will consider to what extent the revisions contributed to reaching the goals originally set, and discuss which lessons were learned from implementation. These are preliminary reflections, a detailed evaluation of the new curriculum will follow after the first full run of the programme.

In the revised curriculum, competencies were introduced to help students to meet the requirements set by employers and society. The implementation of those competencies, and especially, establishment of the principles of constructive alignment and explicit formulation of intended learning outcomes, increased teachers' awareness of what it takes to become and be a 'competent biomedical sciences professional'. This resulted in a more complete programme, in which TLAs and ATs explicitly addressed competencies beyond discipline-specific knowledge and skills. In the old curriculum, for example, feedback on oral presentations was limited to technical, content-related aspects of the presentation. In the revised programme, attention is also given to the delivery of effective presentations, which requires mastery of specific communication skills such as making contact with the audience, voice modulation and posture. To achieve this, workshops on drama techniques were introduced. The task of interweaving the ILOs of the longitudinal trajectories with those of the courses was underestimated initially; considerable communication and coordination efforts were required, since the course co-ordinators' feelings of autonomy were challenged.

Organising education in longitudinal trajectories, with multiple moments of formative feedback breaks with the conventional (summative) approach of courses and course exams. Where the latter stimulates 'studying for the exam', the new approach should foster a mastery-oriented approach and an attitude to continuous performance improvement and competency development. It is too early to assess whether this shift in attitude occurred or to determine whether students indeed become better communicators, collaborators, investigator, organisors and professionals.

To prepare students for a career in a globalizing society, we intended to create an international setting. To this end, English was chosen as language of instruction, allowing students with different cultural and linguistic backgrounds to enter the programme. The influx data of the first two runs of the programme show that this strategy was successful, with 37% of freshmen coming from outside the Netherlands. Although an international intake of students is a precondition, it takes more to create a truly international programme. The revised programme includes workshops to make students aware of diversity and to help them to collaborate in a diverse setting. However, in hindsight, we have to conclude that these TLAs were not supported by clearly defined ILOs and aligned ATs. To improve the international aspect of the programme, ILOs on internationalization will be defined and related TLAs and ATs created. Building a programme in English, in the context of a complete programme reconstruction, appeared to be accomplished relatively easily as most staff members are used to communicate in English in their scientific research domain. Students adapted seemingly effortlessly to the English context. This is not surprising as we have international students that engaged in the enterprise to study abroad and national students that have several biomedical sciences programmes in Dutch as an alternative. The cohort consists of students who have deliberately chosen an English-taught programme and its associated challenges.

Ample options to personalise education were introduced to cope with the expanding knowledge base of biomedical science. The curriculum-design helps students both to master basic biomedical knowledge and to explore the depths of biomedical knowledge by following personal interests. This approach allows them to obtain an overview of the field and to understand basic principles and mechanisms. In addition to coping with the abundance of biomedical knowledge, this personalization creates autonomy for students which is believed to enhance students' intrinsic motivation (Ryan and Deci, 2000). Having to choose requires students to reflect on their competence development in relation to their ambitions and career plans, and to think about steps that need to be taken to achieve their goals. Having to choose and create their own study programme will thus contribute to students' development into life-long learners. It is too early, however, to assess to what extent students appreciate this kind of autonomy. Many of our students come from settings where their influence on topics to learn was minimal. Not only students have to make this shift, also for many teachers this requires some serious rethinking. It will therefore take some time to change beliefs and attitudes, and to create a culture that fosters students' autonomy.

Adequate assessment in competency-based programmes must ensure trustworthy decision making (Driessen et al, 2006), should be developmental, *i.e.* supporting and guiding students' learning and should actively involve students in peer and self evaluation (Buddeberg-Fischer and Herta, 2006; Overeem et al. 2009; Sambunjak et al. 2006; van Schaik et al. 2013). To support meaningful aggregation of assessment data and to facilitate both pass-fail decision and an effective dialogue about progress, organizing the assessment in a portfolio is more than helpful (Klenowski et al. 2006). The first experiences with a portfolio as a longitudinal assessment tool are good. As also indicated before, the challenging aspect is the attitude of students towards learning and self-directedness. Students appreciate the helpfulness of the portfolio in developing their competencies as moderate, at the same time they judge the presence of a mentor as a guide in the academic setting as highly valuable. The main focus of students after one year in the programme still seems to be on passing the exams, they do not seem to appreciate the portfolio and the mentor system as a setting to help them to become independent life-long learners. Again, it is too early for a final judgement, but this is a concern and an aspect of the programme that might require attention in the near future.

To conclude, as a first impression, the framework of the revised BBS@UM is in place, but fine-tuning is still required. Making it a truly international programme and stimulation of self-regulated learning of students still pose challenges. The introduction of competencies as an explicit part of the curriculum and the application of the principles of constructive alignment were appreciated as effective ways to improve the quality of teaching and learning these skills.

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Evaluating PBL Practice: the Bahrain Polytechnic Journey towards Excellence

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Abstract

Bahrain Polytechnic prides itself as a pioneer in the use of problem-based learning in non-medical disciplines in the Middle East and North Africa (MENA) region. Its formalized application in 2014 led to the establishment of a 5-year PBL development plan. Trained academic staff were tasked to convert didactic lectures into tutor-facilitated, student-led, collaborative small-group sessions. Enriching as the training was, there, however, remained a pervading uncertainty of whether or not what was developed fit the description of PBL. Halfway through the 5-year plan, interest to investigate what was occurring within the courses led to the reconstitution of the PBL Steering Committee to explore the status of PBL across the Polytechnic Faculties. The Committee developed the current internal PBL review. Its aim is not only to look into PBL implementation but also provide capacity-building support to the tutors. It is designed to provide recognition of best practices and suggestions and recommendations for improvement. The process involves a semestral cycle of pre-class visit interviews with the course coordinators and tutors, the actual class visits, post-class visit feedback discussions, exploration of learning and teaching resources on the course's Moodle page and an end-of-semester student PBL experience survey. The PBL format of the reviewed course is determined at the culmination of the cycle and is reported back to the Steering Committee and the institution's Academic Board. At this paper's writing, the 3rd Cycle has been completed and reported. So far, 108 courses were reviewed and two predominant formats have been noted, hybridized Problem-based, Project-based Learning and pure Project-based Learning. While still halfway through its completion, the aimed effects of the review have already been noted. The robustness of the review lent significant improvements already being observed in the tutorials. This is envisioned to lead into, not only better academic practice but significant impact on the students' learning experience.

Keywords: Problem-based learning, Project-based learning, Internal Review

Type of contribution: Best practice paper

1 Introduction

Bahrain Polytechnic aims to produce life-long learning, work-ready graduates, equipped with the necessary 21st century employability skills. This is achieved through the use of a vibrant, dynamic and active learning environment. With this in mind, it makes logical sense to choose problem-based learning (PBL) as it has been identified as a particularly powerful pedagogy and teaching and learning approach to promote and develop transferable employability skills amongst students, while they simultaneously acquire domain specific knowledge or content (Kek & Huijser, 2011).

Over the recent years, the institution has embarked on a philosophical and educational methodology modification journey to develop problem-solving, practice-oriented, cognizant professionals. The use of ill-structured, open yet authentic problems became an essential pillar in the PBL curriculum to serve as triggers for learning. The designed problems are based on real-life scenarios or may be hypothetical which mirror actual life situations. These are developed to meet the intended learning outcomes and objectives. A shift from the lecturer driven set-up into the facilitated tutorial session model, engagement in peer-learning, small-group discussions, student collaboration in and outside of the tutorial and emphasis on the development of employability skills are some of the key features that have been embedded into the curriculum.

Training along the lines of problem design, PBL curriculum development, course and programme re-structuring, facilitation skills was sought out and delivered. However, a few years after the initiation of the PBL implementation, there continued to be a subtle permeating lack of confidence among the tutors if whether or not what they were doing in class was PBL at all.

To address this, the internal PBL review was developed. It is an internally conceived system used primarily to evaluate and analyse how PBL actually occurs in the classroom, as well as to provide support for building tutor capacity. Now on its 3rd cycle, the review has proven to be an excellent resource for gathering data on PBL implementation and a collegial process of engaging the academics in further discussions about their courses, problems, activities and overall perspectives on PBL.

2 BRIEF HISTORY AND GOALS OF PBL

Problem-based learning as an educational approach has its origins in the McMaster University School of Medicine, located in Hamilton, Ontario, Canada. September 1969 marked the intake of the first batch of 20 medical students whose learning experience would eventually be known as problem-based learning (PBL). Its inception and development is attributed to the combined work of five doctors, namely Drs. John Evans, William Spaulding, James Anderson, William Nash and Fraser Mustard. Interestingly, their work was primarily a “response to the dissatisfaction and discontentment with their own educational experience and a desire to offer future medical students a less boring experience” (Servant-Miklos VFC, 2018). Since then, several medical schools have adopted the PBL methodology and have reported phenomenal successes. To-date, several educational institutions from a vast list of disciplines and from a variety of levels (lower K-12 to the higher tertiary tiers) have taken on PBL as their main educational mode of delivery and have likewise reported achievements. Much of the sparked interest would be the goals of PBL itself which would be, to transform students who can “construct an extensive and flexible knowledge base, develop effective problem-solving skills, develop self-directed, life-long learning skills; become effective collaborators; and become intrinsically motivated to learn" (Hmelo-Silver, 2004).

3 THE BAHRAIN POLYTECHNIC PBL HISTORY

The implementation of PBL began in July 2010 with the invitation of noted PBL expert Dr. Terry Barrett of University College Dublin. Her series of workshops stimulated the development of a model in response to the initial perceived needs to realize the use of PBL. The model was the product of a collaborative effort between the Deputy CEO for Education Services and a newly established PBL Steering Committee which provided enough flexibility for programme-specific PBL models through which programme teams can decide which of the options would best suit them (Coutts, Huijser & AlMulla, 2012). The response was a series of PBL pilots in different courses across various programmes.

However, due to a number of constraints, (e.g. levels of staff expertise, number of staff needed, amount of resources and workload constraints) the PBL implementation plan was initiated but not completed. The project was re-initiated towards the start of Academic Year 2014-2015. It was proposed that 'course-based PBL' be reintroduced in the institution from September 2014, as it appears to be the best fit considering the current capacity and availability of staff and resources for implementation. In adopting a course-based PBL model, the transition was seen to be easier, as by this time, a number of courses already applied PBL as their main teaching method and a number of other courses were currently being developed in PBL mode.

The Academic Development Directorate was tasked with the responsibility for developing a comprehensive and detailed implementation plan for 'course-based' PBL in the Polytechnic over the next 5 years. Each Faculty was then mandated to manage its programmes in developing their individual courses into the PBL format. For two academic years, good examples of PBL re-developed courses were noted. It was observed, however that despite iterative and continuous training, the progress was not as rapid as expected. There also was a pervading notion of uncertainty among several academic staff if whether or not the activities and overall course designs they produced would fit the description of PBL. Several of the staff were also honest in accepting their lack of confidence in facilitation, reflective discussion and feedback skills. All these prompted the re-establishment of the PBL Steering Committee by the Deputy CEO for Education Services on March 2016 to look into the state of the implementation of PBL across the courses and programmes in the Polytechnic.

4 INTERNAL PBL REVIEW

The new PBL Steering Committee consists of the Chair who is a senior curriculum specialist having extensive PBL experience and PBL champions representing each School. Their initial action was drafting what is currently known as the Bahrain Polytechnic Internal PBL Review process. The draft was initially discussed with the curriculum specialists from the Academic Development Directorate for feedback regarding the process followed by extensive consultation with the Faculty Deans, Heads of Schools and Programme Managers to gain their input regarding the process to ensure robustness and validity. The process was then proposed for discussion at the level of the Academic Board and was eventually approved on June 2016. The PBL Steering Committee, in collaboration with curriculum specialists laid down the plans for the official roll out of the review starting the following 1st semester of AY 2016 – 2017. So, far 3 cycles of the review have been completed where 1 cycle lasts a full semester.

The purposes of the internal PBL review are the:

A. Provision of Tutor Guidance and Support

1. To provide guidance and support to tutors in their PBL development for new courses
2. To provide prompt feedback regarding PBL designed activities
3. To provide expeditious feedback regarding PBL practice by the tutors
4. To identify training needs for tutors to enhance their roles in a PBL environment
5. To identify best PBL practices across the institution

B. Provision of Course-support

1. To affirm courses that are well defined by the Bahrain Polytechnic PBL criteria
2. To provide feedback and support for courses that require further re-development based on the Bahrain Polytechnic PBL criteria

4.1 Stages of the Internal PBL Review:

A. **Orientation of Academic Staff:** Orientation and information dissemination seminar about the purposes and design of the Internal PBL Review; audience would be course coordinators and teaching teams; coordinated by the Programme managers and endorsed by the Faculty Deans and Heads of Schools.

B. **Pre-class Visit Phase: (Weeks 1-3)**
   1. Programme Managers provide the curriculum specialists with the list of courses that are developed and ready for review, together with the names of the coordinators and members of the teaching team.
   2. Curriculum specialists contact course coordinators by email to set-up a pre-class visit discussion about the course. The coordinator's course PBL evaluation form *(Please refer to Appendix 1)* is sent to be filled out and sent back before the meeting.
   3. Prior to the pre-class visit meeting, the curriculum specialists review the coordinator's course PBL evaluation form and the course descriptor.
   4. During the pre-class visit meeting, the coordinators are encouraged to talk about the nature of the course. Discussion focuses on how the PBL criteria are manifested in the course.
   5. The coordinator informs the teaching team of the need to propose class visit schedules. The teaching team members are encouraged to propose different sessions to give the curriculum specialists a broader perspective of the course.
   6. Once a class visit schedule is agreed upon, the tutors provide the curriculum specialists a lesson plan for the session to be visited.

C. **Class Visit Phase:** Throughout **weeks 4-12**, curriculum advisors visit the class in pairs in order to be able to give ample feedback to the tutor. Observations are made from three aspects: tutors and their facilitation skills; the implementation of PBL in the session and the overall learning atmosphere that transpired.

D. **Post-class Visit Feedback Phase:** The curriculum advisors and the tutors discuss through the tutor-supportive observation form *(Please refer to Appendix 2)*. Feedback as well as suggestions and recommendations are provided.

E. **PBL Student Experience Survey:** By **weeks 11-12** of the semester, the online student PBL experience survey is opened up to the students of the courses visited. The 14 questions are structured around the Bahrain Polytechnic PBL Criteria and are answerable through a 4-point Likert scale *(Please refer to Appendix 3)*

F. Course-supportive Phase: By **weeks 12-13** of the semester, the curriculum advisors finalize the collation of the evidence and comments into the course-supportive form *(Please refer to Appendix 4)*. Significant points discussed are: comments about the PBL structure of the course based on the descriptor; comments about the PBL structure on the sessions and the activities as evidenced on the Moodle learning management system (LMS), observed PBL points during the class visit, analysis of the PBL student experience survey. Through these evidences, a recommended format is stated for approval by the PBL Steering Committee.

G. PBL Steering Committee PBL Format Approval Phase: By **week 14,** the recommended formats, as justified by the evidences collated in the course-supportive form are brought to the PBL Steering Committee for approval. The formats proposed may either be **Problem-based Learning (pure); Project-based Learning; Problem-based, Project-based Learning**.

Guiding definitions that inform the format recommendations are:

1. **Problem-based Learning:** "The learning that results from the process of working towards the understanding of a resolution of a problem. The problem is encountered ***first*** in the learning process (Barrows and Tamblyn 1980:1 my emphasis)

2. **Project-based Learning (PrBL):** "Project-based learning begins with an assignment to carry out one or more tasks that lead to the production of a ***final product—a design, a model, a device or a computer simulation.*** The culmination of the project is normally à written and/or oral report summarizing the procedure used to produce the product and presenting the outcome. …. ***In project-based learning, the product is the central focus of the assignment*** and the completion of the project primarily requires or emphasizes the application of previously acquired knowledge." (Prince, M. J., & Felder, R. M. ,2006: 1 my emphasis).

H. Academic Board Information Phase. Approved formats of the courses are reported back to the Academic Board by the Chair of the PBL Steering Committee by **week 15-16**. The acceptance of the formats by the Board is the official "stamp" that a course has successfully finished the review. A digital copy of the course-supportive form is uploaded onto Sharepoint, the institution's document management system. The course coordinators and tutors are given access to these. These forms are to be attached to the end-of-semester course review documents by the course coordinators as evidence of being reviewed for PBL implementation.

4.2 Ongoing Results of the Internal PBL Review

The interplay of metacognition with the presence of cognitive skills and information combined with sufficient motivation have been identified as essential for learners to adequately perform learning activities (ten Cate, et al, 2004). This essential relationship is clearly developed as the learner progresses from the Foundation to the higher degree level, discipline-specific courses at Bahrain Polytechnic. The institution's learning pathway shows the progression from a new student to a work- ready graduate and involves a gradual transition from guided to independent problem solving. Introductory tutor-guided problem-based learning activities combined with problem solving progresses across the years to fully independent problem- and project-based learning experiences in the higher years. This is a general theme observed through the past cycles of the internal PBL review.

To date, three cycles of the review have been completed with the review of 108 courses across the Polytechnic. With this came the approval of the formats of these courses. Table 1 summarizes the results and shall be discussed in a later section.

Table 1 PBL / PrBL Formats Over 3 Cycles of the Internal Review

PBL Steering Committee Approved PBL / PrBL Format	Number of courses (Cycle 1)	Number of courses (Cycle 2)	Number of courses (Cycle 3)	Total
	1st Sem, AY 16-17	2nd Sem, AY 16-17	1st Sem, AY 17-18	
Problem-based Learning (pure)	0	0	0	0
Project-based Learning	13	27	20	60
Problem-based;Project-based Learning	19	13	16	48
TOTAL	**32**	**40**	**36**	**108**

With a total of 250 courses across the Polytechnic, this substantial project is still halfway through its completion.

The student PBL experience survey has presented to be quite a challenge. The responses to the survey have been far from substantial as they have resulted in poor response rates.

5 DISCUSSION

5.1 Tutor -support:

In the time leading up to the official implementation of the internal PBL review, Faculties, Schools and Programmes at Bahrain Polytechnic managed their own PBL development and execution. This was done from different perspectives and standards. This eventually led to a variety of interpretation of what problem-based learning was across the institution. The establishment of the internal review has brought PBL into proper focus and has also highlighted best practices that were being done at the course level, along the lines of project-based learning and a hybrid form of problem-based and project-based learning.

A majority of the tutors had a clear understanding of the role of high-quality problems in terms of their impact on the effectivity of PBL (Sockalingam, N., Rotgans, J., & Schmidt, H., 2012). The major difficulty was the essential use of problems at the very start of the learning cycle as a problem trigger. Through iterative, continuous upskilling training, the academics were re-oriented as to how to properly use well-thought of and designed problems in problem-based and project-based learning.

The pre-class visit meetings have been instrumental in understanding what the course to be visited is all about. The meetings usually involve two curriculum advisors and the course coordinator. The teaching team may or may not join. The main materials for discussion are the course coordinator’s course evaluation form and the course descriptor. Most aspects of the course to be discussed span from the aims, learning outcomes, course and session structure, activities and assessments. Emphasis is around how problem-based and project-based learning principles are used in the sessions.

The tutors are given the prerogative to choose and propose an appropriate session to be visited. The curriculum advisors stay for the whole length of the class paying close attention to how the class is structured along the lines of PBL principles and student-centeredness. Interest is given to the facilitation skills of the tutor and how the activities are handled. As for the students, observation regarding the overall learning atmosphere is emphasized. Collaboration, group learning, peer-to-peer learning and teaching, the degree to which each one is comfortable with provision of peer feedback and reflective learning along the lines of the taught concepts as well as the whole learning experience are also key considerations in the observation.

Within an average of a week, the curriculum advisors fill out the tutor-supportive PBL observation form and call the tutor for a post-class feedback meeting. In this meeting, the different points in the tutor-support form are discussed. Applying proper feedback principles and taking heed of how individuals receive such feedback (Ilgen, Fisher and Taylor, 1979), discussion starts with the highlighting of good, as well as the impressive segments observed in the class. Sections that did not go so well are discussed as points for improvement. Suggestions and recommendations are then set forward. Assurance of confidentiality are given by the advisor to the tutor before both sign copies of the form, one of which goes to the tutor and one to the curriculum advisor to be filed as a matter of record. The signed form is also scanned and filed in an electronic repository.

In a sense, the review has served as a venue for professional development among the academic staff in enhancing their PBL facilitation skills (Tschannen-Moran and McMaster, 2009). The effectiveness of PBL use may be assessed initially through the one-on-one discussions with the tutors. It is very helpful to discuss with them that there needs to be a shift from the usual tutor's role from being a "sage-on-stage" to a "guide-on-the-side" (Morrison, 2014). So, instead of being the main source of information in the session, the tutor transforms into a facilitator and guide for the students' learning. Eventually, this would be clearly seen through the applications in the actual class setting. Another benefit of the individual discussions with the tutors is that they feel safe in discussing their doubts, concerns, and queries about PBL with the advisor which they otherwise might not be able to do in large group settings like training workshops and seminars. The individual discussions have also been helpful in bringing forth their PBL ideas, their problem designs and discussing them in an encouraging environment which helped them determine how they could move forward with such. The review has also provided a way for the PBL Steering Committee and the curriculum advisors to observe best PBL / PrBL practices and encourage these tutors to share these with the larger Polytechnic academic community. These have helped others understand proper PBL / PrBL implementation and in so doing improve on their own practices. For those encouraged to share, this experience further encouraged them to strive more as they were recognized for their exemplary work.

In terms of classroom practice, significant improvements were observed among tutors who were given previous tutor-support feedback. Several of them became more confident towards facilitating rather than full-length lecturing. They became very comfortable in framing open-ended questions and drawing out answers from their students. The tutors themselves have become models for their students in terms of reflective learning.

5.2 Course-support

At almost the same time that the tutor-support form is being filled out by the advisor, the course -support form is also being populated. Pertinent points discussed there would be the session structure as evidenced by the activities as well as the session presentations as seen on the course Moodle page. Analysis is made of the placement and design of problems within the sessions. Significant points discussed about the course during the pre- and post-class visit meetings are included. The overall learning atmosphere during the class visit is also included here. Analysis of the PBL student experience survey also forms part of this segment of the review. All this information feeds into the decision as to which format is to be identified for the course observed.

There are several excellent cases to showcase the effectiveness of the course-supportive segment of the review. Several courses underwent redesigning, as a result. Courses that were characterized by tutor-led discussions and lecturing had the concepts and learning objectives converted into authentic or simulated problems and / or projects. These were assigned to students who were divided into small groups of 3-5 students. The student groups were provided ample student-directed learning time and were asked to come back into tutorial sessions for discussions. Curricular changes caused students to take ownership of their learning thus enhancing their communication, critical thinking, entrepreneurial and problem-solving skills. Other changes involved project delivery that replaced lengthy, written summative examinations. Work-integrated learning also became an integral of the learning experience.

5.3 Format Decision-making Format identifications, as drawn from the definitions of Problem-based learning by Barrows and Tamblyn (1980) and of Project-based Learning by Prince, M. J., & Felder, R. M. (2006), are made when :

1. **Problem-based Learning (pure PBL):** The majority of the problems used in the course are authentic, used in a collaborative manner and more importantly are situated as learning triggers and not mere concept checkers or summaries. No projects in whatever form are submitted at the end of the course.
2. **Project-based Learning (PrBL):** A project (in whatever format, as appropriate to the course) is expected as a student deliverable within specified times within the course or as an end-of-semester requirement. Both open- and closed-ended problems (used more as summaries, concept checkers and less as actual learning triggers) are used, as appropriate, along the course and are all related to the completion of the project. Segments of the project are expected as deliverables at set points in time within the course timeline.
3. **Problem-based, Project-based Learning:** Most of problems used are learning triggers, less of the concept checking, summary type of problems. Problems are authentic, collaborative, research stimulating. Presence of a project deliverable, as appropriate and aligned to the learning outcomes.

5.4 Current outcomes of the review:

Based on Table 1, a total of 108 courses were observed over the past 3 cycles of the review, 60 of which had the project-based learning (PrBL) format, 48 had the hybridized format of problem-based, project-based learning and none were deemed having a pure problem-based learning format (PBL). Having no pure PBL formatted course was initially perceived as a failure of the institution's implementation of its chosen pedagogy. However, upon further discussions with tutors, most of the courses that have been categorized as PrBL or the hybrid form of PBL and PrBL initially were designed as pure PBL. However, due to the challenges of implementing pure PBL in technical and technology-oriented courses such as those in Engineering and ICT, the format shifted to a more appropriate PrBL format or a hybrid of both PBL and PrBL. The advantages of the use of project-based learning in Engineering rather than the problem-based format, particularly in the higher years is mostly geared towards answering the needs of the industry (Mills, J; Treagust, D. 2003-2004). The Business, Logistics, Web Media and Visual Design Schools had courses which did fit the pure PBL format, however projects were introduced to further challenge the development of the students' employability skills as well as showcase the learning outcomes being transformed to evident and tangible projects. These projects were also required by the industry partners.

Notable are common projects that are worked on by students from different courses. To name a few, these are noted among 3rd and 4th year courses in the Engineering School such as in the Mechanical, Electrical Engineering and Web Media programmes, as well as in the Business School, particularly in the Marketing qualification and also in the International Logistics School

To date, 82 tutors have undergone the internal review and hence have benefitted from the tutor-support segment of the process. Suggestions and recommendations were offered as feedback for points that needed to be improved in terms of classroom practice. Validation of good practice was celebrated through positive, encouraging feedback. Some of these tutors were identified and encouraged to share their best practice in academic symposia.

6 CONCLUSION

In general, reviews are utilized to identify exemplars of quality, improve performance, and critically evaluate practices. The internal PBL review was designed along the premise that it could serve both as a tutor-supportive as well as a course-supportive process. Keeping in mind the original mandate to use problem-based learning as the main teaching methodology at the Polytechnic, efforts towards achieving this have been a challenge. This was particularly so because of a myriad of factors including the nature of the courses, as well as the need for more learning resources and appropriate infrastructure to facilitate an appropriate PBL tutorial session. However, despite these challenges, Bahrain Polytechnic academics have used a variety of means to design and conduct PBL activities. As discussed above with the current outcomes of the review, from an expected pure problem-based learning model, a hybrid form of problem- and project-based learning has evolved. Properly done, the hybrid format is actually a seamless united methodology where the use of problem-based learning principles results in the production of an authentic project. The internal review has provided validation for the work that several tutors were already doing. It has also provided a means by which tutors could openly discuss the challenges in their courses, seek consultation about their course and activity in terms of PBL / PrBL. Alternative suggestions and recommendations regarding courses or activities that do not exactly fall under the required criteria are also made during the review. Focused training needs concerning curriculum and activity PBL / PrBL design, facilitation skills, reflection, assessment have also been identified through this review. The best outcome so far has been identifying unique PBL / PrBL ideas through the review and the tutors responsible for these were encouraged to share and present their work through academic symposia and conferences.

For the tutors, additional benefits include enhanced professionalism and collaboration among colleagues, and opportunities to build relationships with students (Thomas, 2000). Comments received from tutors during the post-class visit one-on-one meetings indicated that they (the tutors) now understand the essence of what the methodology is all about and how PBL / PrBL molds the students into the work – ready graduates that the institution endeavours to produce. Several tutors also remarked that the institution's model actually allows a broad range of learning opportunities in the classroom which allows them to cater for diversity amongst their learners. The students who benefit the most from project-based learning (and problem-based learning) tend to be those for whom traditional instructional methods and approaches are not effective (SRI, 2000). Comments that the PBL / PrBL model implemented has actually enhanced engagement and improved academic performance resulting in more self-reliant students has been most encouraging (Walker and Leary, 2009)

7 CHALLENGES

There still are a few challenges that are encountered in the implementation of the review:

1. Number of curriculum specialists / advisors involved in the review: Currently, there are only 3 who are doing the review. Given the number of hours spent through each segment of the review, this would explain why the review is not running as quickly as it should. As per approval of the Academic Board, the review is supposed to end by the culmination of the 2nd semester of Academic year 2019-2020. A report is expected by this time.
2. New courses are being developed each semester in response to the requirements and needs of the industry. These add to the number of courses which would need to be reviewed. An additional challenge is that the PBL Steering Committee has a policy that when new courses are developed, these are allowed to run at least once in a semester as a piloting endeavour before they are reviewed the next time they are offered.
3. Academic staff turn-over has well trained tutors in PBL moving on from the Polytechnic to be replaced by new ones. In most cases, these new tutors would have to go through PBL training, as well as finish the staff induction course - the Certificate for Tertiary Teaching and Learning (CTTL). The PBL Steering Committee has a policy that new tutors must graduate from the semester-long CTTL course before going through the tutor-support segment of the internal review.
4. There are particular tutors and course coordinators who have adverse reactions when their courses are classified as project-based and not problem-based. Despite training, they continue to insist that as long as problems are given to students to work through, even if they are not used as learning triggers, i.e. as concept checkers for instance, the course is still problem-based.
5. Due to the sparse number of curriculum specialists doing the review, follow-up of recommendations brought forward in the course-supportive segment of the review is challenging.
6. The student response to the internal PBL review student experience survey is low. Currently, students are informed by their tutors and through Moodle of the electronic survey in weeks 11-12 of the semester. The tutors are tasked to encourage the students to fill in the survey within the survey period.

8 WAYS FORWARD

Despite the challenges faced, the Academic Board, PBL Steering Committee, the Academic Development Directorate and the Curriculum Development Unit are encouraged by the renewed enthusiasm and fervour to enhance the implementation of the PBL and PrBL methodology in the institution. So, in answer to the challenges above, the following are set as action plans:

1. The PBL Steering Committee chair who himself is one of the curriculum specialists involved in the actual review shall put forward a recommendation to the Academic Board to consider extending the deadline for the completion of the review. An additional Academic Year (2 semesters) shall be put forward for discussion and approval.
2. Part of the proposal of the PBL Steering Committee Chair in action plan 1 would be the institution of a regular review that would cover newly developed courses, even after the completion of the internal PBL review project. This will be proposed first at the level of the PBL Steering Committee and when approved would be elevated to the Academic Board.
3. Part of the proposal mentioned in action plan 2 would include the PBL support to be given to new tutors who would go through a class observation after having completed their CTTL.
4. The Academic Development Directorate through its Curriculum Development Unit in collaboration with the Teaching and Learning Unit shall continue to provide iterative, continuous, aligned, relevant PBL / PrBL training. Open, safe and constructive one-on-one discussions shall be scheduled with tutors / course coordinators with opposing views to determine why their views are such and provide insight on what PBL / PrBL practice really is.
5. A call for aid in the handling of the PBL review has been sent out to the other curriculum specialists and advisors. Training has already begun for an additional three staff to do the review.

6. The curriculum advisors and specialists shall do actual visits to classes on Weeks 11-12 and ask the students to do the survey in class for about 10-15 minutes. This shall hopefully increase the response rate.
7. A survey is being developed and will soon be released to academic staff who have already gone through the review with their courses. The survey is purposed to capture these tutors' thoughts and ideas about, insights gained from the internal PBL review and suggestions to help make it more robust and valid.
8. For the summary report at the culmination of the review, it is viewed that a proposed recommendation to revise the Bahrain Polytechnic model to be that of either Project-based Learning or the hybrid Problem-based, Project-based Learning format be included.

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Appendices

Appendix 1 Coordinator's Course PBL Evaluation Form

Coordinator's
Course PBL Evaluati

Appendix 2 PBL Class Observation Form (Tutor-Support)

Internal PBL Review
Observation Form 2.

Appendix 3 PBL Student Experience Survey

PBL Student
Experience Survey.p

Appendix 4 PBL Internal Review Recommendation and Reporting Form (Course-Support)

PBL Internal Review
Recommendation ar

Development Of Integrated Learning Management System Aligned With UPSI ICGPA Model

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Abstract

Since its inception in 2015, Integrated Cumulative Grade Point Average (iCGPA) has been among the prime agenda of the Malaysia public university including primary teacher education university, Universiti Pendidikan Sultan Idris (UPSI). Apart from the development of iCGPA model according to UPSI's niche, the university is also aligning its academic system by improving and upgrading the Integrated Learning Management System to be in line with the model and the concept of UPSI's iCGPA. This article documents the development of the Integrated Learning Management System according to the reference model by applying the concept of integrated learning domain and principle of constructive alignment.

Keywords: iCGPA; UPSI; Integrated Learning Management System; MySIS.

Type of contribution: Best practice paper.

1. Introduction

Learning Management System (LMS) also referred to as ‘‘learning platforms’’, ‘‘distributed learning systems’’, ‘‘course management systems’’, ‘‘content management systems’’, ‘‘portals’’, and ‘‘instructional management systems’’, combine a range of course or subject management and pedagogical tools to provide a means of designing, building and delivering online learning environments. LMS are scalable systems that can be used to support an entire university’s teaching and learning programmes. LMS have become integral to university curriculum, teaching experiences, and students’ learning experiences since they first emerged on higher education campuses in the 1990s. Their presence is ubiquitous in higher education, with 99% of colleges and universities currently reporting they have an LMS in place.

To meet users’ needs and expectations, the LMS should be mobile friendly, personalized, customizable, adaptive, intuitive, integrated, and designed to enhance student learning. These systems will cater the need of various parties in the university. Within rapid development and demand from the LMS users, a learning system that are flexible enough and able to correspond to the current policy and need from the higher education are much sought after. This paper aims at describing Malaysia premier teacher eduction university, Universiti Pendidikan Sultan Idris (UPSI) experience in revamping its LMS through both improvement for existing module and development of new module to address the iCGPA requirements. The improvement and development of the modules are aligned with the conceptualization of UPSI iCGPA model. In between the description of the module, the paper also highlight principle and theories behind the decisions.

2. UPSI Learning Management

UPSI currently utilizes a home-grown LMS known as University Integrated Management System (UIMS). UIMS comprises MySIS, MyUPSI Portal, MyFIS, MyGuru2 and MyHRA modules. These array of modules are highly integrated to ensure efficiency, reliability and integrity retrieval of data. The UIMS has been develop with the collaboration between university’s ICT Centre, top management and faculty administration to ensure optimum system application among various type of users. UPSI outlines two main principles in each online system development and improvement; problem-based solution and value-based solution. These principles lead to learning management systems that are easy, efficient and effective to ensure a responsive delivery service according to the need and demand of the customers. In UPSI, the UIMS serve lecturers, students, administrators and officers who look after the academic matters in the departments. In particular, the UIMS function as digital learning environments for students and administrative systems for faculty to manage their courses. Similar to other LMS, UPSI UIMS is develop in way that are flexible and dynamics to cater for any changes and improvement with regards to the current demand from the users. For the purpose of this paper, the subsequent part of the writing focuses only on MySIS that currently serves academic needs.

3. My Student Information System (MySIS): A System for iCGPA in UPSI

One of the MQA accreditation requirements is continuous quality improvements. UPSI taking a big leap to monitor academic programme by acquiring performance indicator through course learning outcome (LO) achievements. The CLOM (Course Learning Outcomes Monitoring) system was introduced since Semester 1

Session 2010/2011 to evaluate course learning outcome (LO). CLOM provides achievement index for each LO and index for the whole course. CLOM objective is as following:

- To provide a performance indicator mechanism to LO and programme.
- To assist faculty and departments to monitor and review implementation of teaching and learning activities towards better achievements of LO.

MySIS serves as a system platform to realize CLOM concept. Since its inception, there is no major changes occurred on MySIS. However, recent introduction if iCGPA to all Malaysian public universities in 2015 and later to private university and college has prompted major changes on MySIS. MySIS serves as a point of departure for UPSI to begin her maiden journey in iCGPA. In general terms, iCGPA role is to steer constructive alignment concept to ensure the design of the curriculum the implementation of curriculum and the assessment process, be it course or programme level, achieve quality. The CLOM concept is still there but it is further enhance by realizing the constructive alignment concepts. In fact, to cater for the iCGPA requirements, a brand new module called constructive alignment is developed.

As depicted in Figure 1, MySIS consist of several modules to administer academic matters. ICT Centre, alongside with the Centre for Academic Development and Academic Affair Division are the guardian of the MySIS module and the users consist of lecturer, academic-related staff and students.The first module, Course Outline (CO) serve as main academic database and resources that keep all the relevant information related to academic course. In particular, CO consist of Programme Learning Outcome (PLO), Institutional Learning Outcome (ILO), Course Learning Outcome (CLO), learning domain (cognitive, affective and psychomotor), course synopsis, teaching and learning activity and assessment plan. With this array of information, CO is regards as a main database in way that these data will be utilize by other modules also in MySIS. The data from CO is utilized by 'pulling' it to the other module.

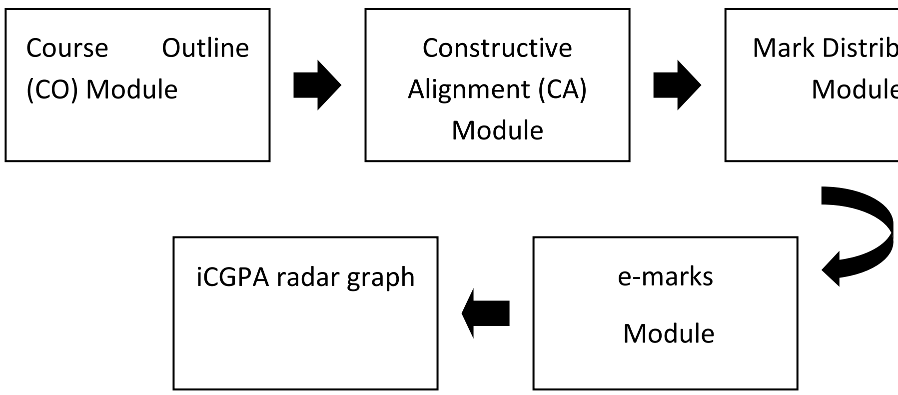

Figure 1: MySIS system comprises variety of modules to generate iCGPA radar graph

Once the course coordinator fills the information in CO, the head of department and the faculty dean will verify the content. This step ensures validity of the data and serves as the first checkpoint for Continuous Quality Improvement (CQI). As depicted in Figure 1, some of the data from CO will be load to the subsequent module known as Constructive Alignment (CA). As the name suggests, the CA module require the coordinator to map the learning outcome (LO) (taken from CO system) with the respective teaching and learning activity and assessment methods. The CA module echoes with Biggs (2003) definition of constructive alignment stated as "*student-centred learning activities and assessment tasks should be aligned with the learning outcomes of the course, resulting in a consistent system of measuring LO achievement".* Each LO has its own weightage (determine by the course coordinator) that in turns correspond with the weightage of assessment methods. The following table exemplifies the weightage alignments:

Table 1: Alignment between LOs and assessments methods

Learning Outcome (LO)	Assessment Methods	
	Academic Discourse (30%)	Final Examination (20%)
LO1: Synthesize issues and challenges related to the implementation of ESD in classroom (30%)	20%	10%
LO2:Apply ESD concept in teaching and learning session (20%)	10%	10%

Vertical Alignment

Horizontal Alignment

The horizontal alignment (LO-based) and vertical alignment (assessment-based) between LOs and assessment is vital to ensure fair assessment and appropriate learning time spend to achieve a particular LO. The CA module is also cater the need of vertical-alignment (assessment-based) to ensure the assessment weightage is mapped accordingly across the LO. For example, the weightage of final examination (refer to Table 1) is 20%, the system will ensure that 20% is mapped accordingly across related LOs. In this example, the 20% of final examination is distribute among two LOs (LO1 and LO2) which represent 10% respectively. The CA module is develop in a way that those elements (LO weightage, assessment weightage and student learning time) are correspond to each other and achieve both horizontal and vertical alignment. As far as the OBE curriculum concerns, explicit planning on how LO is being measured and achieved is vital to ensure a successful execution of the course and continuous quality improvement.

The next process is to set up the mark distributions and type for all the assessments and aligned them to the learning outcomes on Mark Distribution module. This module is present based on the assessment techniques declared in the CA system previously. For example, if the coordinator declares that quiz and final examination as the assessment to achieve LO of the course, both assessments will also appear in the Mark Distribution Module. This is to gives the idea that module in MySIS could communicate to each other by synchronization. In the current practice, the course coordinator should click on the LO box and this click indicate that particular LO is measured through that assessments. The system control the process by ensuring that each LO is clicked at least once. Therefore, the CA concept is implicitly applied on the Mark Distribution Module.

e-Marks module is a platform for the lecturers to key in the marks of their students. e-Marks module cater for both the coursework and final examination (if any) marks. The layout of the e-Marks is unique from one course to another since it is depending on the previous declaration in the previous module. In particular, LO is first determined and declared on CO module, the alignment of LO and assessment is first declared on CA module and the marks for each assessments is first declared on the Mark Distribution module. This is to imply that these different module within MySIS are highly synchronize to ensure consistency of the information. Although the layout of the e-Marks is different from one course to another, it is appear based on the assessment technique and not based on the LO. This is to simplify the key-in process in which for example, if a particular assessment technique corresponds to two LOs (hence two different marks and two different column), the column to key-in the marks is position side-by-side.

Finally, the system will gather the marks in the e-Marks module based on the LO to generate the radar graph of iCGPA. Radar graph of iCGPA consist of nine arms that are align with the MQF learning domain. In order to determine to what extend a student has achieved a particular learning domain, the system need to 'read' the marks based on the LO since each LO has been mapped with their respective learning domain (either cognitive, affective or psychomotor learning domain) in the CO module earlier. Hence, the way the system gather the marks from the e-Marks module echoed from the early setting of the LO by the course coordinator in the CO system. For example, if a LO is mapped to two different assessment techniques, the system will gather marks from that two different assessment techniques and calculate it in the form of common CGPA point. However, the radar graph of iCGPA should represent the holistic performance of a student in that particular semester. For example, let say a student scored 3.42 point for his Knowledge arm and 3.00 point for his Problem Solving Skills arm in the radar graph of iCGPA, this value is actually a cumulative value from several courses of that current semester. Table 2 depicts the example:

Table 2: Calculation formula by the system to generate radar graph of iCGPA

Course and LO	iCGPA Performance	Knowledge	Problem Solving
1. Course A			
LO1 (Knowledge)		LO1 (Course A)	LO2 (Course A)
LO2 (Problem Solving)		+	+
LO3 (Problem Solving)		LO1 (Course B)	LO3 (Course A)
2. Course B		+	+
LO1 (Knowledge)		LO2 (Course B)	LO3 (Course B)
LO2 (Knowledge)		/3	/3
LO3 (Problem Solving)		=	=
		3.42	3.00

Based on Table 2, the student enrolled in two courses whereby Course A consist of three LOs (one LO is Knowledge and another two is Problem Solving) and Course B also consist of three LOs (two LO is knowledge and one is Problem Solving). So the system will accumulate scores of similar type of LOs (in this case, knowledge-based LO and Problem Solving-based LO) from similar or different courses and average it according to the number of LOs involve to achieve the iCGPA performance. Once this process is completed, the radar graph of iCGPA will be made available to the students in Student Portal platforms.

4. Conclusion

The iCGPA initiative has brought tremendous changes both in conceptualizing it according to UPSI niche and system requirement. As an educational university, the iCGPA model must reflect UPSI core business and at the same time, system development should run parallel to ensure effective execution of iCGPA. The existing MySIS system that boasts CLOM already entrenched OBE concept as devoted in iCGPA. However, there are several improvement to the existing modules and development of the new module (i.e. Course Outline (CO), Constructive Alignment (CA), Mark Distribution, and E-Marks) to realize and pave the way for the iCGPA implementation. To ensure a successful implementation of iCGPA, it should not solely depend on the development of the system, but the common understanding behind iCGPA concept among the users (e.g: course coordinator, lecturer, academic administrator) are equally important. Though the current reforms in UPSI academic system are thorough, UPSI is committed to sustain the academic system from time to time.

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Exploring the Complementarity of Problem Based Learning with Outcomes Based Education in Engineering Education: A case study in South Africa

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Abstract

Problem Based Learning (PBL) is being argued as the way forward in engineering education within the Outcomes Based Education (OBE) environment. The various issues related to OBE and PBL have been examined by seveal sholars, however, whether they can complement each other has not been explored explicitly. Therefore, the objective of the study was to examine the complementarity of the PBL and OBE in engineering education. The study was conducted by using a case study of a University of Technology (UoT) in South Africa. Evidences from the stakeholders' perceptions such as students and lecturers as well as evaluation of the student works in the workshops and assignments designed by the lecturers suggest that OBE and PBL can complement each other. Also, if industry problems are integrated with the learning programmes of engineering education in UoTs, the desired outcomes and higher competency among the students can be attained.

Keywords: competency, engineering education, industry problems, outcomes based education, problem base learning

Type of contribution: research paper

1 Introduction

Outcomes Based Education (OBE) is prevalent in engineering education in the Universities of Technologies (UoT) of South Africa. However, questions are raised whether OBE enable attainment of the requisite learning outcomes and make the students competent. Consequently, Problem Based Learning (PBL) is argued to be an alternate form of education that could suffice to the challenges of achieving outcomes and competence in tangible forms.

According to scholars such as Biggs (1999), and Biggs and Tang (2007), OBE is one of the most effective teaching and learning methods/facilitation process which imparts deep learning. In the OBE, the teaching and learning is constructively aligned with regards to the intended learning outcomes (ILO), teaching and learning activities and assessment tasks. Consequently, it is argued that deep learning is objectively possible through constructive alignment of the learning programme or the course as the case may be (Tagg, 2003). In this case the outcomes are always associated with every set of activities one decides to perform. The ILOs, apparently decide the methodology and its implementation to achieve the desired end results. This becomes more relevant specifically in higher engineering education where knowledge and/or skill are essential not only to achieve competency but also to find engineering solutions to non-engineering socio-economic challenges and for the public goods. Consequently, it becomes more essential that- outcomes of a subject, teaching and learning activities and assessment tasks need to be appropriately- constructively aligned to achieve the desired level of success (Barsoum, 2017; DfES, 2006; European Commission, 2001; OECD, 1996). There are two parts to the constructive alignment, first, students construct meaning from what they do to learn and second, the teacher aligns and contextualises the planned learning activities and learning resources with the learning outcomes (Barsoum 2017; Biggs 1999; Biggs and Tang 2007; Dreyer, Engelbrecht and Swart 2012). The basic premise on which the whole system lies is that the curriculum and syllabus are designed in such a way that the teaching and learning activities and assessment tasks are aligned with the learning outcomes that are intended in the course or the programme (Divjak and Kukec, 2008; Ramsden, 2003). Also, Structure of Observed Learning Outcomes (SOLO) taxonomy or revised Bloom's taxonomy usually creates the ILOs and aligns the teaching and learning activities and assessment tasks. For example, the outcome statements should contain a learning activity, "a verb" that students need to perform to best achieve the outcome. The verb says what the relevant learning activities should be that the students need to undertake in order to attain the ILOs. It also helps to map the levels of understanding that can be built into the ILOs and to create the assessment criteria and rubrics (Brabrand and Dahl, 2009; Biggs and Tang, 2007).

However, the OBE system education is criticised from the point of view that constructive alignment is virtually impossible to get fully right. Also, it limits the students to the cognitive learnings and refrain from exploring beyond the obvious (Brady, 2006; Donnelly, 2007; McCarthy, 1993). Besides, it is also uncertain that whether the requisite learning outcomes attained and students achieve the desired competency level. One of the challenges of measuring the outcomes and competency in OBE enabled theoretical based courses is that it is very complicated and it is nearly impossible to assess different cognitive and competency levels through the conventional assessment methods (Brady, 2006; Donnelly, 2007; McCarthy, 1993).

Problem-based learning (PBL) on the other hand is a curricular design and pedagogical method in which a student learns by using real-life problems and situations. It is usually conducted in small groups with specialised knowledge and to solve practical and real life problems. It emphasises on the individual independence and communication and discussion skills among group members (Chen, 2008; Duch, Groh, Allen, 2001). It is basically student or learner driven in which students explore and try to solve open-ended problems in small, collaborative seminar groups where lecturers take on the role as 'facilitators' of learning. In this process it is argued that while the students contribute individually and in groups it also engenders specific cognitive characteristics in the student's, such as recognizing and updating knowledge deficits through self-directed learning (Biley and Smith, 1998), critically reflective (Williams, 2001), and being autonomous and unafraid to challenges (Biley and Smith, 1998; Moore, 2009).

According to scholars, there are three main requirements of PBL— learning by doing, learning in the context, and focusing on the student (Chen, 2008). In PBL, the students work through problems in a systematic way to accomplish learning objectives that have been identified by them and each problem is overseen by the teachers. Evaluation based on the goals set by the students and the learning outcomes of the subject is the vital characteristics of the PBL (Alavi, 1995; Barrows, 1988; Rideout and Carpio, 2001; Solomon, 2011; Wolf, 2007). In the process, it also allows to move away from the traditional process of teaching and learning and offers the students flexibility to learn according to the context and environment (Dattilo and Brewer, 2007; Özbıçakçı, Bilik, İntepeler, 2012). PBL has been in vogue in fields of study such as nursing, medicine, etc., across the world. It is yet to practice significantly in certain fields of study such as engineering particularly in South Africa, although it has started to place its foot in the engineering education landscape. However, like OBE system, achieving the intended learning objectives is one of vital characteristics of PBL (Dolmans, Gijselaers, Schmidt, 1993; Özbıçakçı, Bilik, İntepeler, 2012), which provides opportunities for linkages between the two.

Nevertheless, while the implications of both OBE and PBL have been studied in different contexts, whether PBL and OBE can complement each other and enable students to attain the desired outcomes and competence have not been explicitly studied particularly in the context of engineering education in South

Africa. Therefore, the objective of this paper is to examine whether PBL and OBE can complement each other and how PBL can be integrated into OBE in Engineering in South Africa. For this purpose, a case study was performed by considering the Central University of Technology, Free State in South Africa. A survey, two workshops and focus group discussions were conducted to collect data on perceptions of the stakeholders such as students, and lecturers as well as evidences on the working of PBL. Findings suggest that students and lecturers are open to PBL and is relevant to engineering education. The lecturers could able to frame industry based problems (assignments) within the framework of OBE in consultation with the industry and challenge partners. The students participated in the workshops could bring out engineering solutions to relevant industry related problems within a limited time period showing an acceptable competency level in higher cognitive attributes of OBE such as analysis, design and problem solving. Thus, OBE and PBL can complement each other and if industry problems in consultation with industry partners are integrated with the learning programmes of engineering education in UoTs, the desired outcomes and higher competency among the students can be attained.

2 Methods

A survey research method was used to collect both qualitative and quantitative data. Also, two PBL based workshops were conducted followed by focus group discussions. Besides, certain lecturers were assigned to develop PBL assignments for the courses they offer in undergraduate engineering education. The survey was conducted among the 40 participants of the workshops (both lecturers or students) by use of a pre-tested questionnaire through convenient sampling process. The questionnaire was prepared based on the lessons learned from the literature review and experiences from case studies of different PBL based offerings in the universities such as University College London (UCL), UK. The various parameters included in the questionnaire are acceptability and usefulness of the PBL, prerequisites such as knowledge, and competency before developing PBL assignments, pre-requisite knowledge and skill required for the students, role of industry and challenge partners, importance of multi-disciplinary engagement, etc.

Further, for hands on experience of the lecturers and students on OBE based PBL, two industry related PBL workshops were conducted in which 12 lecturers and 28 students were participated. The workshops were facilitated by two facilitators for two days each. A number of industry partners and challenge partners were invited to interact with the participants of the workshops and provide feedbacks on the work of the participants. The challenge partners included the stakeholders to whom the problem belongs to; they are the people belonging to Government, municipalities, entrepreneurs, business men, etc. The role of the challenge partners is to provide feedback on the alignment of the PBL assignment students chosen with the societal or industry challenges, its acceptability, available alternatives, sustainability, cost, etc. The industry (technical) partners include the people who would provide technical and design guidance based on their experience and knowledge. Further, academicians were invited to provide support the students with theoretical knowledge on design and technology. The students and lecturers selected belong to three engineering disciplines such as Civil Engineering, Mechanical Engineering and Electrical, Electronics and Computer Engineering. The students were divided into groups of three to five students having at least one student from each engineering discipline in each group. The lectures participated in the workshop acted as mentors to the designated groups. The groups and mentors were decided before the start of the workshop and informed to the participants. The workshops were structured according to a time constraint schedule of events and activities. The sequence of events and activities include introduction of the PBL and providing theoretical back ground and delineation of outcomes, selection of problems by the groups, discussion among the groups, preparation of design brief, discussion with challenge partners to finalise the problem, finalisation and presentation of the design brief, conceptualisation and creation of alternatives, discussion with industry partners, selection of the final alternative, design, presentation and evaluation of the final design.

Also, a focus group discussion was conducted among the students, lecturers, industry partners and experts participated in the workshops. The discussions were conducted by non-structured informal interview and group discussion methods and the opinions and narratives were compiled. In continuation of the process, the lecturers were assigned to develop PBL premised teaching and learning tasks and assignments and incorporate them in their course works. In this context, the lecturers have undertaken industry visits and made discussions with industry partners to formulate industry based problems.

The data collected, the outcomes and lessons from workshops and focus group discussions were analysed both qualitatively and quantitatively. The survey data were analysed by use of descriptive statistics and percent analysis. The qualitative data were analysed by use of narrative and interpretive methods under the themes such as requirements and challenges of OBE linked PBL, role of industry and challenge partners, and integration of the PBL into the curriculum. The teaching and learning and assignments prepared by the lecturers were evaluated by comparing with the OBE premised constructive alignment and PBL tasks and assessments.

3 Results

Three aspects such as perception of students and lecturers on acceptability and relevancy of PBL in engineering education, student performance on PBL assignments during the workshops and OBE linked PBL assignments prepared by the lecturers in order to integrate them into the teaching and learning tasks were analysed. The results of these analyses are presented in the following sections.

3.1 Perception of students and lecturers on acceptability and relevancy

Table 1 presents the perceptions of lecturers and students regarding the various issues related to acceptability and relevancy of PBL in engineering education. The evaluation was made under three aspects such as (1) acceptability, relevancy and usefulness for engineering education, (2) pre-requisite knowledge and skill required and (3) challenges with regards to PBL. It is found that most of the respondents (92.5%) found it relevant. It is acceptable to more than three fourth of the students and four fifth of the lecturers. According to the majority of the students and lectures it can enhance both practical and theoretical knowledge, although a higher percentage (85.5%) of respondents perceive that it will enhance more practical knowledge than the theoretical knowledge (72.5%). Further, PBL is found to be an enjoyable experience to a majority (77.5%) of the respondents. These findings indicate that PBL in engineering education is acceptable to both students and lecturers as well as relevant and useful and can assist in enhancing both theoretical and practical knowledge.

However, there is a need for certain pre-requisites for the implementation and success of PBL in engineering education. It is revealed that according to 77.5% of the students they should have prior theoretical and practical knowledge that are required to solve the problems and 85% students perceive that cognitive abilities such as analytical skill (72.5%), design and creativity (85.5%) are highly essential to succeed in PBL. Also, more than 75% respondents believe that multidisciplinary knowledge is essential. Besides, although presentation skill is essential, a relatively lesser segment of the respondents perceive that it is necessary as a pre-requisite. Therefore, it is found that prior theoretical and practical knowledge on the subjects and availability of multidisciplinary knowledge at an appropriate level should be the precursors to the PBL. Further, cognitive abilities such as analytical skill, design and creativity are imperative before taking of PBL.

Time constraint is found to be the most important challenge followed by intensiveness and stressfulness. Respondents found that the programme is highly intensive and stressful because of the pressures to deliver within a limited time frame. Narrowing down to relevant industry problem linked to broader socio-economic challenges, availability of industry partners and challenge partners remain concerns. However, adaptability to a heterogeneous group is not a major challenge. Thus, it is imperative that while designing PBL, scheduling of activities and time required for deliverables should be appropriately done. Besides, appropriate challenge partners and industry partners who would provide timely and relevant feedbacks and inputs should be an integral part of the PBL.

Table 1: Perceptions regarding PBL in engineering education.

Aspects	Total sample size N	Frequency	Percentage
Acceptability, relevancy and usefulness			
PBL is relevant	40	37	92.5
PBL is acceptable to students	30	23	76.6
PBL is acceptable to lecturers	12	10	83.3
PBL is useful to enhance theoretical knowledge	40	29	72.5
PBL is useful to enhance practical knowledge	40	34	85.5
PBL is useful to enhance both theoretical and practical knowledge	40	32	80.0
PBL is enjoyable	40	31	77.5
Prerequisite knowledges and skill required			
Theories and principles	40	31	77.5
Analytical skills	40	29	72.5
Design and creativity	40	34	85.0
Multidisciplinary knowledge	40	30	75.0
Presentation skill	40	27	67.5
Challenges with regards to PBL			
Time constraints	40	37	92.5
Adaptability to heterogeneous group works	40	19	47.5
Narrowing down to a relevant industry based problem linked to broader socio-economic challenges	40	23	57.5
Availability of appropriate challenge partners	40	27	67.5
Availability of appropriate industry partners	40	25	62.5
PBL is intensive and stressful	40	29	72.5

3.2 Student performance on PBL assignments during the workshops

The students participated in the workshops were asked to work on an industry related problem premised upon then the Sustainable Development Goals (SDG) of the United Nations. The deliverables and intended learning outcomes (ILOs) were set and informed to the students. As mentioned in the methodology section the students were grouped heterogeneously and mentored by lecturers. The challenge partners and industry partners were invited to discuss with the groups on the problem and provide their feedbacks. The deliverables and outcomes were evaluated by a panel by use of a rubric such as relevancy, design brief, conceptualisation, alternatives, design and final product. However, it was difficult for the groups to come up with a detailed design or product within the limited time. So, the outcomes were measured based on the conceptual designs. The performance and competencies were measured on the level and quality of outputs of the groups. The snapshot of a problem worked on by a group in the workshop is provided below.

The challenge: Affordable manufacturing of medical implants and accessories for all in Africa

The problem: Manufacturing of mobility equipment for physically challenged people in the rural areas of South Africa.

Background to the challenge and the problem:

According to Census, South Africa, 2011 (Census, SA, 2011), that 2870130 South Africans (7.5%) live with various disabilities and the demographic profile shows that black Africans have the highest probability of disablement. Although, the provision of mobility devices is an integral part of the national health-care system, lack of access to affordable assistive devices remains a challenge in South Africa particularly in rural areas. It is observed that majority of the people with mobility disability are largely poor and predominantly belong to non- urban areas. The lack of access to affordable assistive devices translates into social and economic isolation, leading to limited participation in community life and advancement in other spheres of life. Despite the existence of numerous legislations pertaining to access, many persons with disabilities still have an unmet need for assistive devices, limiting their inclusion in many activities. Besides, limited usage of assistive devices is more prevalent among the black Africans compared to other population groups. Thus, there exist a need for affordable manufacturing of mobility equipment for physically challenged people in South Africa.

Objective: The objective was to design a motor driven wheel chair conforming to the South African National Standards (SANS) that can be manufactured by use of locally available materials, which is suitable to the rural areas (can move on non-paved or gravel roads/ pathways) and affordable.

Methodology and learning tasks: The methods include review of wheel chair products available currently and their design, analysis of locally available materials and identification of appropriate materials and use of design software to design the product.

The team: The team constitutes two persons from electrical engineering, two from civil engineering and one from mechanical engineering. The team was mentored by one lecturer from electrical engineering with software and modelling background and one from mechanical engineering with product manufacturing back ground.

The challenge partners identified were Government – Department of health, Hospitals, Research institutions (Product Development Technology Station (PDTS), of the Central University of Technology, Free State, South Africa), Civil Society and physically disabled people. The industry partners identified were local manufacturing industries.

Although, the ultimate outcome was manufacturing an affordable motor driven wheelchair, the ILO of the group in the workshop was to develop a conceptual design of a wheel chair of desirable characteristics as envisaged by the group.

The final design

Figure 1 presents the final conceptual design of the affordable wheel chair that can be used by mobility disabled people in the rural areas of South Africa.

Figure 1: Conceptual design of the affordable wheel chair.

The snapshot provides the example of the framing of an industry related problem that is socio-economically relevant (in alignment with SDG) and the teaching and learning activities and assessment tasks are constructively aligned with regards to OBE. The assessment of the design was conducted by use of the rubric as mentioned above in terms of relevancy, design brief, conceptualisation, alternatives, design and final product. According to the assessment panel, the product and design envisaged are relevant, the design brief was well prepared and clear, the conceptual design was acceptable in the context of rural areas. Comparative cost analyses were also conducted. The product could be significantly cheap and can be affordable to people in comparison to the products available currently. However, according to the design team, the full design and product development may take at least four months. Although, the full design could not be made and competency level could not be evaluated in absolute terms, the PBL work indicates that the students could bring out engineering solutions to relevant industry related problems within a limited time period showing an acceptable competency level in higher cognitive attributes of OBE such as analysis, design and problem solving.

3.3 OBE Linked PBL assignments

In conjuction with the workshops conducted, the lecturers were provided with the task to develop PBL based assignments to be incorporated in the teaching and learning activities of the subjects they offer. For this purpose, they had to visit the industry or workplaces to explore different industry related problems that they are looking to embark upon. Further, lecturers and industry partners were engaged in a series of the discussions to narrow down to a number of industry problems based on which PBL problems were developed as assignments.

The snapshot of such an assignment is provided below.

Assignment title: Temperature control of refrigerator system for a craft beer manufacturing system

Purpose:

The purpose of this assignment is to develop a control system for the switched systems in a craft beer brewer. The switch will enable the temperature of the brewer to be always maintained between 18^0C and 23^0 C to ensure a perfect brew. The aim of the project is to first create a mathematical model on MATLAB to meet the said condition and then implement the model using a lightbulb to ensure that model can work in real life scenario. The implementation need to be done using an Arduino interface with a solid state relay and a temperature sensor.

Intended Learning Outcomes:

The students will able to: (1) design a mathematical model by using the Simulink of MATLAB software to develop a control system for the switched systems in a craft beer brewer, (2) construct the hardware set up by using Arduino interface with a solid state relay and a temperature sensor and (3) apply it to test its working in the real-life scenario.

Equipment needed: The equipment needed are Arduino Uno, Lightbulb, Solid state relay, and Temperature sensor

Software needed: The software to be used are MATLAB and Arduino.

Cognitive learning activities on the propjet:

1. Create a system block diagram
2. Design the mathematical model of the system
3. Create a Simulink model to control the relay
    a. Model to read the temperature of the light bulb
    b. Store the two values 18◦ Celsius and 23◦ Celsius as reference points
    c. Switch ON the model at 18◦ Celsius and OFF at 23◦ Celsius.
4. Construct the hardware setup with the Arduino as the interface between the software and hardware
5. Test the working of the model
6. Recreate the model with a P control and theorize your work by stating the necessity of P control over an ON/OFF control.

Assessment tasks:

The assessment of the project will be conducted based on the successful completion of the tasks such as software modelling, hardware modelling, design and construction of hardware set up, testing of the working of the model and presentation. The assessment will be conducted by use of a relevant rubric.

Challenge partners and industry partners: The challenge partners are the craft brewer industries and the industry partners include software industry and relay manufacturing industry.

Based on the snapshot of the assignment, Table 2 provides OBE premised constructive alignment of the assignment with regards to ILO, teaching and learning activities and assessment tasks.

Table 2: OBE premised constructive alignment of the PBL assignment

ILO	**Teaching and learning activities**	**Assessment tasks**
Develop a control system for the switched systems in a craft beer brewer	Preparation of system block diagram, Use of MATLAB for developing mathematical model of the system,	Software modelling, Hardware modelling,

	Use the Simulink model to control the relay, Use of Arduino as the interface between the software and hardware to construct the hardware setup, Testing of the working of the model, Re-creation of the model with the control and theorize the work by stating the necessity of P control over an ON/OFF control.	Design and Construction of hardware set up, Testing of the working of the model and Presentation.

The snapshot of the assignment shows that the assignment framed is an electronics and electrical engineering industry related problem that needs the multidisciplinary knowledge from the fields related to control systems, computer science, software development, thermodynamics, and mathematics, and is relevant to craft brewer industries. The ILO of the assignment is found to be aligned with apposite teaching and learning activities and assessment tasks that is the hallmark of OBE. Thus, it is found that the lecturers could able to frame industry based problems within the framework of OBE in consultation with the industry partners.

4 Discussion and conclusion

The perceptions of the students and lecturers indicated that the PBL is both acceptable and relevant and it has the ability to enhance both practical and theoretical knowledge. It needs a certain pre-requisite such as students should have prior theoretical and practical knowledge as well as analytical skill, design and creativity. Although, time constraint could be a challenge and make it a little stressful, it could be an enjoyable experience. Further, while the role of challenge and industry partners are critical, their availability and integration in the learning process is a challenge. According to the focus group, PBL is more relevant to industries and can make the industries work closely with the academic institutions of higher learning. The teaching and learning activities such as projects and assignments should be based on actual industry based problems and need to be developed in consultation with the industrial partners.

Further, according to scholars, PBL is a curricular design and pedagogical method that is focused on the learner. It used real-life problems and situations to stimulate students' learning (Chen, 2008; Duch, Groh, Allen, 2001). The students explore challenging, open-ended problems that has both society and industry relevant. OBE suggests that the ILOs are constructively aligned with teaching and learning activities and assessment tasks. The teaching and learning activities are generally premised on the cognitive learning activities such as understanding, demonstrating, applying, analysing, evaluating, design, creating, etc., (Biggs and Tang, 2007). As such these cognitive learning activities are the basic and essential requirements and outcomes of the successful completion of PBL projects. The evidences from the PBL assignments show that the three main requirements of PBL- learning by doing, learning in context, and focusing on the student are achieved as well as the problems were well structured and pragmatic (Chen, 2008). In this regard, it is evidenced from the workshops conducted that the students could bring out engineering solutions to relevant industry related problems within a limited time period showing an acceptable competency level in higher cognitive attributes of OBE such as application, analysis, design and problem solving (Tagg, 2003). Based on these evidences it can be construed that OBE and PBL can complement each other and if industry problems in consultation with industry and challenge partners are integrated with the learning programmes of engineering education in UoTs, the desired outcomes and higher competency among the students can attained.

However, the study has certain limitations such as it is based on limited survey data and two workshops. Therefore, further investigations are necessary with actual implementation of PBL within an OBE environment from a number of engineering programmes, which would provide higher insights to the issue.

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A Conceptual Framework for Choosing Problem-Based Learning (PBL) or Traditional Approaches in Sport Coaching

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Abstract

Singapore's sport masterplan Vision 2030 seeks to build inclusive communities and social cohesion through sport. To achieve this, we will need sport coaches who are trained holistically in terms of technical skills and pedagogy. The Diploma in Sport Coaching programme of the Republic Polytechnic (RP) in Singapore, which trains students to be professional sport coaches, is an integral part of this endeavour.

Problem-Based Learning (PBL) is a key pedagogy practised in RP. Essentially, this entails a collaborative approach between the coaches and the learners. The coaches inculcate a conducive learning environment, provide appropriate facilitation and learning scaffold, and administer appropriate assessments to provide useful feedback to the learners. Correspondingly, the learners build a capacity to reflect, leverage on self-directed learning, build upon prior knowledge as well as engage in collaborative learning with their peers.

While PBL has been adopted in many disciplines, it is still rather new in the realm of sport coaching. While the traditional approach to sport coaching relies primarily on direct instruction whereby coaches demonstrate and students mimic the physical movements, the future of sport coaching will have to embrace more contemporary modalities. This is especially so in elite performance coaching whereby coaches will not be able to perform as well as the athletes; hence, they will not be able to fully rely on the traditional approach. In such situations, how can coaches continue to 'coach' and add value to their athletes?

In this paper, observations and reflections of sport coaching based on the traditional didactic approach and the PBL pedagogy in four sports are discussed. Following this, a framework to guide coaches on when and how the different pedagogical approaches may be employed is proposed. It is hoped that this paper will contribute to the body of knowledge for the development of instructional strategies in coaching various other sports.

Keywords: Problem-Based Learning, pedagogy, curriculum, sport coaching.

Type of contribution: Review/Conceptual paper

1 Introduction

Problem-Based Learning (PBL) has been adopted in numerous field of studies, particularly in medicine and engineering (Barrows & Tamblyn, 1980; Echavarria, 2010). Even though it has been practised in varying extent for some time, its suitability is still hotly debated (Koh, 2016). This paper is an attempt to apply PBL beyond the pursuit of academic studies, such as for sport coaching.

Accordingly, the objective of this paper is to reflect on and discuss the experience in applying PBL in sport coaching and comparing this with the traditional didactic approach. Following this, a framework to guide coaches on where and how the different pedagogical approaches may be adopted is proposed. It is hoped that this paper will not only contribute to the body of knowledge on PBL, but also augment the knowledge and skills of coach developers and coaches in the realm of sport coaching.

2 Literature review

Vision 2030 is the masterplan for sport development in Singapore. It seeks to build inclusive communities and social cohesion through sport. To achieve this, the continual upgrading of the competencies of sport coaches will be crucial. The Diploma in Sport Coaching programme of the Republic Polytechnic (RP) in Singapore, which trains students to be professional sport coaches to support the development of the sport industry is an integral part of this endeavour.

The development of the PBL was motivated by the desire to have alternative approaches to teaching and learning beyond the traditional didactic approach. In particular, the latter is generally characterised as teacher-centric where the teacher is regarded as an expert having all the knowledge. Correspondingly, the learners learn by being totally dependent on the information disseminated by the teacher.

On the other hand, PBL entails a collaborative approach between teachers and the learners, as well as among the learners themselves. Instead of positioning himself or herself at the centre of learning, the teacher who employs the PBL plays the role as a facilitator and places the learners as the centre of learning. The teacher seeks to create a conducive learning environment, provides appropriate facilitation and scaffolding, and administers appropriate assessments to provide useful feedback loops. Correspondingly, the learners will build a capacity to reflect, leverage on self-directed learning, build upon prior knowledge as well as engage in collaborative learning with peers (Republic Polytechnic, 2018).

Kolmos, De Graaaff, and Du (2009) have crystallised the various models of PBL taking into cognizance that the principles of learning should include not just dealing with the substantive contents, but also cognitive learning around problems, and collaborations in the social contextap. Beyond the description above, there were also attempts to frame PBL not as a distinct pedagogy, but as an evolution from the traditional teaching approach. In this regard, Walton and Matthews (1989) tried to position PBL as a general education strategy rather than merely a teaching method. Harden and Davis (1998) treated PBL as a continuum between problem-based learning and information-orientated learning, and sought to avoid the polarisation of viewpoints between enthusiasts and traditionalists. Likewise, Ashworth and Mosston (n.d.) explained that teaching styles will manifest themselves as a spectrum rather than isolated pedagogical ideologies. In a similar vein, Maudsley (1999) postulated that PBL can be considered as both a pedagogical method as well as a philosophy for teaching and learning.

With regard to implementation of PBL in practice, Duncan and Al-Nakeeb (2006) highlighted that while PBL offers advantages in terms of student enjoyment, engagement and development of criticality compared to traditional approaches, it will require more time and teaching resources. Jones and Turner (2006) as well as Chow, Tsai, and Louie (2008) similarly noted that the interactive dynamics in a PBL lesson would naturally be resource intensive. In addition, there were also other learning difficulties highlighted. At times, learners became frustrated with the problematic scenarios posed and the ambiguity therein. Some of them found it challenging to speak up as they preferred to just listen and let the teachers do most of the talking like in a conventional classroom. There were also some learners who were reluctant to work in groups and preferred to learn as individuals instead. Not unexpectedly, personality or cultural issues of the learners as well as the teachers would exert an influence also.

Notwithstanding the challenges, the potential merits of using the PBL pedagogy cannot be ignored. Jones and Turner (2006) found that it provided opportunities for students in sport coaching to truly apply theoretical knowledge in practical situations and this allows students to better appreciate the inherent complexity of coaching. As PBL is a key pedagogical approach employed by RP for all courses of study, including the Diploma in Sport Coaching, the search for best practices in leveraging on the strength of PBL in the realm of sport coaching will need to continue. Where the traditional approach in sport coaching relies primarily on didactic teaching, whereby coaches will demonstrate and students will mimic the physical movements, the future of sport coaching will have to embrace more contemporary modalities in order to cater to a diverse spectrum of learners with different learning styles and preferences.

A case in point is in elite performance coaching whereby it is likely that coaches will not be able to execute the sporting performance as well as the athletes. In such situations, how can the coaches continue to 'coach' their athletes? Furthermore, the government intends to promote sport beyond the segments of children and youth to also include adults and seniors. For coaches who are more accumstomed to coaching children and youth, what variationa in the coaching approach should they employ to cater to the more diverse backgrounds and physical conditions of the adults and seniors? Thus, faced with the more demanding environment in sport coaching, coaches will need competencies beyond the technical skills of the sport in order to be effective in coaching. They will need to identify 'how' to teach in addition to 'what' to teach.

3 Approach

According to Lewis, Perry, and Hurd (2002), lesson study is a form of inquiry in which several teachers collaborative to plan, teach, observe, review and share the results of of their learning. In the process, the teachers carefully explore how learners learn, think and implement change as a result of the lessons. Lewis et al. (2002) added that the practice of lesson study can lead to instructional improvements as teachers can become more knowledgeable about how their students learn.

The approach employed in this paper mimics some elements of this. The paper is written based primarily on observation and reflection of the authors from their experience over the years performing the roles of sport coaches, coach educators, and curriculum developers for sport coaching programmes.

Rather than having pre-determined stages for conducting a survey or an experiment, in this study, the learnings were accumulated over a journey of observation, discovery and reflection. Based on this, a conceptual framework is recommended with the hope that it will help to inform practice. The observation from several sports also allowed the unique contexts situated in the coaching of each sport to be discussed.

4 Discussion

4.1 Taekwondo

In Singapore, taekwondo classes are commonly available at the community clubs, schools or private coaching academies. The typical learners include children, teenagers, as well as adults and seniors. The particular learning moment discussed here is the teaching of roundhouse kick, a common martial art movement.

Figure 1. Phases of roundhouse kick.

In the traditional didactic approach, the coach will typically break down a movement into discreet stages as shown in the figure above and instruct the learners to mimic him or her. It was commonly observed that the coaches do not provide explanations as to 'why' a certain move is executed in a certain manner. The instructions given were largely procedural. Non-conformance with the instructions would be regarded as wrong. It was also observed that it pre-supposed the learners having the cognitive disposition and physical ability to follow the instructions and execute the movement. Correspondingly, when learners were not able do that, the coach would rarely investigate if there could be other reasons that prevented the learners from executing the kicks. Following this, the communication dynamics were dominated by the coach giving instructions and pointing out mistakes. The knowledge and skills of the coach were regarded as of absolute superiority. If at all, learners would only ask the coach questions for clarifications, but there was hardly any sharing of their own reflections on the learning experience.

Indeed, the breaking down of a movement into discrete parts is indeed a common 'regression' technique used in sport coaching. However, when inappropriately performed, such as when learners were asked to pause at rather unnatural junctures of what is supposed to be a continous action, they may become overwhelmed by having to maintain balance rather than executing the kick. Furthermore, excessive feedback by way of coaches merely criticising incorrect movements may also be counter-productive as sufficient time and space should be given to the learners to go through the cycle of learning involving iterations of observation, practice, reflection, and re-attempt.

PBL offers an alternative approach to this teaching scenario more commonly observed in private coaching academies where classes are usually smaller and where the participants are more diverse culturally. For instance, the coach would be conscious that he or she does not want to overload the learners with too many instructions upfront. The coach also recognised that the learners were of different ages and may have different abilities. His or her intention at this stage was to let the learners try kicking within their respective comfort levels and feel how their bodies respond to the stimulus. The coach would ask questions like: "Did you manage to hit the target? Which part of your body feels the stretch? What difficulties do youencounter? What adjustments would you make?

Beyond merely executing the movement, the coach would subsequently challenge the learners to consider how the technique may be applied. He or she may introduce progression by getting learners to form pairs to facilitate peer-to-peer learning, getting them to simulate attacking and defensive sequence with the use of the technique. In addition, the coach will also get the learners to rotate and change partners so that they may encounter varied conditions that will help them internalise their learning on the application aspects of the technique.

Thus, in a PBL lesson, activities were intentionally designed for the learners to develop the capacity to immerse in a cycle of self-directed learning by continuously and spontaneously trying, reflecting, correcting and trying again. In addition, the coach would endeavour to nurture an environment where learners can collaborate in peer learning. Instead of making him or herself the focal point, the coach would scaffold and facilitate the interactions such that the learners were encouraged and empowered to explore and suggest solutions to various learning issues encountered. Indeed, further to learning the techniques, PBL also offers the coach a lot of scope to address the cognitive aspects of sport, such as those relating to the understanding the physical and physiological conditions of each individual learner, and how they may complement their sport training with targeted strength and conditioning, as discussed further in the next example on Yoga.

4.2 Yoga

Learners of yoga attend yoga sessions for varied reasons. Some do it as a form of exercise, others seek out yoga for injury rehabilitation or as a process of self-investigation with the intention of engaging in therapy to alleviate health conditions, such as relieve of chronic pain, depression or Post Traumatic Stress Disorder (PTSD) (Brilliant, 2017). As each learner would come with his or her respective problem, it is unlikely that there a single approach that will suit all learners in the same class. Rather, the practice would be framed by the needs of each learner, and the guidance by the coach would be geared towards solving the specific problem each learner presents. Hence, yoga by nature will lend itself very well to PBL. In fact, if yoga is delivered in a didactic manner whereby the coach will just teach the poses and movements, it will defeat the purpose. Some applications of PBL in the teaching of yoga is discussed below.


Figure 2a


Figure 2b

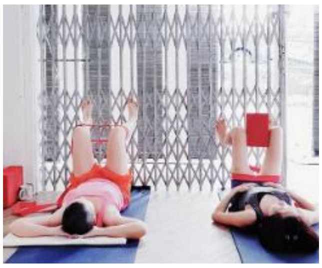
Figure 2c

Figure 2. Yoga poses tailored to unique goals of the learners.

In Figure 2a, straps were placed around the backs of the knees and the legs to help relieve lower back tension. But, the learner initially felt that this solution actually worsen her situation. The coach and learner subsequently collaborated and explored various adjustments taking into consideration the learner's prior learning. Finally, they found the solution by placing two blocks under her feet which made all the differences.

In Figure 2b, the coach shared that when the learner on the right first started practising yoga, she had rather stiff legs and tight hips. As her physical ability improved, so did her cognitive understanding of the purpose of practice. Leveraging on the initial demonstrations by the coach, the learner was able to problem-solve and improvise by increasing the sitting height as she understood how this modification tailored to her specific conditions.

In Figure 2c, the learner on the left has extremely flexible hip joints and her knees were falling out to the sides. She intuitively took a strap to hold them hip-width apart comfortably. Taking cue from her learning partner, the learner on the right placed a block between her knees to engage them hip-width apart comfortably. This stems from her realisation that she has tight hip joints which required the modification as she has made.

It is also observed that the learners in yoga in Singapore are generaly adults from diverse cultural backgrounds. Hence, they are observed to be more amenable to engaging the coach in a problem-solving context surrounding their specific needs. Correspondingly, coaches whose personalities are more engaging will tend to support a more consultative learning environment. These factors can be taken into consideration in the choice of pedagogy to be adopted by the coach.

4.3 Bowling

In competitive ten-pin bowling, athletes have to learn to make tactical decisions. This may be making adjustments of the standing position at the approach area or selecting the appropriate ball. An optimal angle of entry to the pins will have a higher chance of a strike, i.e. all the 10 pins down at first throw. These decisions are significantly influenced by the oiling condition of the bowling lanes. An authoritative coach who uses the didactic teaching approach may instruct his athletes on how to make such final adjustments. Conversely, a coach who uses the PBL approach may seek to build the capacity of the athletes to make such decisions themselves.

For example, a particular oiling pattern was made known to the participants a month before a tournament. In a coach-centered regime and where the coach is domineering, the coach instructed the athletes to tackle such oiling pattern by rolling the ball in a certain prescribed manner. However, during the tournament, there were changes in the oiling conditions due to various factors, such as the topography of the lanes, the varied co-efficient of friction between the balls and the surface of the lanes, the viscosity of the oil which may be affected by the ambient temperature, etc. Hence, the performance of the athletes were below expectation. However, since the coach's instructions were not to be questioned, the ability of the athletes to make tactical decisions on the field of play were observably hampered. When they could not play well, they would look towards the coach hoping to be told the solutions. They also dared not veer from the instructions of the coach as they were afraid of being reprimanded.

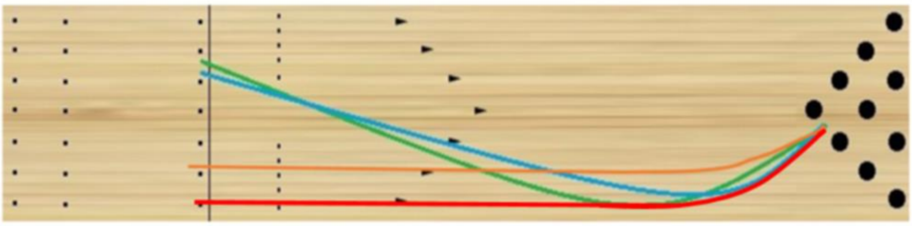

Figure 3. Possible trajectories of bowling ball to tackle different oiling patterns on the lane.

On the other hand, where the PBL approach was employed, the athletes learned how they respond to the changing oiling conditions of the lanes. Initially, the coach would let the bowlers tackle varying senarios in an exploratory manner. The coach would then dialogue with the athletes on how the ball would travel down the lane through the stages of skit, hook and roll towards the pins under various circumstances. The coach then employed performance analysis technology to record and analyse the trajectory of the balls. As the athletes had different playing styles, they were to observe how the different playing styles affect the transitions of the ball and hence engage each other in peer-to-peer collaborative learning. They were also asked to try to develop their own techniques and strategies to deal with changing competitive environment. During tournaments, athletes may seek tactical advice from the coach. Instead of telling the athletes the answers directly, the coach would dialogue with them to recall the learnings they had gleaned from decisions they had made previously. Thus, challenges encountered were turned into learning moments. In such an learner-centred coaching approach, the coach is just a facilitator. Instead of telling the solutions to the learners, the coach could scaffold their learning and build their capacities to collaborate and engage in self-directed learning. There was also a great emphasis on reflections, whereby the athletes would write reflections about their learnings from the day via 'Whatsapp' messages on their way home to the coach. The coach would then leverage on such reflections as feedback for his planning of the subsequent lessons.

4.4 Volleyball

A variety of sports are offered as Co-Curricular Activities (CCA) alongside Physical Education (PE) at schools in Singapore. Specifically, the primary goals are to get the learners to acquire a range of skills to participate in a variety of physical activities as well as to gain some understanding on how to do so. Such educational goals are understandably demanding, especially when there are constraints of limited curriculum time. Accordingly, coaches were observed to place a lot of emphasis on efficiency so as to optimise the on-task time by learners (Martens, 2012). The coaches can then have more observations of the learners' performance and provide more feedback (Metzler, 2011). They would adopt the coach-centered and traditional didactic approach in the lesson design and delivery. They would be the content experts and focus on dissemination of information to the learners. Correspondingly, learners would receive the information as it is, without being encouraged to evaluate, let alone construct their own learning. This approach would also help the coach to deal with learners' behavioural issues.

On the other hand, the same learning outcomes may be accomplished leveraging on the PBL approach when the lesson is conducted in a different setting. For instance, for adults at a community club, he or she is able to do so due to the higher level of maturity in the cognitive and affective domains of adults. It also helps when the coach is not constrained within the time-tables of lessons in a school setting.

In this context, the coach's intention is to provide a safe environment for learners to try, make mistakes, reflect and construct their own learning. He or she would try to activate prior knowledge by asking learners of their past experience, their strength and weaknesses with regard to the sport. He or she would ask the learners to form pairs or small groups to facilitate peer-to-peer learning. Thereafter, he or she would invite the team to play some simulated games with modified rules to focus on different aspects of learning.

At the conclusion of the lesson, the coach would provide a plenary debrief to connect the various learning points. He or she would invite the learners to reflect on what challenges were encountered, explore possible solutions to the them, which may be technical issues related to specific sport skills, tactical issues relating to the performance of the team, as well as physical and physiological issues relating to the conditions of each individual. Very often, the coach will also facilitate a closure, by getting the learnes to reflect what went well can be improved, and what their next personal learning goals are.

In the earlier example about learning volleyball in the PE lesson, the traditional didactic approach was used. It served the coach well as the coaching time and other resources were limited, and class size was huge. As such, on-task practices took priority over learners' discussion. The high volume of practice tasks allowed the learners to achieve the learning outcomee in the psychomotor domain.

On the other hand, the PBL approach was used in coaching the adults. In this context, the coach was able to go beyond teaching the technical aspect of underarm pass to also address the tactical aspect. With more time available and the higher level of maturity of the learners, the coach was able to give them more ownership of their learning through facilitation. Taking a holistic view, it can be seen that both the traditional didactic and PBL approaches in coaching could be deployed to serve different learning situations. There is not a ‘better’ pedagogical approach that a coach should use for any learning situation. Instead, he or she should examine each learning situation and deploy the appropriate approach best suited to support learning.

5 Lessons learned

This paper discussed the pedagogical approaches in the coaching of several sports. Whilst the traditional didactic approach is observed to be more commonly employed, coaches who are familiar with the more contemporary modalities of coaching like PBL were able to leverage on such alternatives to enhance their coaching effectiveness. As the cases studies have illustrated, these are situations where the learners are relatively heterogeneous and their needs are rather varied; where the learning outcome is more focused on developing capacity to engage in continuous self-directed learning in the long term, as where the learning is focus on tactical skills andstrategy. On the other hand, didactic coaching may be preferred in situations where the needs of the learners are relatively similar; where learning outcomes include a specific technical skill, and where the learners have relatively little or no prior knowledge or experience. Additional factors for comparison are summarised below.

Table 1: Traditional didactic and PBL approaches in sport coaching (Adapted from Metzler, 2011)

	Factors	**Traditional didactic approach**	**PBL approach**
1	Learning outcomes	Suitable for technical skills	Appropriate for tactical skills and developing team strategy
2	Teaching environment	Time and resources constrained	Time and resources not constrained. Possible with smaller class size
3	Student developmental stages	Limited prior knowledge	Students have some prior knowledge; ready to engage in the cognitive and affective domains
4	Student learning preferences	More accepted in the Asian context	More prevalent in the western culture
5	Domain priorities	Mostly psychomotor	Psychomotor, Cognitive and Affective
6	Task structure	Simple and repetitive drills	Games, modified plays, practices that require cognitive engagement
7	Sequencing of learning tasks	Instruction, demonstration, practice	Prior knowledge, scaffolding, exploration, dialogue, collaborative and self-directed learning, reflections
8	Assessment of learning outcomes	Primarily psychomotor	Holistic, involving psychomotor, cognitive and affective domains
9	Reflections by coach	Primarily coach-centric	Primarily learner-centric. Coach prioritises feedback and needs of learners

Hence, rather than discussing which pedagogy is superior or more contemporary, we would recommend that PBL can be employed to replace or complement the traditional didactic approach to deal with the variety of coaching situations, as shown in the examples earlier. Other than the choice of pedagogy, the approach to engaging the learners in a classroom or in the sporting arena may also be influenced by the personality of the coach and the techniques he or she may possess. This argument is also recognised in Metzler (2011) who postulated that the choice of pedagogy for a coaching session will be affected by factors including the intended learning outcomes, teaching environment, student developmental stages and readiness, student learning preferences, domain priorities, task structure, sequencing of learning tasks, assessment of learning outcomes, and assessment of instructional practices. Furthermore, as feedback and two-way communications are integral aspects in the PBL learning environment, the successful adoption of the PBL approach will also depend on the existence of a social and learning culture whereby the learners are more predisposed to participate in communications and collaborations, which is more ingrained in the western culture but less so in the Asian context. Beyond that the nature of the sport will also have an impact on the readiness and suitability of the sport in adopting PBL in coaching. As Ojala and Thorpe (2015) shared, creative sport like snowboarding which emphasises personal creativity and expressions may be more amenable to adopt PBL for coaching compared with other relatively more traditional sports.

Reflecting on the application of PBL in medical education, Koh (2016) concluded that PBL should be regarded as a general education strategy and not merely a teaching method, and it represents just one of the many pedagogies rather than it being a panacea. This also holds true in the application of PBL in sport coaching. Accordingly, coaches will have to develop a variety of competencies and equip themselves with a rich repertoire of pedagogies so that they have the versatility to deploy the most appropriate pedagogy to cater to the different types of learners in different situations as shown in Figure 4.

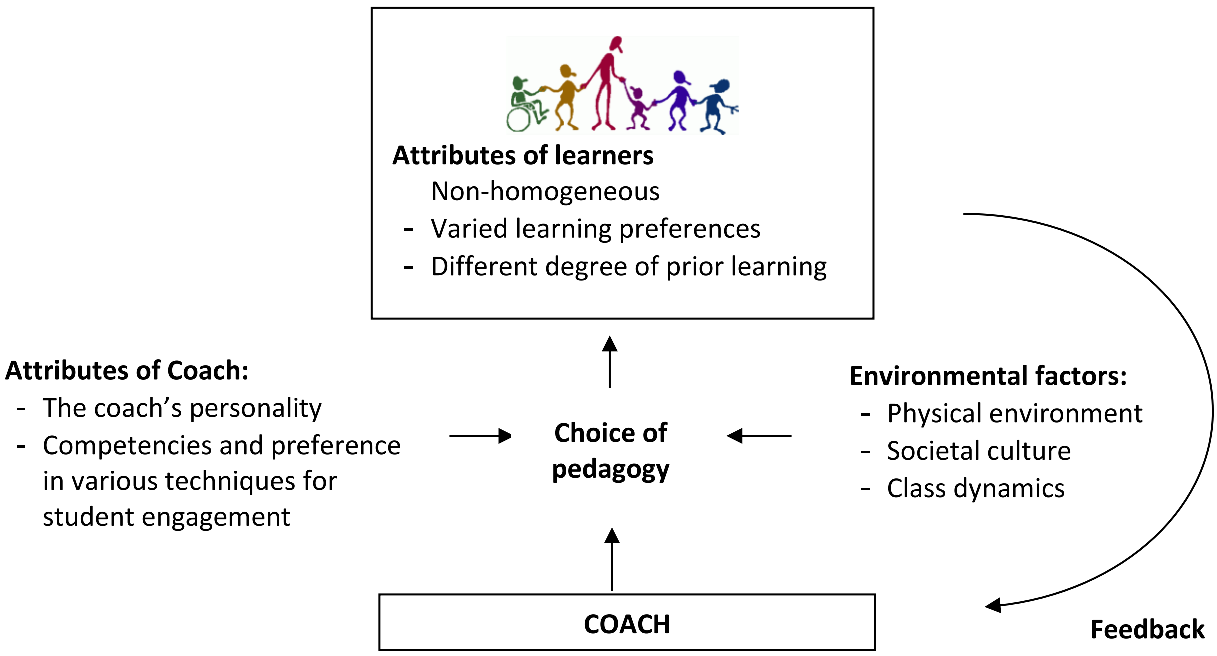

Figure 4. Framework for selecting the pedagogical approach in sport coaching

Consequently, the development of such deeper understanding and competency to discern, choose and apply the appropriate pedagogy to different situations will have to be incorporated into the curriculum for coach development. Beyond this paper, an exploratory study on the adoption and efficacy of the different pedagogies of sport coaching across different cultures and in different sports could be conducted.

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Use of problem-based learning in teaching International Business with imported textbooks from developed countries

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Abstract

The use of textbooks presented the context of developed countries has both advantages and disadvantages for learners and teachers in developing countries. The approach and presentation of content in textbooks of developed countries, especially in the United States, is often different from the approach of Vietnam. Hence, it is logical to apply a more effective teaching method than the traditional approach. PBL therefore was taken into consideration. In International Business course, lecturers and students need to be familiar with many international contents such as modern international trade theories, FDI, managerial issues to overseas workers etc. to solve problems addressed by case studies in the textbook. As a consequence, the use of imported textbooks with PBL implementation would be a very good option as it equips Vietnamese students with the up-to-date knowledge and necessary skills at the same time to adapt quickly with the FDI enterprises' requirements. In this paper, the authors use the observational and quantitative method on lecturers and learners to test the value of using foreign textbook when implementing PBL. The results show that, compared with the traditional teaching method, the ratio of students who passed are getting higher over time and so does their good score range.

Keywords: problem-based learning (PBL), textbook, International Business.

Type of contribution: best practice paper.

1 Introduction

Globalization and Vietnam's open-door policy have led to significant changes in the development of university curricula (VHNT, 2016), requiring an equivalent change in teaching methods. The internationalization of higher education has contributed to improving the quality, learning experience, and bringing students the new career potentials (Anh, 2017). Universities have innovated their teaching methods ten years ago, such as the University of Posts and Telecommunications Technology, to gradually replace obsolete traditional teaching methods. In this context, it is necessary to Duy Tan University (DTU) looking for more appropriate teaching methods. The change from education philosophy to curriculum, learning materials will contribute to the training of people with global thinking, the ability to cooperate and work in the international environment.

Duy Tan University is one of the leading private universities in Vietnam that has grasped the development trend of society, aiming to train learners to work in the international environment as a mission. In addition to improving the facilities with modern facilities, improving the level of teaching staff, the school has chosen a new way to enhance international cooperation with universities having the high prestige to train a high quality human resources to accelerate the integration process of Vietnam with the world. Duy Tan University has transferred the business administration curriculum with Penn State University on teaching methods and resources for specialized subjects. International Business is one of the subjects transferred to equip learners with the knowledge to join the global labor market in the fastest, least barrier-free way. The approach of the authors is to prepare U.S. students with the knowledge and skills to go abroad to work is not suitable to the conditions in Vietnam - the country receiving mainly investment direct human resources, hire Vietnamese employees to work for foreign companies investing in Vietnam. In fact, the labor productivity and quality in Vietnam is relatively low. Vietnam is short of skilled labors. Labors' soft skills such as teamwork skills, foreign language, critical thinking, creative thinking, technology compliance are also quite low. Some areas have to hire foreigners. (Trang, 2018) In order to contribute to addressing this limitation, International Business course in the cooperation program has adapted its approach, syllabus with U.S. curriculum, and problem-based learning (PBL) orientation.

In the Business Administration program, the International Business course is usually taught in the 3rd or 4th year. It requires the prerequisites including Principles of Management, Microeconomics, Macroeconomics, Human Resource Management, Principles of Marketing and Operations Management. This course has two distinct objectives:

(1) Provide knowledge related to international business so that students can apply in the workplace

(2) Perfect students' professional skills such as communication skills (writing, presentation), creative thinking and critical thinking, teamwork skills, information collection and data processing in the real business environment, especially at FDI firms in Vietnam.

Course content consists of two parts: (1) International business environment such as, inter alia, international trade theory, cultural and political differences between countries, and (2) Specific business activities such as how to enter foreign markets, strategies for foreign markets / international business strategies, and general value chain activities including human resources, marketing, production management, logistic, R & D.

With the amount of knowledge needed to transfer as well as the requirement to meet the course objectives, lecturers need a variety of teaching methods, appropriate assessment methods as well as effective support of the learning system. Among them, textbooks are considered as a standard source of information for a subject and a tool for teaching and learning (Graves, 1999). The use of the available textbooks compiled in a country with advanced modern education will save time and resources for instructors. Moreover, with limited time for each course, if there are enough textbooks, the instructors will ask students to read before class then save time on other activities (Hue, 2017). To maximize the role of the textbook in teaching, it is a must to select the appropriate teaching method. As an evident result, the use of textbooks with PBL is a good option. PBL is a learner-centered teaching method that primarily learners in the real context, assigning tasks and specific issues to the learner for solving. Compared to conventional teaching, PBL encourages students to collaborate in groups and automatically learn to address practical issues that are currently a concern of the business. Through this learning method, students are trained in soft skills such as teamwork, creativity, reasoning, critical thinking, information processing, and the way they respond. Currently, the International Business course is assessed as follows: Final score = test score + practice score = (midterm + final exam) * 50% + (attendance + quiz / case-study + project) * 50%. The final exam consists of two parts: a multiple choice test and a brief questionnaire on case studies written in the textbook, if necessary.

After reviewing the above information, this paper aims to:

1. Check the difference in student achievement in the non-PBL and PBL courses.

2. Demonstrate that the use of learning resources from developed countries applied in the Vietnamese environment needs to adjust the content and select appropriate teaching methods.

3. Demonstrate the choice of teaching methods appropriate to each subject in each type of training program. That is why we conducted a study to answer the question: “Although there have been subjective perceptions of the changes, we are not entirely sure of this approach as it is not yet possible to determine exactly how the new curriculum incorporates American curriculum and PBL methods. Are there significant advances in student achievement in this subject?”

2 Literature review

2.1 Textbook structure

With traditional Business Administration approach, International Business course is taught with a variety of books as it only emphasize on transfer the knowledge from instruction to students. Students must listen to lectures, take notes, and ask questions, read a variety of materials to gather information and knowledge. Nevertheless, this method does not promote the development of skills, talents, aptitude and competitive spirit but merely adds the basic knowledge. Since the 2014-2015 year, the course have been switched to PBL approach: knowledge based on practical problems; students are required to work in groups to discuss, research and solve problems under the guidance of their immediate instructor.

Global Business Today 8th - 10th edition by Charles W. Hill was selected to use as textbook for teaching. Its structure consists of 5 sessions: Introduction to globalization, national differences in political-economic culture, international investment and trade, global monetary system and competition in the global market. Among them, session 2 and 5 are the core content that equips learners with both knowledge and skills to participate in the international labor market. To succeed in working abroad, students need to know the difference in political economy and customs of the country. To survive in the global marketplace, businesses need to choose the right international business strategy, choose a model to enter the foreign market, understand the production, global, logistics, marketing, R&D and Human. Understanding the global economy and demonstrating respect for diversity and cultural differences, therefore, is necessary for all involved in business and careers, regardless of size or type of business or career endeavor. Just like the introductory textbook on the McGraw-Hill website, "Global Business Today appeals instructors looking for an analytical approach to the course” and “Global Business Today is known for being practical, which is an important point as many instructors who teach this course are often not researchers, but come from the business world".

The case studies mentioned in the book are real situations from businesses in the US or other foreign countries investing such as Starbucks and Coffee, Apple and IPhone, Business culture in China, Panasonic and Walmart in Japan, Avon, IBM, GM in China, Phillips Overseas Venture, Boeing, Indian Automotive Industry, Global Marketing of Ford, Lenovo, P & G. etc. Attached to the lecture content at the beginning and end of each chapter. Businesses in these case studies are mostly companies from the United States and other developed countries who have gone abroad to find problems with their destination. At the same time, they have been operating in Vietnam such as Starbucks, Panasonic, IBM, Ford, Phillips and employing a large number of Vietnamese employees. According to the results of the Census of Economics in 2017 of the General Department of Statistics, FDI increased by an average of 15 people / 1 business compared to 2012, while the average employed a business fell from 32 to 27 in which state-owned enterprises and non-state enterprises reduced by 20 persons and 3 persons per enterprise respectively. Therefore, the introduction of PBL implementation in International Business for both traditional Business Administration program and BA-PSU is indispensable.

2.2 PBL

The origin of Problem-Based Learning (PBL) derives from Don Woods as he teaches his chemistry majors at McMaster University in Canada. However, the term PBL is really well known in the world after the modern method of education is widely used in medical science at McMaster University. PBL-based learning is primarily based on work among small groups.

There are now many different approaches of PBL implementation (Graaff & Kolmos, 2007) such as “a problem a day” approach, developed by the Republic Polytechnic, Singapore, and named as "one-day one-problem Approach" (every day without a problem). With this approach, students spend a whole day researching a problem. After one week, students will study 5 different but related issues; Problem-based Learning or Online - Use the online teaching methods combined with PBL; or Problem-based Learning in Early Years Education.

Aalborg University's PBL model: In the 70s of 20th century, there are two universities established in Denmark: Roskilde University Center in 1972 and Aalborg University in 1974. The following is a one-semester model designed by the PBL method of Aalborg University, Denmark.

50% courses	**Course** **5 ECTS**	**Course** **5 ECTS**	**Course** **5 ECTS**
50% project	Project 15 ECTS In groups of up to 8 persons		

Figure 1: PBL model of Aalborg University

Conditions for Implementation: The basic theory of PBL is that the learning process shall be mainly based on small groups, so the prerequisite for organizing PBL classes is that the number of students in the class should not exceed 30 students per class. 30 students / class with a small group size of 4-6 students / group will help the group size not exceed 5 groups, which is more convenient for lecturers during the interaction with the group. (Graaff & Kolmos, 2007)

Stakeholders in teaching by PBL: (Powell, 2003) once said, "The biggest challenge for a university's leadership up to now is to persuade the teaching staff. The student renounces the familiar teaching practices that are being applied daily to invest energy in a new form of education in which many new ways of thinking are realized." One of the principles of PBL is to promote the role of classroom lecturers on the condition that the instructor must be and have experienced the process of learning and cultivating experience from a group of co-workers Innovate teaching methodology according to PBL.

Overview of research related to curriculum and learning materials when implementing PBL: In the field of medical education, many studies have been conducted to explore the influence and relationship between the use of the library and the teaching of PBL to medical students. These studies were scattered between 1992 and 2008. (Rankin, 1992) (Marshall JG, 1993) (EA, 2008). From the author Rankin et al. point out that: "Medical Students in PBL and conventional medical school library and Curricula were compared on library and information-seeking competencies, behaviors, and perceptions. The results showed some significant differences (P less than 0.05) between PBL and conventional curriculum students, suggesting that PBL students were more frequent library users, using information resources that supported the independent learning process, acquired information-seeking skills at an earlier stage in their medical education, and reported greater ease in using these skills." (Rankin, 1992)

For teaching economics students, the 2013 study by Satish Nargundkar et al. shows that by using a modified textbook, compiling from the original curriculum and then developing the PBL teaching, the results achieved against the curriculum for teaching traditional teaching methods is very positive. Specifically, "We found that this approach motivated the students and improved their performance on a departmental final exam by about 9% on average, or almost one letter grade. When measured on Critical Thinking Questions alone, the improvement was roughly 24% on average. Finally, it also improved the task group performance by 6%." (Nargundkar, Samaddar, & Mukhopadhyay, 2013) . Based on the study by Satish Nargundkar et al., Hala ML Enaba et al. suggest that for basic marketing classes, in order to apply PBL to teaching, it is essential to have a revised curriculum (a reversed book to improve teaching effectiveness. (Enaba, Fouad, & Nargundkar, 2016)

In Asian countries, a study more than 30 years ago in Thailand shows that "textbooks may affect achievement by substituting for additional postsecondary mathematics education of teachers and by providing a more comprehensive curriculum." (Lockheed, Vail, & Fuller, 1986). At Yonsei University College of Medicine, Korea, in 2002, another study confirms that Asian students are very dependent on the curriculum during their studies. Specifically, "Students rely heavily on using textbooks during their self-regulated learning. And the elements greatly effecting the learning environment are the physical environment and the use of humor in class. " (Y & S, 2002). In Vietnam, PBL is a research field that is not new but still has few results. Currently, there is no study that has evaluated the effectiveness of use of textbooks from affiliate programs with overseas for undergraduate teaching in Vietnam in general and economics and business administration major in particular.

From there, we come to two following hypothesis:

H1: Vietnamese students studying International Business by American textbooks with PBL method will achieve good results.

H2: The combination between American textbooks, PBL method and relevant assessment methodology will better classify students' learning outcomes.

3 Research methodology

3.1 Business Administration program description

International cooperation is a strategy set out from the first days of establishing DTU's International School. The success of collaboration program with Carnegie Mellon University in IT field has created a great turning point in the training of high quality IT human resources. Thanks to it, DTU has continued to sign with Pennsylvania State University (PSU) to give birth the collaboration program (PSU program) in Business Administration, Tourism, and Finance & Banking. The pedagogical feature of the PSU program is a combination of theoretical and practical knowledge that allows graduates to quickly enter the labor market. In an effort to develop and improve the Bachelor's degree in Management and Services, a survey by PSU on business owners was conducted to find out more about the characteristics that business owners find necessary and important for new employees. Business owners emphasize such factors as problem-solving skills, negotiation skills, critical thinking, presentation skills, writing and personality maturity. All of these elements are integrated into the curriculum, reflected in PBL teaching methods and learning resources.

At DTU, there are currently two different programs in business administration including Vietnamese Business Administration and PSU Business Administration collaboration program, whose materials and teaching methods were transferred from PSU. Both programs have International Business course in the curriculum.

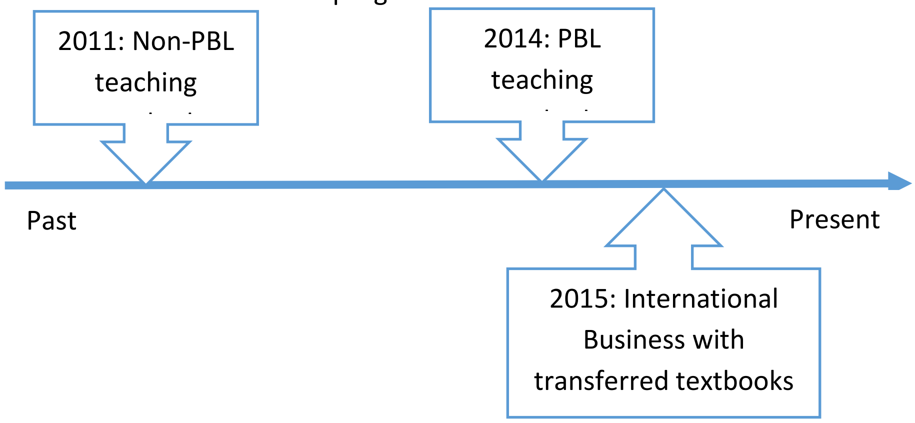

Figure 2: PBL Timeline

Since 2015, DTU has started International Business course in the PSU Business Administration collaboration program.

3.2 PBL implementation of International Business with materials from Penn State University

The PSU Business Administration collaboration program had been implemented from the academic year of 2010-2011 but till 2014-2015, it was then delivered to students.

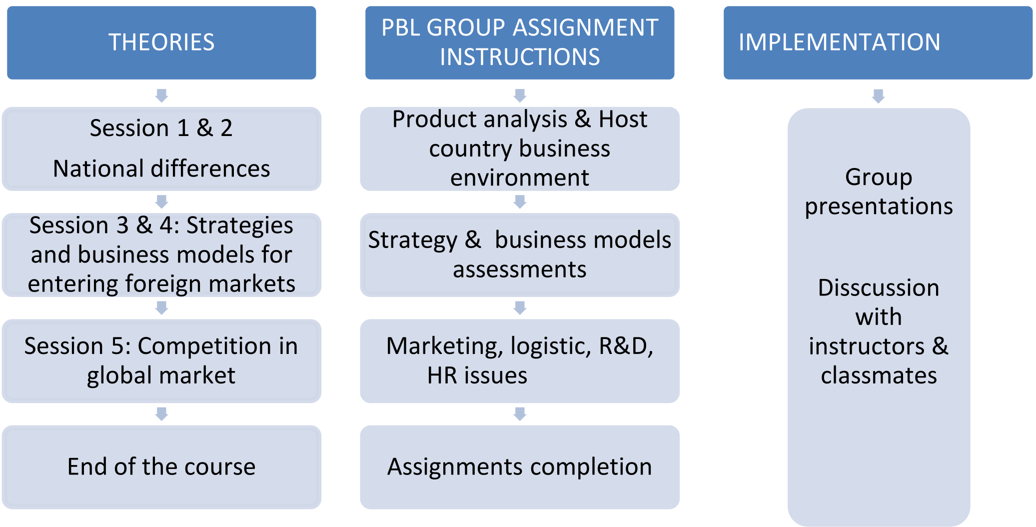

Figure 3: International Business PBL Implementation Process

Faculties of both programs then agreed that (1) the main objective of the course is to prepare students to understand and to work successfully in this global environment, develop in students the awareness of the impact of environmental forces including politics, regulations, legalities, economics, culture, technology and competition, (2) select case studies from books, then ask open questions for each situation, ask students to analyze and find a way to solve that problem when students work in capital enterprises. FDI in Vietnam and (3) using the PBL method in the project group exercise of the subject.

For group assignment, the lecturers present the problem topic to 4-6 student groups. Group are required to solve the addressed problem in three phases: (1) select and analyze the product and/or service, (2) analyze the business environment in Vietnam and chosen foreign country; and (3) deal with issues that arise when working in FDI enterprises in Vietnam or doing business with foreign partners. The duration of the student's group assignments is associated with theoretical knowledge presented in the book.

3.3 Data collection & Research Process

The data used in this study was collected from student scores on the DTU's archive from 2011 to 2018. Although there are many classes in each year, we arrange them under school year and program including student outcomes without PBL, outcomes with PBL and outcomes when we use PBL with American textbooks in 2014-2015, 2015-2016, 2016-2017 and 2017-2018. Data for the period 2011-2014 only derives from traditional training programs because there were no collaboration programs and no PBL in teaching at the moment. The number of students having academic results archived on DTU's database is shown in the table below:

Table 1: Number of students archived on DTU's database

	International Business with PBL in Vietnamese Business Administration Program	**International Business with PBL in PSU Business Administration Collaboration Program**
2014-2015	56	34
2015-2016	152	50
2016-2017	196	57
2017-2018	146	61

This research focuses on the analysis and comparison of learning outcomes so we proceed in three steps: (1) describe in details of the Business Administration programs currently available at DTU, (2) collect the International Business' score data of each program for each year and (3) conduct the descriptive statistics the results of the data.

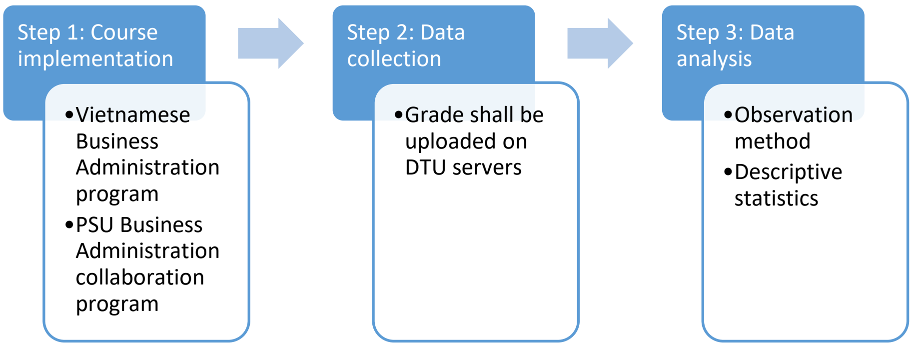

Figure 4: Research Process

4 Results & Discussion

As of International Business' outcomes: We have processed the statistics of International Business in the Vietnamese Business Administration program without applying PBL, the percentage of students passing the course is 70% in the period 2011- 2013 and up to 90% in the 2013-2014 school year. This passing ratio greatly depends on the midterm and final exams. Students who want to get high scores often have to listen, take note, and memorize so that they can correctly answer questions in the test.

Statistics of non-PBL classes in Vietnamese Business Administration program are as follows:

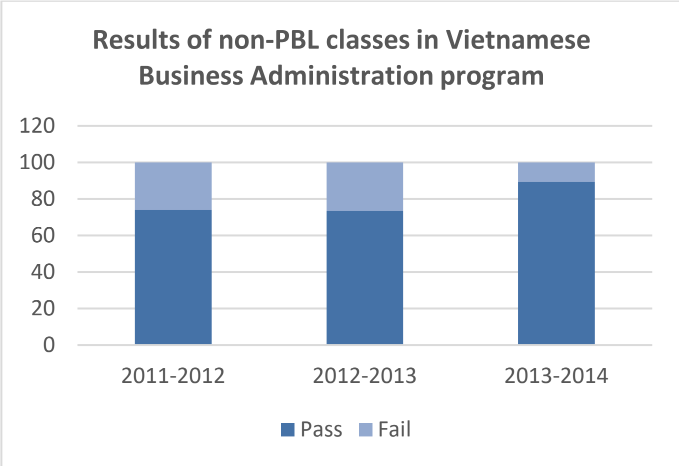

Figure 5: Results of non-PBL classes in Vietnamese Business Administration program

Below is the comparison about how International Business course which had been implemented since the 2014-2015 school year differs from traditional teaching method.

Table 2: Comparison of teaching methods

	Non-PBL teaching method	**PBL teaching method**
Implementation	Students attend classes, listen to lectures and take notes as required by lecturers. Group exercise is implemented by dividing into small groups of students to discuss assumptions prepared by the instructor. The case studies focus on the issues of disputes that Vietnamese businesses face when engaging in international trade. So, the subject easily bored students. This way students are very passive and do not attract students to register for the course.	- Lecture on basic theory account for 30% of the study time of the whole course. At the beginning and the end of each chapter, students read and discuss case studies in Global Business Today and simultaneously present the story of FDI enterprises encountered in Vietnam. The remaining time is used to implement PBL group assignment. - Classes are divided into small groups, each group consists of 4-6 students. The content of the group exercise is specifically calculated to be consistent with all lessons. Each lecture student will have a Q & A section and a teacher orientation. - Finally, the student will write a complete project, with a self-assessment of the team's contribution on a 100-point scale.

Since 2014-2015, PBL was applied for both Vietnamese and collaborative Business Administration programs. However, the importance weight of the activities in the two programs differs, as shown in the following table:

Table 3: Comparison of importance weight allocation

	Vietnamese Business Administration Program	**PSU Business Administration Collaboration Program**

Importance weight allocation	- Attendance: 10%	- Attendance: 10%
	- Group assignment: 20%	- Quizzes: 15%
	- Mid-term: 15%	- Mid-term: 20%
	- Final test: 55%	- Group assignment: 25%
		- Final test: 30%

From here, there have been a big difference between these two programs in passing ratio with descriptive statistics shown as follows:

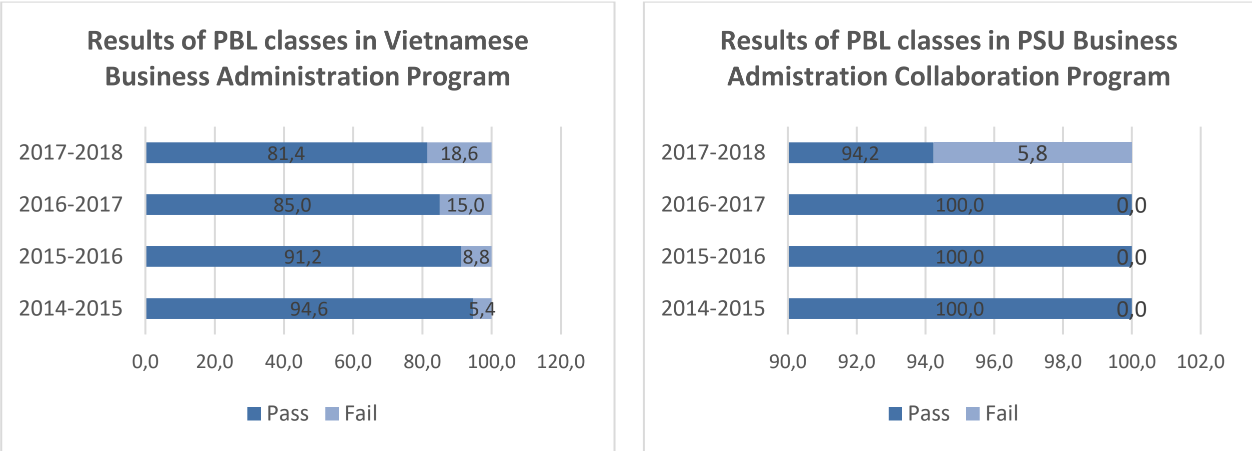

Figure 6: Results of PBL classes in both programs

Thanks to the adjustment of assessment, the use of modern learning materials and PBL method focusing on group exercises, 100% of PSU Business Administration Collaboration program's students has passed the course for the 2014 – 2017 period. Meanwhile, the percentage of Vietnamese Business Administration's students had decreased year after year. This is explained by observing the fact that the Vietnamese program students are still required to heavily memorizing lectures to pass the midterm and final exams as they will be assessed by what they memorized from these lessons in the tests. Additionally, the total importance weight of the midterm and the final test is 70%. If the results of these two tests are low then the final average score will be low for sure. In contrast, PBL teaching methods are primarily based on activities, use of questions, explanations, proofs and coordination. As a consequence, the results of the midterm and final test accounted for only 50% of the whole course, so the learning pressure by memorizing was lowered, and more autonomous activities were added. This is the evidence to positively confirm H1.

As of grade distribution among Internal Business' outcomes: The traditional program that began using the PBL teaching method since 2014 has improved student achievement over the years as above. In terms of grade, the average score over the years improved gradually over 7.0 in the 2017-2018 school year but the standard deviation has increased clearly. Although the frequency of 7.0-8.5 band score increased but many low grades makes the mean decreases. In the last two school year, 50% of the students have achieved a grade of 7.5-7.85 or higher, significantly higher than the first two years. Compared to the other, 8.3 appear most while the highest score of 9.0 only emerged from the 2015-2016 school year.

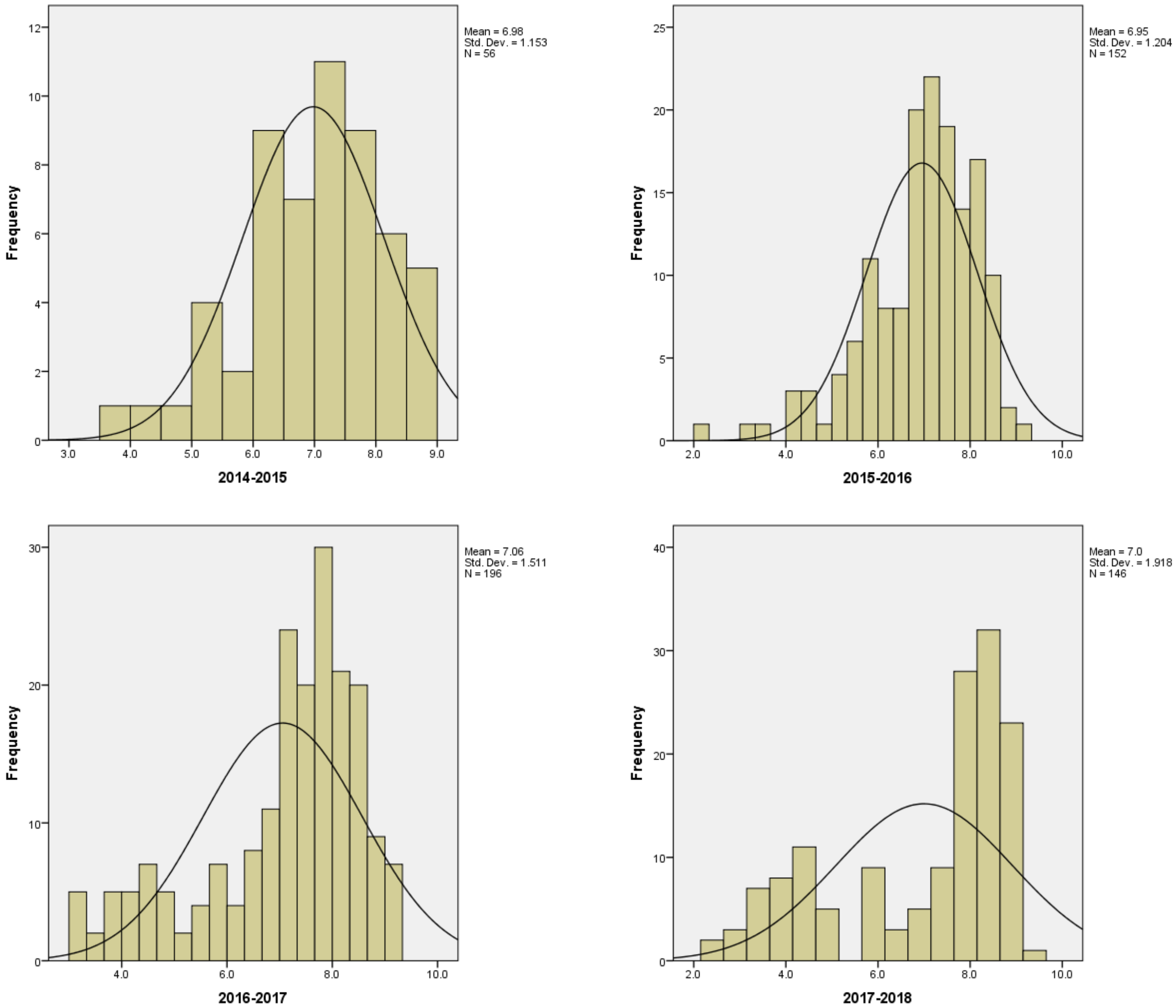

Figure 7: Grade distribution of PBL classes in Vietnamese Business Administration Program

In terms of the PSU end-of-course grade distribution, PBL classes have a number of frequency differences over years. The school year of 2016-2017 had the lowest mean (7.73) and the school year 2017-2018 had the highest mean (7.89) which was generally in the range of 7.5-8.0, equivalent "A" band score. The difference between high and low points is very clear, affecting the mean value. The outliers of the 2014-2015 school year fall into 6 and continue for the next 2 years, while 2017-2018 have the left outlier from 2.0 to 6.0. From the school year 2015-2016, by the median, we see that more than 50% of students achieved high scores from 7.6 to 8.3, increasing over 3 years. The frequency of high grade (>8.0) has increased in the last two years, which reached over 20% in this year.

While the highest point in the Vietnamese Business Administration program is 9.2, the PSU program is 9.6. This demonstrates that the use of PBL in teaching effectively improves students' scores. Grade distribution of student project also demonstrates this insight.

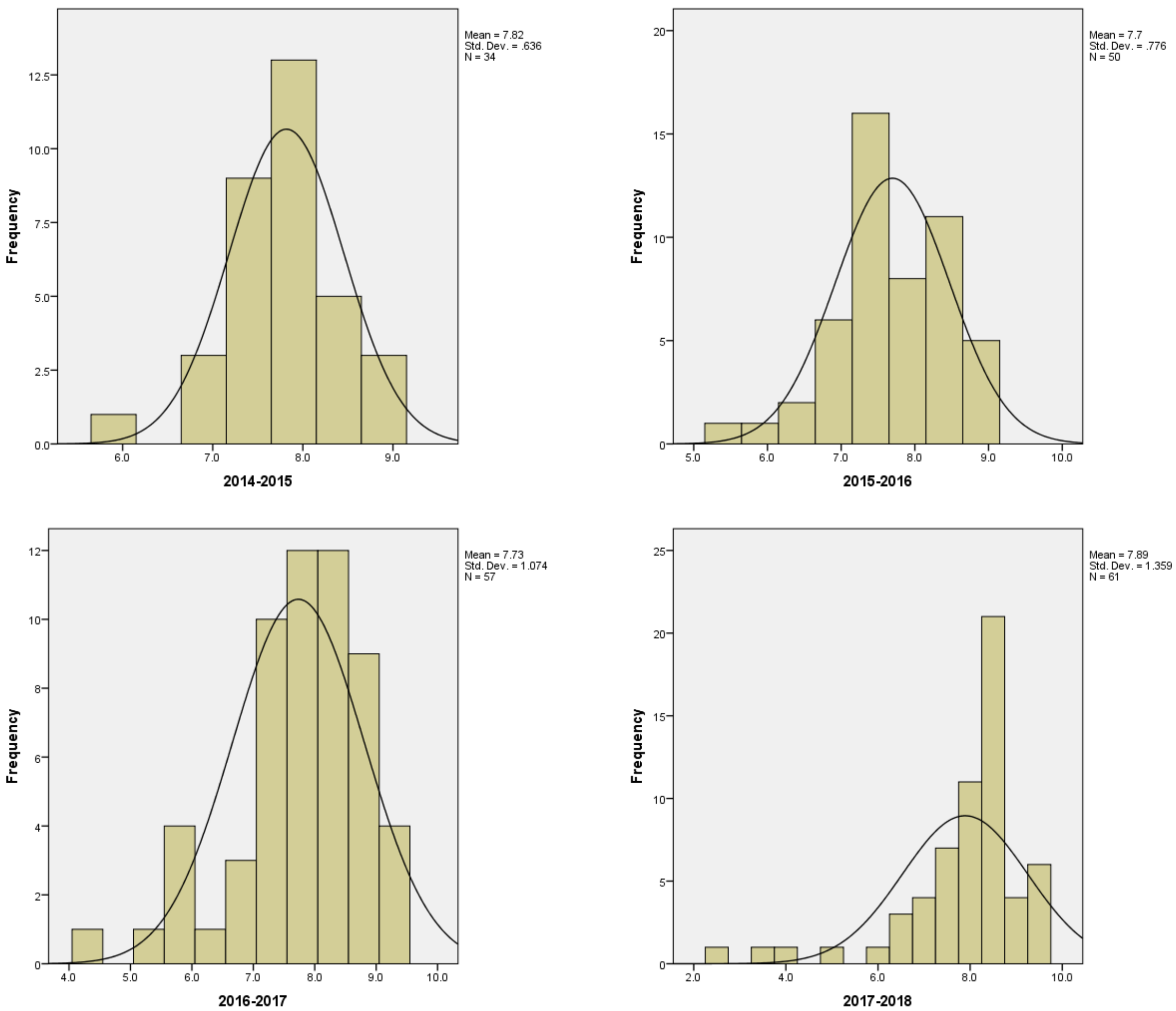

Figure 8: Grade distribution of PBL classes in PSU Business Administration Collaboration Program

Through two above grade distribution figures of the two programs, the most frequent grade of the two programs do not differ much, but the average score of the PSU program is much higher. In addition, more than 50% of PSU program students' score are above 7.6-8.3, while this score is 7.1-7.85 for the Vietnamese program. This difference is mainly due to two reasons: (1) PSU instructors have been better trained by Penn State University and they were active in using materials and applying PBL teaching method at the beginning of the program while Vietnamese program instructors were slower to adjust their syllabus when implementing PBL; (2) PSU instructors are more experienced over time in guiding students to perform problem assignments, adjusting contents closer to reality.

In addition, the percentage of students who passed the course in undergraduate classes (less than 35 students) is often higher than those in the overcrowded classes. Classes with fewer students are more convenient for organizing group exercises and case studies. The "Quick Check/Quizzes" accounts for 15% of the total, and faculty members often ask students to answer short questions about selected case studies of businesses according to book questions and usually add them. Questions related to the operation of enterprises in Vietnam or Southeast Asian countries - where there are significant differences in the environment compared to the mother country. This forces students to learn in advance through various sources of information, so easily achieve high scores. Case studies help students develop richer understanding in the real world. Therefore, it is necessary to have the combination between textbooks, PBL method and relevant assessment methodology to better classify students' learning outcomes, which positively confirm H2.

5 Conclusion & Limitation

With the expectation that students will be able to apply knowledge and skills taught in International Business course to work well in foreign companies, DTU has used PBL to teach with adjustments for the PSU Business Administration Collaboration program to suit the business environment of Vietnam. Our study once again affirm that there were significant advances in student achievement in this subject. Plus, regarding the collaboration program, it is necessary to have a synchronous transfer including the syllabus, reading materials such as students' textbooks and instructors' manual as well as class organization and teaching methods adjusted under the local business conditions, academic environment and the abilities of learners.

Although the differences in academic performance show the superiority of the teaching methodology, the feedback from alumni who have learned PBL is also an important factor. We considered the latter is the critical drawback of our study. It will certainly be studied in the future.

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Project-based Learning Activities in English for Tourism Classes

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Abstract

Project-based Learning (PBL) is an approach that uses task-based problems to engage students in active and multidisciplinary learning. In PBL classes, students are involved in real and challenging matters which allow them to learn from real life situations. In recent years, this curriculum model has been applied in teaching English for Specific Purposes (ESP) to students at the tertiary level at Duy Tan University (DTU), Vietnam. Tourism is a field which has seen a considerable development over the recent period in our country, and the command of the English language represents a requirement in tourism industry. Therefore, English for Tourism is a compulsory course to students in tourism at DTU. This paper was conducted to examine the effectiveness of applying the project-based teaching approach in a course of English for Tourism through four distinct projects carried out with students of English for Tourism from Foreign Languages Faculty, Duy Tan University. Through project-based learning, students learn how to use English and technology tools to fulfill PBL tasks rather than paying much attention to language learning. The projects are described and evaluated. In addition, interviews were conducted to report on teachers and students' experiences in implementing project-based activities in their English for Tourism classes, discovering the benefits and limitations of the activities, and how they resolve the issues. The case study involves 172 third-year students of English for Tourism and four English teachers who participated in learning and teaching of English for Tourism in the first semester of academic year of 2017. This paper is hoped to be a useful reference for educators who are seeking for effective ways in teaching English for Tourism.

Keywords: project-based learning, English for Tourism, technology in EFL learning, English for Specific Purposes (ESP), interdisciplinary study

Type of contribution: Best Practice Papers

1 Introduction

Vietnamese economy has witnessed a big step in tourism industry. In recent years, the number of international visitors to Vietnam in general and Danang city in particular has been significantly increasing. Therefore, English communication is necessary ever than before. English for Tourism, consequently, has become a "favorite" major for many students. However, teaching and learning English are always a big challenge for Vietnamese people since the syllabus, textbook as well as teaching methods seem to focus mainly on theory and rote learning so that students can pass the exams. The learners do not have enough motivation to engage in learning activities as they are lack of authenticity. As a result, any revision of teaching methods is more essential than ever.

There have been no perfect or absolutely effective teaching methods for all of the learners. In history, a large number of teaching methods have been applied and got certain effects such as Grammar Translation, Audio Lingual and Communicative Language Teaching (CLT) (Richard & Rodgers, 2000). Later, several teaching approaches apply CLT like Content-Based and Task-Based. Among the various methods of communicative language teaching, project-based learning has been considered as an effective model in enhancing students' motivation. In PBL classes, learners have opportunities to do projects in authentic situations. Learning and experiencing help students improve their long-term memorization and develop critical thinking as well as problem solving skills. Because of its benefits, PBL has been applied in many Vietnamese schools including Duy Tan University at different levels.

Although many studies have been carried out in the application of the PBL model in foreign language education, there have been few studies related to that with Vietnamese university students (Khanh N., 2015; Felipe A., Amouroux E., Thanh P. and Stojcevski A., 2016). Even fewer studies have been carried out to investigate the PBL activities in English for Tourism courses in the Vietnamese context.

This paper focuses on introducing and describing four authentic PBL activities which were applied in English for Tourism classes at Duy Tan University in the first semester of the academic year 2017. Concurrently, the benefits and limitations of each activity will be discussed through the projects assessment. In addition, interviews will be carried out to collect teachers and learners' feedback on the activities.

It is hoped that this paper will bring about a new look of teaching and learning English for Tourism via PBL activities. Also, it needs to be stressed here that this study will be a useful reference for those who are seeking for effective ways in teaching English for Tourism.

2 Problem-Based Learning (PBL) in English as Foreign Language (EFL) Education

The Project-based learning model has gained popularity in educational practice and it was greatly influenced by the communicative approach approximately at the beginning of the 1980s (Hymes, 1972; Canale & Swain, 1980). There have recently been a lot of researches on the implementation of PBL in different levels and fields of learning throughout the world (Barron et al, 1998; Hmelo-Silver, 2004; Grant, 2011). They all admit that PBL is a flexible method which allows interdisciplinary learning in a meaningful way.

Project-Based Learning (PBL) was initially adapted to foreign language education during the eighties (Krashen, 1982) in order to provide learners with chances "to interact and communicate with each other and with native speakers of the target language in authentic context" (Beckett, 2002). It has been defined by various authors in foreign language practice as a powerful and motivating method to develop learners' foreign language through learning by doing. According to Ribe & Vidal (1993), PBL is a systematic instruction method that develops students' language skills, cognitive domains and global personality skills through conducting projects. Moss and Van Duzer (1998) considered PBL as "an instructional approach that contextualizes learning by presenting learners with problems to solve or products to develop. In EFL classes, projects are multi-skill activities focusing on topics or themes rather than on a specific language target. The language learners have chance to work together with hand-on experience in an authentic and meaningful context which they do not have in any traditional language classes to create an end-product.

3 Project-Based Learning (PBL) in English for Tourism Classes at Duy Tan University (DTU)

English for Tourism is one of the compulsory courses for English majored students at Duy Tan University.

The course is mainly for junior students who are supposed to use English for at least basic communication since they have already finished the courses of four core English skills in the previous academic years. The course aims at introducing students about tourism industry in Vietnam in general and in Danang city in particular then giving them the very basic knowledge about the job of a tourism employee.

The course lasts 12 weeks, and students spend three hours per week in class. Normally, the number of students in most of ESP classes at DTU is around forty. Therefore, they are required to work in groups of five (sometimes up to seven) including a leader.

In the first two weeks, teacher gives a lecture on PBL regarding definitions, steps of project development, roles of the teacher and the students as well as the rubric for assessment to students. Then, she introduces some basic terms about travel industry, the role of tourism industry as one of the major revenue sources in Vietnam and the way it develops the country. Next, the teacher shows short videos about tourist attractions in Vietnam and Danang to help students understand more about tourism industry in their area. Students then form their groups based on their interest and expectation. Each group is asked to think about the ideas to develop tourism in Danang city, one of the major destinations of domestic and international tourists in Vietnam. Four different project ideas are subsequently introduced to the whole class, and the teacher tells her students that they have a chance to choose one of the four projects to carry out. They can also discuss with her to get the agreement on the final outcomes.

In the third week, each group works independently to decide their project's name. Then, they submit the name to the teacher and get feedback from her. If different groups have the same idea, they have to negotiate to make a few modifications. When the project's name is approved, the group continues to make a framework for it. Additionally, the work of group discussion and gathering background information for the project is carried out outside classroom. The groups have to decide what, where, when and how they would collect the data. By researching the information, students can realize the real situation of Danang tourism, its strengths as well as weaknesses.

After finishing reading the background information from the sources, each group draws up a list of suggestions to develop an aspect of Danang tourism in the following week. The groups also make presentations in front of the whole class to report on their research progress.

The results of investigation and the project proposal outline are shown so that the group gets some more feedback from the teacher and other groups. The feedback includes comments on the choice of project's components, its schedule and the end product. If the outline is approved, they can distribute the tasks for each member.

The work of data collection and analysis is carried out in the fifth week. In addition to searching for a variety of information sources from the Internet, magazines, newspapers and libraries, students have to take some field trips to collect more authentic data and get visuals as evidence. In particular, they visit different tourist attractions around the city, taking photos and making interviews with international visitors and local people there. Afterwards, they discuss with other members to select the needed piece of information. All of this work must be finished in the first five weeks.

In week six, once all the data have been collected, each group makes another presentation on their progress as well as the results of data collection and analysis. The figures and visuals are shown as the evidence of their work. Feedback and suggestions from teacher and the other groups are also provided at the end of the presentations.

The work of week 7 includes designing group's product. Here, technological skills play a big role as students mostly work with their laptop to process data. Teacher's instructions are needed at this stage. During the discussions, the teacher can make some notes of students' ideas on her individual project diary.

In weeks 8 and 9 students revise their projects based on the feedback to meet the requirement of assessment criteria. At the same time, they prepare power point slides for the coming presentations. The teacher's support is provided for all groups if necessary. Then, students make final reflection of goals, experience and success during project work.

Weeks 10 and 11 are for group showcases. Students present their projects in front of the teacher, other classmates and some guests including other teachers and maybe experts in tourism industry and foreign language learning. The audience can ask further questions after each presentation. Then, they give their comments and suggestions. The teacher takes note on students' work and gives them feedback at the end of the class.

The final assessment is conducted in the last week. The grades are based on the English language proficiency, students' performance and the quality of project. Teacher also hands out the grade sheets and asks students to grade themselves well as their group members. Then, teacher and students work together and make more suggestions for revision in order to improve the projects. Students are encouraged to publish their products and update the information in their project regularly so that their work remains authentic.

4 Research Methodology

This paper used descriptive method to introduce four PBL activities in English for Tourism classes at DTU, the stages of implementation as well as the needed facility to finish the projects. It also used qualitative method to investigate the effectiveness and challenges of implementing PBL activities in English for Tourism classes to Vietnamese students. Data collection included open-ended interview questions to four teachers and 20 randomly chosen students who had experience in teaching and learning English for Tourism using the PBL model. The interviews were conducted at the end of the course to identify the participants' level of satisfaction on the projects and the factors that affect the implementation.

5 PBL Activities in English for Tourism Classes

At the end of the second week, after the videos about Vietnam and Danang tourism are played, teacher suggests four different PBL activities to the students: designing travel brochure, making a video about Danang travel, operating a city tour and creating a Facebook travel page.

The following step is to introduce eight different topics related to Danang tourism: Danang tourist attractions, Danang cuisine, Danang traditional handicraft villages, Danang festivals, Danang night life, Danang transportation, Danang accommodations and Danang adventures. Each group is in charge of designing whether a brochure, a video, a tour or a Facebook travel page to introduce one of the eight given topics. The choice of topic is based on their experience and interest. The description of each project will be clarified as follows.

5.1 Activity 1: Designing a Travel Brochure

Travel brochures have been used by travelers for getting information about their trip such as the details of itinerary, maps and places to go. To have an eye-catching brochure, firstly, the group search for information from various sources (the Internet, books, magazines, other available brochures) and include images as well as authentic numbers in their brochure. Then, they write brief descriptions, making drafts, presenting, revising and publishing the brochure.

Designing travel brochure is seen as a "comfortable" work for the teacher and students since the class time is controlled the most. In addition, the common size of a travel brochure can be as large as an A4 paper, and the language use in the brochure should not be so complicated. Therefore, most of students can manage the work of writing content. Moreover, because a brochure is a tangible product, it seems easy to evaluate its quality.

On the other hand, the most challenging task for students to do this project is that many of them are too ambitious that they want to "scatter" too much information in the brochure. As a result, the design looks so unattractive and unprofessional that they have to make several drafts before the end-product. In fact, the cost for making a brochure is usually much higher than expected. Another challenge for students comes from the lack of technological skills. Some students have troubles with inserting and editing pictures. It also takes them a lot of time to design the slides for presentations.

5.2 Activity 2: Producing a Video

Student-produced video has always been an excellent EFL language learning activity which requires learners' participation in a variety of ways. Nowadays, with the relatively recent advances in digital video technology, it has become easier than ever for students to produce a video introducing about Danang tourism. All they need is just a video camera or even their smart phone to help them record the visuals related to their project theme.

Students are required to make a video about one of the given topics with 10 to 15 minutes in length including English subtitles. After choosing the topic for their video, students plan for collecting data. Then, the on-site visits help them take photos and film on the real sites. After making revisions according to teacher and other groups' feedback, the video is uploaded on YouTube and shared.

The main advantage of making video is that it is a valuable chance for students to experience the real-life working environment. Through the on-site visits, they can discover new interesting tourist attractions, recreational places, original local products and so on. Hence, a video seems to be the most authentic product among the four projects.

However, making video is a time-consuming task. Students have to decide on the destinations and choose "golden hours" to catch the best moments for filming. Moreover, technological skills needed to use video cameras and editing software make this type of project challenging for many students. In fact, inserting any sound, music or students' voice in the video makes the video better. Thus, it is important that students speak English fluently enough.

5.3 Activity 3: Operating a City Tour

To create an authentic tour based on a particular topic, students spend a lot of time on reading materials. They also meet their tour guide friends to learn some experience and ask for advice, or they can choose to interview international tourists in the city to know about their interests. Then, the "best" destinations for the tour are decided. The tasks of collecting and analyzing more data and making presentations are implemented after that. The groups can get valuable feedback from teachers and tour guide friends on the practicability of the tour. At the end of the last course, students selected the most feasible tour to go on together. It was the tour to Danang traditional handicraft villages. The group members played the role as tour guides to lead the whole class. That was really an exciting experience for them.

Operating a tour is not an easy task for any tour guide; it is even more difficult for the students who have almost no experiences in designing a tour in reality. However, this project seems to attract a large number of students because it is directly related to their future job. By doing this, students put more effort into their project.

5.4 Activity 4: Creating a Facebook Travel Group

Undoubtedly, Facebook nowadays becomes the most popular network where people can connect and share their interests. A huge amount of information is posted on Facebook every single day including the information about tourist attractions. Taking this advantage, students can do a project which helps them create a Facebook page to introduce Danang tourism. And in fact, a large number of students found this project the most interesting among the four projects. It is because those young learners are so familiar with the social network. Besides, it doesn't cost much to post something on Facebook.

At first, students find references on travel websites, in newspapers and books or from other Facebook pages to narrow the topic. Then, they decide on useful information and what they think can interest tourists to post on their page. After outlining the main points involved in the topic, students spend one day to take a field trip. A lot of pictures are taken, then edited and posted on the group page with the descriptions.

Despite a lot of advantages, managing a Facebook page is not an easy work at all. Students have to spend too much time on Facebook to update the information as well as responding to the others' comments since the success of the project is based on the popularity of group page, the number of members and followers and the number of shares and comments. Therefore, the students who are responsible for administrating the pages feel under pressure as it is time-consuming. Besides, students have to pay a lot of attention to their writing skills. They should know how to paraphrase and summarize the pieces of information but not just copying or sharing them. That makes their page worth following.

6 Discussion and Implications

6.1 Advantages of PBL Activities in Teaching English for Tourism

It cannot be denied that PBL has brought about a lot of benefits in EFL teaching and learning. Through the four PBL projects, students can enhance both academic achievement and the content knowledge relevant to the course. Particularly, not only has the level of English proficiency been improved but also the knowledge about tourism industry has been broadened.

When being asked about what they like the most from the course, many students agreed that it was autonomy. For them, being not only the learners but also the doers of their project is a fascinating experience. That makes PBL different from other traditional courses.

Moreover, students have chance to learn a variety of life skills through conducting the projects. All of the group members should know how to collaborate with one, express their own ideas, respect the others and acknowledge their opinions. Their critical thinking and problem-solving skills have also been developed via group discussions. Besides, the presenting, communicative and technological skills play important roles during the process of making group's product. Especially, in PBL classes, students have chance to develop higher-order thinking skills including data analyzing and interpreting.

In addition, it is the matter of cultural characteristics that most of Vietnamese feel more secured if they work in group. They tend to be more obedient, hard-working and polite. Many of them become more responsible for their tasks in order to finish the group's project.

Another significant effect of PBL model in language class is that it can increase motivation among students. Instead of sitting in the same seat day by day and trying to respect the teacher's lectures, students now have chance to ask questions about the project theme; they can share their ideas with other group members and get valuable advice from their teacher and friends. As a result, students feel more involved in learning. One student also said "*When I visited a pottery village, the warmly welcome of the local people there really impressed me. I saw some old ladies speaking English with an international tourist. I was really disappointed with myself. I must learn English better".* It is hoped that the student respects her major more.

Last but not least, taking field trips helps students have a vivid description of their future job. Visiting travel businesses and tourist attractions, students can learn more real-life knowledge to fill the gap between theory and practice. Sometimes, they realize their misunderstanding of some theories. For example, one student admitted that before a trip to a resort in Hoi An ancient town, she had not realized the different between "double room" and "twin room". Obviously, what students learn from real life situation makes them remember longer.

6.2 Challenges of PBL Activities in Teaching English for Tourism

One of the main challenges for students to complete the projects as interviewed is time- pressure. A lot of students complained that they did not have enough time to collect the data outside the classroom because they also have many other courses at school and their schedules vary among the group members. Furthermore, it took them too much time on working with their laptop, editing the content and designing PowerPoint presentations. Some students think that it would be better if they did not have to deal with technical problems.

Another drawback is that as the majority of language students had got almost no experiences in tourism industry before, students had troubles with new terms relating to the field. Thus, they had to search for background information from various sources to make sure about the terms before putting them in their reports. It is only the problem of the students but also of the teachers. All of the four teachers whose major is the English language admitted that they felt nervous when facing technical terms. Therefore, they had to make more effort before an ESP class than that of other general English courses.

Additionally, even though students have learnt a lot of language courses during their previous academic years, they did not have many chances to work in groups. When they work with the others, they consider the difficulties in distributing tasks for every group member. Some of them feel unfair if they are asked to deal with the tasks that they are less interested in. They also think that their role was undervalued.

What is more, two groups said they witnessed technical challenges when making videos or using video editing software. Although they have filmed a lot of videos in different destinations, the permitted time for the final video is from 10 to 15 minutes. Then, they had to those videos and merge a number of small recordings into one. That was a nerve-wracking task. Another trouble came from adding English subtitles into the video. They must be meticulous and careful to avoid any mistake.

Furthermore, the influence of mother tongue is a barrier for the achievement of learning outcomes. Since all of the teachers are Vietnamese, sometimes, they speak Vietnamese to explain difficult terms and give students advices. Those are not recommended for junior English majored students.

Finally, due to the reflection of collectivist culture, Vietnamese students tend to avoid comments and feedback to the others. They prefer to keep their own feelings to avoid confrontation and do not want to cause the others to lose face or feel embarrassed. Moreover, some students feel nervous when standing out to report their project in front of the whole class. It could lead to their poor performances.

7 Implications

The implementation of PBL activities in teaching and learning of English for Tourism is never an easy process for both Vietnamese teacher and students. In the course, students not only learn about tourism industry but also practice using English in real-life environment. Although the activities have a lot of benefits for both teachers and students, some limitations are inevitable. The suggestions below will help teachers and students minimize those drawbacks and improve their future projects.

First of all, it is necessary that students speak English in the work-progress discussions. Also, they should respect their friends' presentation, listen and give comments on their friends' work in English. In fact, practice helps students improve their English proficiency especially doing project in authentic environment.

Secondly, to make the project more qualified, students are encouraged to interview international tourists and local people in the city to grasp more evidence on the real situation of the city tourism. It is not difficult to find out the tourists at public places as Danang is one of the favorite destinations for international tourists in Vietnam.

Moreover, it is not late for students to enrich their knowledge in the tourism industry. Besides researching the materials in English, they can read some books about tourism in Vietnamese as references, or the Internet is also a good choice for those who want to get up-to-date information about tourism.

For the teacher, it is a hard job especially for those who get used to material-based teaching methods to change their mind. In PBL classes, they are no longer considered to be the knowledge provider but the facilitator who gives support to students if necessary. However, teacher should always be the one who can give students the correct guide to lead students to the target in the shortest time.

Since the English for Tourism class is mainly for junior students who have passed many other English courses, it is recommended that the teacher speaks English at all times in classroom. She must be knowledgeable not only in the language but also in other aspects including knowledge about tourism, technological skills and so on.

Finally, the learning outcomes should be set according to students' level of proficiency so that they do not feel stressful and they think that they can achieve them. Before introducing a project, teacher should consider its feasibility and students' interest in it. Also, it is necessary to make discussions with other co-workers to get more ideas about different projects. Furthermore, teacher can keep in contact with the employees from the local businesses for more consultations.

8 Conclusion

Project-based learning activities for English for Tourism courses require both students and teacher to carefully prepare and be aware of unexpected disagreements between the team members. However, if they can create successful products, the learning outcomes are much more meaningful than passing tests and other traditional modes of assessment. Besides the grades and academic credits that they earn at the end of the course, students may create authentic products which meet the demands of businesses. Furthermore, through conducting the projects, students can connect their knowledge of the English language to real-life situations. Also, their life skills such as critical-thinking, problem-solving and technological skills have been improved a lot. In addition to benefits, teacher and students have also witnessed some limitations and unexpected problems. To avoid these shortcomings, it is needed that teachers do more research on the real situation of businesses to have more authentic choices for project work.

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Integrating project-based learning and cognitive apprenticeship in the instructional design of a computer programming course

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Abstract

Teaching computer programming to novices has always been challenging. This paper describes how the engineering school of a polytechnic in Singapore makes use of combined instructional approaches namely project-based learning and cognitive apprenticeship to design, develop and implement a foundational course in computer programming. The course is currently in its first run with 300 students from three different diploma programmes within the School of Engineering. These students are in their second year of study in their respective programmes. The rationale for the selection of these two instructional approaches is presented, followed by a description of the course, lesson and assessment structures. Examples of course materials are provided to illustrate how the desired instructional strategies can be implemented in the classroom. The challenges faced during the implementation to the course structure will also be discussed.

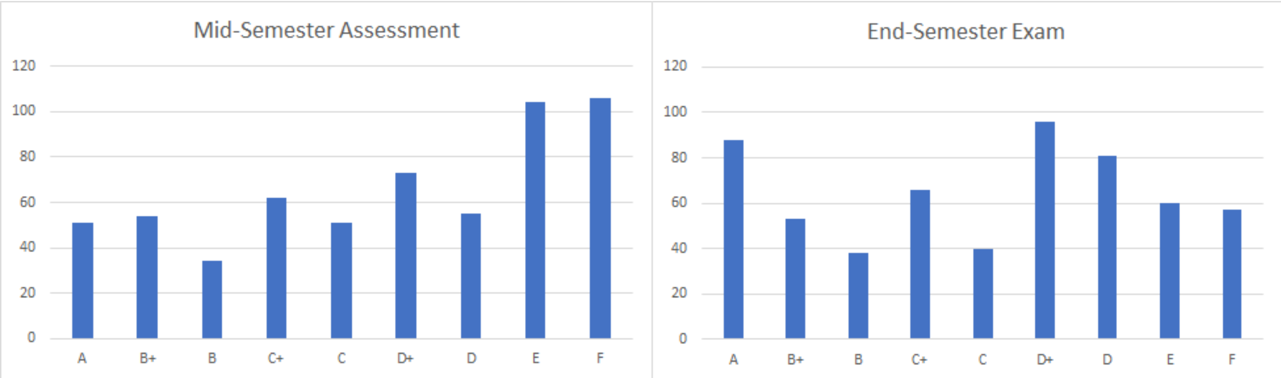
Keywords: Cognitive apprenticeship, project-based learning, instructional design, computer programming

Type of contribution: Best practice paper.

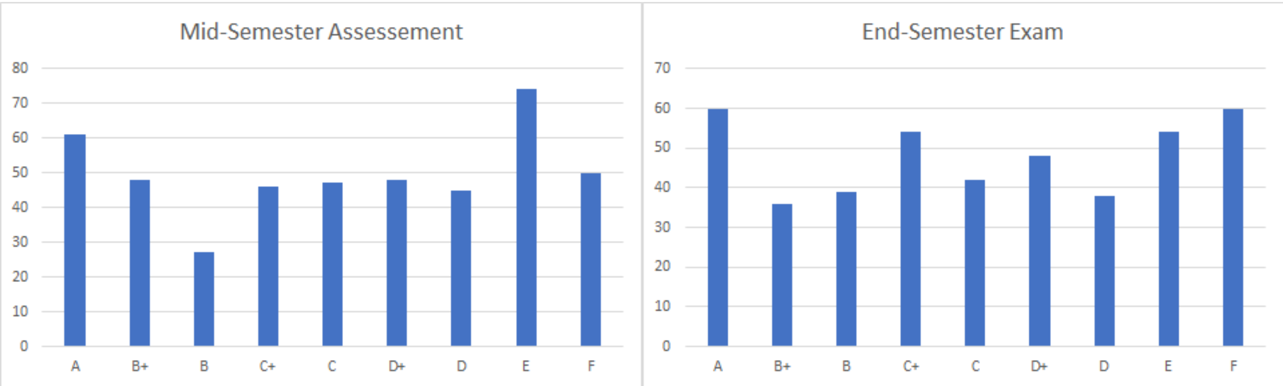
1 Introduction

Trying to teach anyone to create a computer program using any of the available programming languages is always challenging when the student has no prior experience with writing code (Lahtinen, Ala-Mutka, & Järvinen, 2005; McGettrick et al., 2005). In the School of Engineering, computer programming is a compulsory subject for all engineering students in the polytechnic. A typical engineering student in the polytechnic takes 4 to 5 subjects per semester, with one day per week allocated to each subject. Most subjects offered by the School of Engineering has the same number of modular credits, regardless of the mode of instruction.

Performance in the computer programming subject tends to be polarized, with most of the students either performing very well or faring poorly in tests, regardless of the programming language being taught. Figure 1 shows students' test performance in two programming courses in the mid-semester and end-semester examination in 2016.



Programming language taught: Python



Programming language taught: C

Figure 1: Test performance in computer programming courses in 2016.

Therefore, the School of Engineering is constantly on the lookout for more effective methods of teaching this subject.

Computer programming is a skill, and similar to any other skills, it is acquired through performing the task itself, and not by reading about it or listening to an expert talk about it. Based on the experiences of our lecturers teaching programming courses, students who did not do well in such courses often encountered difficulties right from the start of the course, which led them to give up midway and end up failing the course. Therefore, it is important to manage the cognitive load on the students in conjunction with their motivational issues throughout the course.

Programming techniques, when stripped of their contexts, may appear to be purely academic and meaningless to a student who is new to the subject. This is the reason why instructional strategies with a focus on the authenticity and situatedness of knowledge have been adopted by educators world-wide to deliver programming courses (Barg et al., 2000; Esteves et al., 2009). However, in the context of computer programming, authentic learning does not simply mean learning to code through the writing of codes. In order for the learning to be authentic, learners must be able to see how their codes are being deployed in real-world applications. Only then will they find the learning to be meaningful, and it is a well-researched fact that finding meaning in what we are doing is hugely motivational (Dweck, 1986; Wigfield & Eccles, 2000). At the same time, some forms of coaching and scaffolding should be available while the learner is fumbling through the coding process. Otherwise, the end result of this endeavor is likely to be frustration and demotivation.

Therefore, in three of the diploma programmes within the School of Engineering, computer programming as a subject will be taught using a combination of project-based learning and cognitive apprenticeship. Students are given projects to work on, where the codes that they write fulfill a business need. The projects are often variations or subsets of real projects from industry that the lecturer has undertaken. This addresses the authenticity and situatedness of the learning. Lesson delivery-wise, cognitive apprenticeship will be adopted as the teaching strategy because of its emphasis on effective coaching and guidance. Students observe the thought processes and techniques used by the expert, in this case the lecturer, and subsequently imitate and practise these techniques and methods under the lecturer's guidance. Course materials are carefully designed to facilitate and encourage such modelling and coaching behaviors in the classroom. The following sections present the materials designed for one of the projects and explain the rationale behind the design.

2 Integrating cognitive apprenticeship with project-based learning

Computer programming is a discipline that requires cognitive strategies to be formulated followed by the actual execution of the strategies through software coding. The challenge faced by newcomers to this field is not so much in the mastering of the syntax of the programming language, but in the process of how to combine the language constructs into a meaningful program (Vihavainen, Paksula, & Luukkainen, 2011). Skills in this discipline, as opposed to disciplines that emphasise abstract conceptual and factual knowledge, are best acquired initially by observing and imitating the thought processes of an expert in the domain. This resonates with the philosophy of cognitive apprenticeship, a term that was first coined by Collins, Brown, and Newman (1989). In their own words, cognitive apprenticeship "is a model of instruction that goes back to apprenticeship but incorporates elements of schooling."

Figure 2 shows the typical strategies adopted in a cognitive apprenticeship approach to instruction (Collins et al., 1989):

Figure 2: Strategies in cognitive apprenticeship.

During the modeling phase, the apprentice observes the expert performing the task. In the context of a programming lesson, rather than simply providing students with a worked example to replicate, the lecturer is making visible his thought processes while he is performing the task of writing a program. The apprentice then attempts to execute the process himself with guidance from the expert (Coaching phase). Once the apprentice has acquired a certain level of competency and confidence, the expert fades out and let the apprentice take on greater responsibility in completing the task.

While the ideas in cognitive apprenticeship guides the design of the course materials and lesson delivery so that learning can be made manageable for students, the perspective of project-based learning is used to create the framework of the entire course in order to tackle the lack of motivation in students towards the subject. Project-based learning requires a problem that drive activities and culminates in a product that addresses the problem. By carefully designing projects to be authentic in nature, the knowledge that students acquire is given a context. All the learning activities in the classroom work towards a tangible, usable outcome. This can increase students' interests and enhance their understanding of the subject (Blumenfeld et al., 1991). At first glance this may appear similar to problem-based learning, but what differentiates the two is that learners in a project-based learning environment are provided with requirements and specifications for an end product that they are supposed to deliver at the end of the project, and there is more focus being placed in following correct procedures, compared to problem-based learning (Savery, 2006).

By integrating project-based learning with cognitive apprenticeship in the teaching of computer programming skills, it is anticipated that students will be better able to better acquire the skills compared to using traditional methods of teaching.

3 Course description

The 13-week course "Programming and Data Analysis" is organized around 4 projects, with each project building upon the skills acquired in the previous projects. The structure of the curriculum is such that one day per week in the students' timetable is allocated to this course. Table 1 lists the activities carried out in a typical lesson in this course.

Table 1: Breakdown of learning activities in a typical lesson in the course.

Time	Classroom Activity
09:15 am – 09:20 am	Review previous lesson's quiz answers
09:20 am – 10:15 am	Lecture interspersed with 5-minute exercises
11:00 am – 12:30 pm	Work in teams on worksheet to practice new skills acquired during lecture
02:00 pm – 03:30 pm	Students continue to work on their project where they have left off in the previous week
03:30 pm – 04:00 pm	Complete quiz and reflection journal

The students taking this course are enrolled in diploma programmes ranging from logistics to aviation. Students work in teams of 4 to 5 to tackle the projects. Each student is evaluated individually based on his contributions to the projects, the outcome of the projects and the marks that he or she obtained in weekly quizzes and 2 pen-and-paper examinations. Figure 3 shows an example of a project in the course.

Staff training status tracking

Every staff of Company XYZ needs to attend some compulsory training courses within 3 years of joining the company. The required course for each staff is different, depending on the department that the staff belongs to. Below is the list of courses that are prescribed for selected departments in the company.

Department	Mandatory courses to complete
All departments	• Customer service • Dealing with difficult people
Quality control	• Six Sigma Jumpstart Training
Sales and Marketing	• Digital and social media marketing strategies
Production	• Workplace Safety and Health (Level 1)

Currently Lucia, a human resource executive in the company, is tracking the training completion status of their staff by manually going through an Excel spreadsheet that contains the courses attended by every staff and checking whether any staff has not completed his/her required training before the deadline. This method is both time-consuming and error-prone. The name list of all staff in this company and the courses that they have attended can be found in the file "staff_list.xlsx".

Your project is to create an Excel macro that will go through staff_list.xlsx automatically and generate a report containing the names of the staff that have not completed their training after the deadline.

Figure 3: Sample project.

The contexts of the projects are set to mimic actual activities carried out in the industries where the students' respective diploma programmes are preparing them for future jobs that they might undertake. This will help students when they proceed with their internships in these companies during their final year in the course and also after they graduate and join the workforce.

4 Instructional design

This section describes the activities carried out in a typical lesson in the course, with examples of course materials provided to illustrate how they support the implementation of the cognitive apprenticeship approach. Lessons are designed in a way that will facilitate the use of the "Modeling – Coaching – Fading" strategy by lecturers. The day starts with a lecture given by lecturers. Such lectures are meant to be interactive sessions, with facts interspersed with pop quizzes and practice questions.

Figure 4 shows a presentation slide from one of the lessons. It is an example of the modeling strategy being used in the teaching of the conditional loop, a concept of programming. In this instance, the lecturer demonstrates how to use a loop to add the numbers in two columns of a spreadsheet. He then explains the meaning of the codes, and students proceed to replicate the codes on their own computers and see the result for themselves.

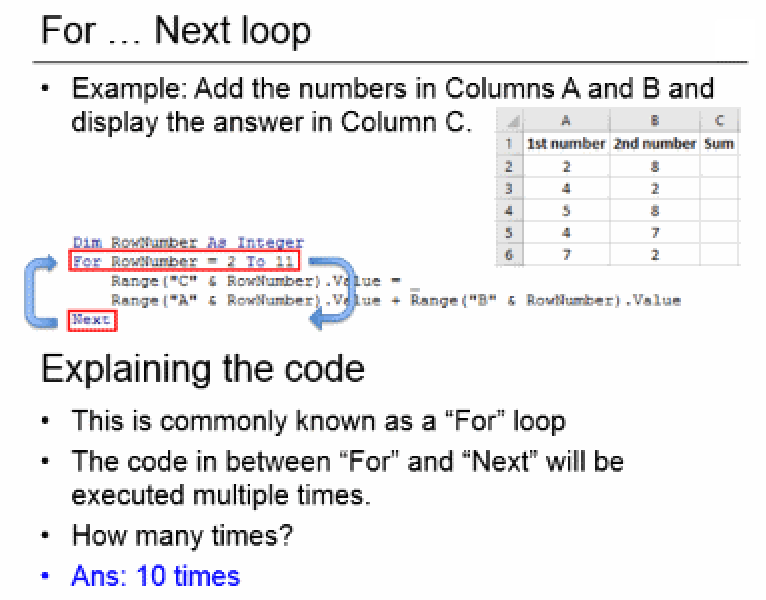


Figure 4: Modeling strategy.

The slide shown in Figure 5 comes immediately after the previous demonstration. Students are asked to work on an exercise that mirrors the demonstration that had just been conducted, and the lecturer is on hand to provide guidance and feedback. This is where we can see the coaching strategy being applied.

Figure 5: Coaching strategy.

The modeling-coaching loop continues throughout the first phase of the day's lesson, with the tasks increasing in complexity until students have acquired sufficient confidence and skills to attempt more difficult questions. Figure 6 is an example of a more complex question in the topic of conditional loops. At this point, the lecturer is letting the student take centre-stage in the learning and only providing pointers when there is a need (Fading phase).

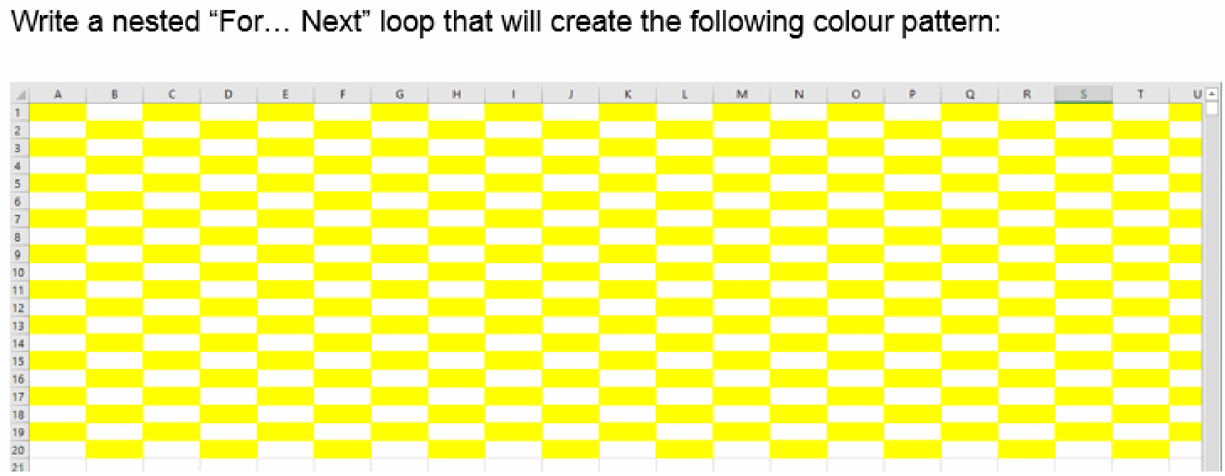


Figure 6: Fading strategy.

In the final phase of the lesson, students apply techniques and concepts learned during the day to specific portions of their project. This is an important part of the lesson where the knowledge gained is given a real-world context. Scaffolding for this part of the lesson is provided through guiding questions in a log sheet. The question shown in Figure 7 requires students to make use of their newly-acquired knowledge of conditional loops to sieve through the data in their project.

Individual log sheet

Write a VBA subroutine that will fill in all the columns in the "Summary" sheet of staff_list.xlsx with information of ALL staff in the company. Since there are 100 staff in the company, you should end up with 101 rows in the "Summary" sheet after your subroutine is run.

Figure 7: Project-specific question in log sheet.

Every lesson ends with a practical quiz to assess individual students' attainment of knowledge. Students also reflect on what happened during the day by writing a reflective journal.

5 Assessment methods

Students in this programming course are grouped into teams of 4 to 5. As such, they are also assessed both as an individual and as a team. During every lesson, each student is assessed individually for his commitment to the lesson, contribution to his team's learning, the role he played in the project and the amount of competency he gained at the end of the lesson. The student's contribution to the project is assessed through the individual log sheets that he submits after every lesson. Since each team member is assigned a different task within the project, every log sheet within the team will be unique and will be assessed for the quality of the answers and the timeliness of submission.

The entire team is also assessed for the quality of the work that they submitted in terms of the codes written and the software documentation. The marks obtained by the student in the individual component and team component of the assessment will count towards the computation of the student's final grade.

Other than the assessment methods described above, there are also two formal examinations administered during the course. These open-book examinations are designed to assess individual competency in programming and make up 60% of the final grade for the subject.

6 Preliminary Results

This programming course is still ongoing at the time of writing this paper, and a complete analysis of its effectiveness can only be conducted after the first run has ended. However, we will present in this section some feedback from students and lecturer of the instructional strategy adopted in this course.

Tenth week into the course, all students completed a survey on the course. The survey comprises of 15 items that make up four measures: Perceived Quality of Curriculum, Perceived Quality of Learning Resources, Perceived Value of Learning and Overall rating. The means and standard deviations of these measures are shown in Table 2.

Table 2: Mean and Standard deviation of the measures in the survey.

Measure	Possible range	N	Mean	SD
Perceived Quality of Curriculum	1 – 5	327	4.21	0.92
Perceived Quality of Learning Resources	1 – 5	327	4.19	0.90
Perceived Value of Learning	1 – 5	327	4.14	1.01
Overall Rating	1 – 5	327	4.19	0.93

Students were also asked to give qualitative feedback on what they enjoyed about the course and in what ways the course can be improved. In analysing the qualitative feedback, one theme that emerged was the feeling among students of the irrelevance of computer programming to their respective courses of study. The following were sample comments in the same vein:

> "Tell us how we can apply programming in [sic] our future prospects."

> "Not having this module for engineering study as it is irrelevant"

> "If I can understand on how this module will be beneficial to my course, then I can learn better."

These comments seem to suggest that the projects that have been designed to drive the learning activities have been relegated to a less prominent position in the lessons. This could be due to the projects not being well-designed. As such, instead of using the project objectives to drive their learning, students were treating the project requirements as an afterthought and a chore that is to be completed at the end of the lesson. Evidence of this can be seen from the following student's comment:

> "I don't understand the need for log sheet as the exam would not include the log sheet questions and I would rather go through some separate exercise or revision to help supplement our learning."

Further work needs to be done to address this issue.

7 Challenges

During the curriculum development phase, one challenge is to create projects that will allow students to acquire the desired learning outcomes while still being pitched at a suitable difficulty level for the students. A trial run of the first project in the course with a group of 15 students revealed that there is still a gap between the acquisition of skills and the application to solve a problem. Traditional instructional methods often stop after teaching students the direct application of a technique, such as using “For loops” to search the contents of a spreadsheet. With project-based learning, projects derived from real industry needs will be used to drive the learning of these skills. Here, we find ourselves in a conundrum. Solving real-world IT problems often require strategising and developing a plan before any actual coding is done. This requires experience, something which a novice at programming understandably lack. During the trial run, students understood the need from industry for the project that they were asked to work on. They were also able to master all the requisite programming skills to complete the project. However, a common question that came up after students had completed the worksheet and it was time to apply what they had learned on their project is “Now, what do I do next?”

This learning gap is currently bridged with the help of the lecturer in class. The lecturer plays an important role not only in helping students acquire the programming skills needed to complete the project, but also in helping students figure out how they can use their newly-acquired skills to do it. The challenge to the curriculum development team is in creating scaffolds that can help students to bridge the learning gap without overly relying on the lecturer in class.

8 Conclusion

The integration of project-based learning with cognitive apprenticeship in a programming course is a new initiative that the School of Engineering is currently embarking on. We believe that students’ interests in the subject can be enhanced by providing a real-world context via projects to apply the techniques and concepts being taught. Besides coming up with good projects, careful design of the accompanying course materials such as worksheets and lecture slides are just as important in order to ensure students’ learning is well-scaffolded throughout the process.

The programming language that the students learn in this course is Visual Basic for Applications (VBA). This is because VBA programming skills that are acquired in this subject will be useful to the students in these diploma programmes when they subsequently work in the industries that they have been training for. However, we believe that the framework described in this paper is just as applicable to a programming course teaching a different language. The course is currently still in its inaugural run and a formal evaluation of the effectiveness of this integrated project-based learning and cognitive instructional model will be conducted once the semester has concluded. We hope that our efforts will inspire other educators who are facing similar challenges in teaching foundational programming courses, and acquire some ideas for the redesign of how programming courses are taught.

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Deep understanding of fundamentals underlying the operation of a system: using rotation of projects, peer and self-assessment

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Abstract

Projects development in courses of Engineering and Business at Universidad Nacional de Colombia are common. The students perform the assigned projects during each semester, but in many cases they focus on the project tasks and fail to reach a deep understanding of the knowledge that underlies the system operation. For this reason, it is necessary to implement mechanisms that promote reflection on the project development process to help students understand how and why the designed system operates. The mechanisms proposed in this research are the following: rotation of projects between teams and self and peer-assessment. The project rotation process is done twice during the semester. In each rotation session, the groups go through four phases: 1) understand what was done, 2) reflect on the way it was done, 3) give possibilities to change what was done and the future of the project, 4) make decisions regarding the future of the project. After each rotation session, three types of assessment are carried out: 1) peer-assessment of the process, 2) peer-assessment of the product and 3) professor assessment of the process and the product.

Keywords: rotation of projects, PBL, peer- assessment, group-based learning

Type of contribution: best practice paper

1 Introduction

Traditional lecturing is the most common form of education in Colombia. The Universidad Nacional de Colombia is an institution with 150 years of academic life. 3000 teachers work in the training of 50,000 students in virtually all knowledge areas. As a major research university, the University also concerns itself with teaching, hence multiple efforts to apply concepts of active learning, interdisciplinary projects and Project Based Learning (PBL) and Service Project Based Learning are being further introduced. The professors involved in these experiences initiate a process to achieve systematization and coherence of their experiences.

This article presents the application of projects development in the classroom, with self, peer and group-assessment, and an added innovation: rotation of projects. During the academic semester, each group sends its project to another to continue its development in a rotation that is done twice in the semester. In organizational environments, job rotation has been proposed as a practice that helps to reduce monotony, boredom, and exhaustion. Furthermore, rotation among projects has been promoted mainly in software engineering projects (Santos, da Silva et al., 2017) and, in recent years, it has begun to be used in educational processes (Urdangarin, Fernandes et al., 2008; Fernández-Samacá, Ramírez et al., 2012; Vassos, Harms et al., 2018).

This innovation strategy was carried out in two courses: a postgraduate course in the Master of Engineering program, called “Machine Vision” (MV), and an undergraduate course in the Business Administration program, called “Information Systems” (IS).

The group of teachers who carry out this innovation is concerned with improving the deep learning of their students. Deep Learning is associated with intrinsic motivation and real interest in the task content. If it is achieved, the student focuses on the understanding of learning concepts, trying to relate the parts to each other. In addition, it seeks to relate new ideas to prior knowledge, and concepts to everyday experiences. In other words, the students personalize the task, making it meaningful for their own individual experience and for the real world, hence creating more possibilities for the transfer of knowledge to other types of situations and contexts (Chin and Brown, 2000, Le Roux and Nagel, 2018).

Additionally, the strategy aims for students to have the experience of taking over a project that another team had started. This type of situation is common among technology companies in Colombia, given the high mobility of professionals, mainly of the youngest (Semana Educación, 2017)

When receiving the project and the responsibility to continue with it in the state in which it is, the students perform a real group and peer-assessment exercise that eliminates some problems of these types of assessments, shown in the literature (Race, 2001). Students focus on understanding the project they received, assess their progress and find weaknesses that must be overcome, instead of only grading their peers.

In consequence, students are put into an environment that aims to motivate them to be protagonists of their learning process, facilitate collaborative work among student teams, stimulate reflection on fundamental concepts, enable knowledge transfer to other contexts and confront the student with real situations of project development. Additionally, students strengthen their oral and written communication skills.

This methodology is framed within the principles of PBL (De Graaff and Kolmos, 2003), since the group of students develops **active learning** activities by identifying problems, proposing and developing solutions to **real problems** and in **specific contexts**. In this sense, a **research methodology** is being followed. On the other hand, learning is developed **in teams and between teams**, promoting the students the transfer of the knowledge acquired in **the context of the other team**.

This work aims to find alternative answers for the following question: How can students working on a group project develop a deep knowledge of the fundamental concepts associated with the system?

2 Design of the intervention

For this research, two (2) courses were selected for using projects within their learning activities (Table 1).

The projects of each course consist of four (4) stages:

- In **Stage 1**, students must select a real problem that they must study and understand in light of the concepts worked on in class.
- In **Stage 2**, students should identify difficulties present in the problem studied and related to the concepts worked in class. The problem must be specified and justified.
- In **Stage 3**, students must propose viable solutions for these problems, based on the tools used in class.
- In **Stage 4**, students must consolidate the solution proposed for the problem.

Table 1: Description of the intervened courses.

	Course	
	Machine Vision (MV)	Information System (IS)
Number of students	21	30
Level	Master	Bachelor
Program	Industrial Automation	Business
Mandatory	Non	Yes
Project learning objectives	Appropriate the fundamental concepts (LO1) Apply the concepts in different contexts (LO2) Improve written and oral communication skills (LO3) Be able to self-assessing and self-learning (LO4) Identify problems in real situations (LO5) Be able to propose solutions in real situations (LO6) Be able to do collaborative work among student teams (LO7)	
Fundamental concepts	Stages of a Machine Vision System. Image Characterization Techniques. Features, Detectors, Descriptors and Matching.	Information System components Modelling of information systems Types of Information systems Contributions of information systems
Type of Project	Defined Problem	Problem Search
Number of groups	5	8
Members by group	4 groups of 4 and 1 group of 5	2 groups of 3 and 6 groups of 4

The intervention required modifications in the course methodology during its execution. The projects began with the traditional strategy: each team would be responsible for a project in all its stages, but the necessary modifications for the intervention were agreed on later with the students. The intervention began at the end of stage 1 of the project (week 4) and ended at the beginning of stage 4 (week 14) (see Figure 1).

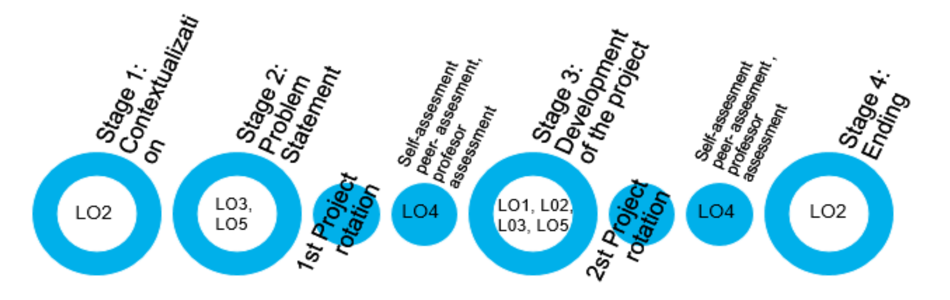
Activities and Learning objectives (LO)						
Course timeline	Week 1 to 4	Week 5 to 8	Week 9	Week 10 to 12	Week 13	Week 14 to 16
Professor role	Lecturer	Lecturer, Facilitator	Facilitator	Lecturer Facilitator	Facilitator	Evaluator
Student role		Resources Researchers	Self-evaluator Peer-evaluator	Idea-makers Implementer	Self-evaluator Peer-evaluator	Completer

Figure 1: Intervention description.

As defined above, the intervention completely encompasses Stages 2 and 3 of the project. At the end of each of these stages, the work teams must submit a written report, with previously established guidelines, giving an account of the activities carried out. After sending the report, there is a project rotation session. This report is used to assess the process and as starting document for the next stage of the project. In total there

will be two rotation sessions: the first one in week 9 (at the end of Stage 2) and the second in week 13 (at the end of Stage 3), as shown in Figure 1.
The rotations are made at the end of Stages 2 and 3 of the project since at this point students will have clear deliverables.

Each rotation session aims to pass the project from one group to another. In each session, groups are expected to go through four moments (Figure 2): 1) understand what the previous group did; 2) reflect on the way it was done; 3) identify aspects to correct, improve or continue the work done; and 4) make decisions in agreement between the two teams regarding the future of the project. To facilitate the four moments in the rotation session, each member of the receiving team must prepare questions before the session for the first three moments.

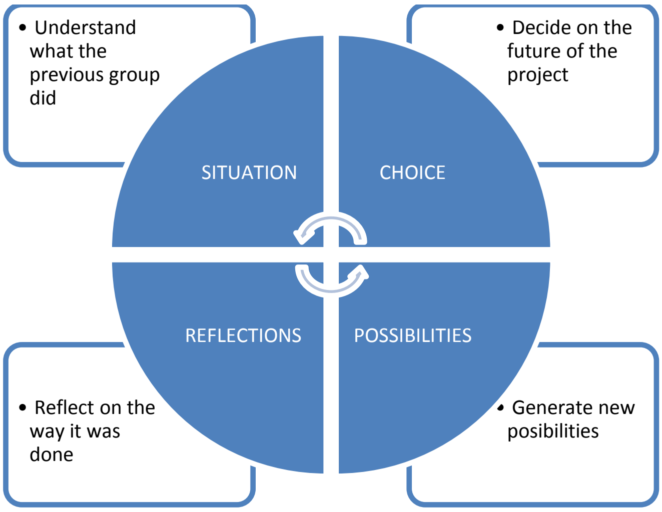


Figure 2: Facilitation guide for the rotation session (Monrad-Spliid, 2018)

The rotation session is divided into two parts. In the first one, half of the groups receive a new project and the other half deliver their project according to the methodology described above (Figure 3) (e.g. Team 1 delivers to Team 2; Team 3 to Team 4, etc.). In the second part, the roles change: the teams that received the project, now deliver their project (e.g. Team 2 gives to team 3; team 4 to team 5, etc.). For the second session teams are rotated so that each project is delivered to a team other than that from which they received the project.

During the rotations, one student per team is designated as a process recorder. The records or minutes permit reviewing *a posteriori* the development of the activity in order to identify dysfunctions in the teams and the options to improve the intervention. At the end of the rotation session, the teams self- and peer-assess different aspects, as detailed in the following section.

3 Methodology

3.1. Assessment

In order to analyze the type of learning (deep or superficial) of the students, they were monitored, particularly in the project rotation session. Additionally, assessment criteria were defined with relation to the learning objectives, which were applied in the self and peer assessment modes for each student.

Self-Assessment

In the search for soft skills, such as the ability to work on a team, a self-assessment of the process is defined. The group that delivers the project must assess its own process, according to its progress, through the following criteria.

Table 2: Criteria for self-assessment of the process made

Assessment criteria	Description	Learning Objective
Team Integration	Participation and integration with the group	LO7
Teamwork organization	Teamwork planning and organization	LO7
Contribution to the team	Contribution to teamwork	LO7
Tolerance to the opinions of team members	Respect, tolerance and appreciation of the other's ideas	LO7
Responsibility and Commitment	Responsibility and commitment in the fulfillment of the team tasks	LO7
State of the art	Review of multiple sources	
Reading documents in another language	Review of sources in another language	
Identification of the problem	Understanding and statement of the problem to be solved in a clear and complete manner	LO5
Different points of view	Analyzing the **problem** situation from different points of view	LO5
Multiple solutions	Analyzing many options adjusting to the specific problem to achieve an adequate solution	LO6
Innovation in the use of techniques – Originality	Merging multiple techniques taking advantage of them to achieve a solution with originality	LO6
Degree of learning	Thoroughly understand the conceptual foundations that can be used to solve the problem	LO1 LO2
Effort	Degree of effort	

Peer-Assessment

Considering that all students are participating in the development of some project and that all projects have a similar degree of progress, students are expected to have the ability to analyze the quality of another team product. Likewise, the receiving group must evaluate the product, by means of the following peer-assessment criteria.

Table 3: Criteria for peer-assessment of the product received

Assessment criteria	Description	Learning Objective
Project name	The title clearly describes the project	LO3
Project objectives	It presents the objectives and a reflection upon its importance	LO3
Methodology	It includes a conceptual framework and reflects on the techniques used for the development of the project	LO3, LO1
Contextualization of the Project	It includes a complete, clear and coherent contextualization of the project	LO5, LO6
Analysis of the Situation or Problem	It includes an analysis of the problem situation	LO1, LO2, LO5, LO6
Evidence of conceptual elements	The product demonstrates the conceptual elements worked on in the course	LO2
Relevance of the problem	The problem / solution is relevant in the work context.	LO1, LO2, LO5, LO6
Innovative Solution	The solution will have a high and positive effect with respect to the initial situation	LO1, LO2, LO6, LO7

Meets the requirements	The product meets all the established requirements	
Format Compliance	It complies with the format indicated	LO3
Use of the referencing system (APA)	It uses the referencing system properly	LO3
Clarity and coherence	It is written clearly and coherently	LO3
Synthesis	It maintains its wording according to appropriate structural guidelines	LO3

3.2. Intervention Assessment

Besides assessing the performance of the students in both the process (teamwork) and the result of the project (product), the assessment of the intervention was also considered. The intervention assessment will permit identification of its effects on the learning process and define adjustments for future implementations. For this assessment, following the proposal of Fernández-Samacá et al (2012), criteria aligned with the learning objectives were defined in an instrument for the intervention assessment. This instrument was filled by each student individually.

Regarding LO1 "Fundamental concepts" and LO2 "Concepts in different contexts", 15 criteria were defined specifically for each course. For the Information System (IS) course, the criteria are related to the components of an information system within an organization, the best electronic devices for an organizational context, the types of business applications existing in the market, the new information technologies in an organization and a systems methodology. For the Machine Vision (MV) course, the criteria are related to the components of a machine vision system, the features that allow characterizing the objects, the different existing detectors and descriptors, the matching techniques and the classifiers.

For the other learning objectives, the criteria were the same for the two courses.

- LO3. Written and oral skills: Eight (8) criteria related to the ability to communicate effectively, ability to write reports rigorously, ability to communicate ideas orally, and the use of resources in another language.
- LO4. Self-assessing and self-learning: Five (5) criteria related to bibliography consultation, acquisition of research skills and attitude, development of creativity, innovation and resourcefulness in the proposal of solutions, and learning management.
- LO5. Problems in real situations: One (1) criterion related to the identification and solution of project difficulties.
- LO6. Solutions in real situations: Three (3) criteria related to the acquisition of ability to solve problems, to put knowledge into practice, and for the economic analysis of solutions.
- LO7. Collaborative work: Five (5) criteria related to the acquisition of the ability to teamwork, active participation in meetings, and leadership and orientation of activities.

Finally, looking for additional information about the process, three open questions were posed about the positive and negative aspects of the intervention and its use in other contexts.

4 Results

Considering the differences between the courses, the results are presented separately. The measurement instruments mentioned in the preceding section (Self, Peer and Intervention assessment) were applied to all students after performing the intervention. The results are summarized below.

4.1. Assessment of the process and the product

Figures in this section present, for each of the criteria evaluated, and for each grade per criterion, the number of students who consider that they have met the criteria in that grade.

Course Machine Vision (MV)

As shown in Figure 3, students showed a good perception of their own team performance, as well as their level of learning. These results are consistent with the assessments made after both rotations.

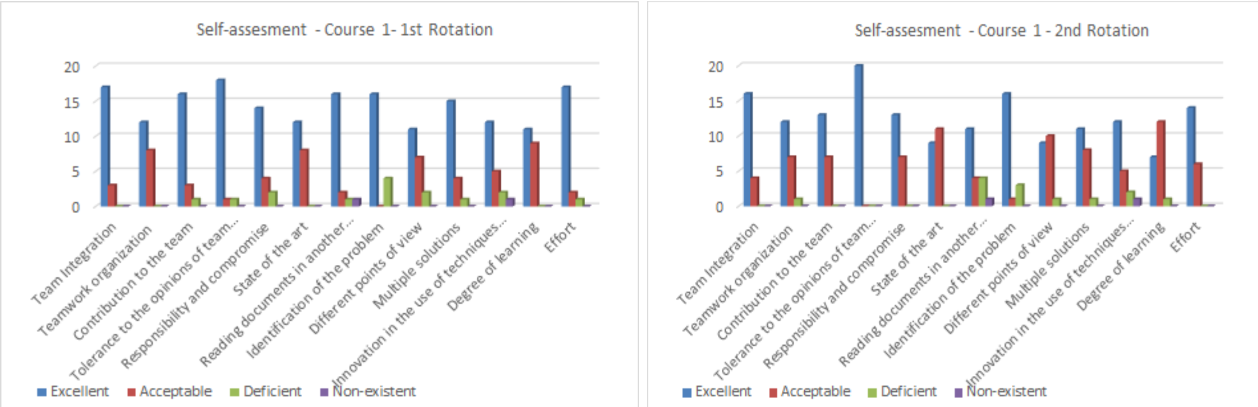


Figure 3: Self-assessment results in the course Machine Vision.

Although results show that the learning objectives were generally accomplished in the first assessment, there is a tendency towards a good achievement in the second intervention assessment, particularly in the criterion about tolerance towards the opinions of other members of the group, which increased (figure 3).

On the other hand, the results of the peer-assessment (Figure 4) show that the perception of the performance of another work team is adequate, but inferior to that of the own team. These results are also consistent between the two rotations.

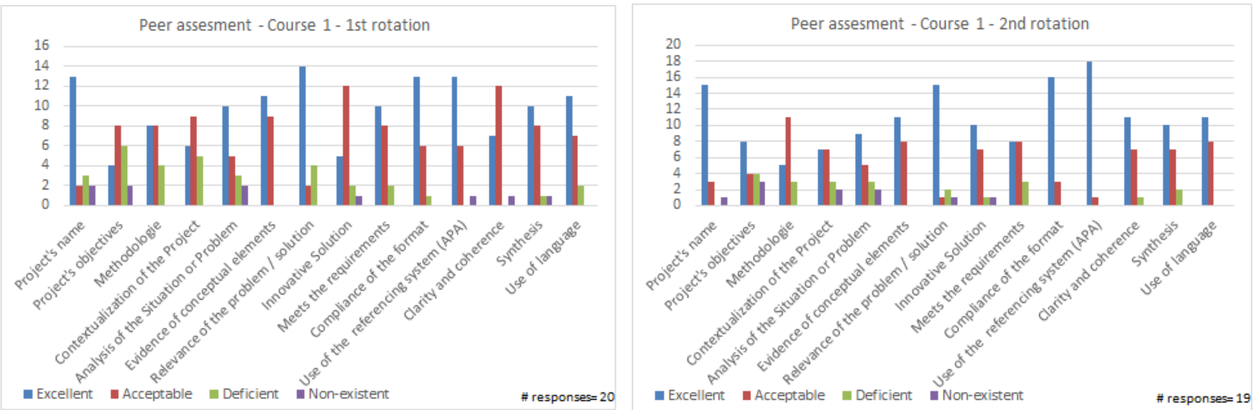


Figure 4: Peer-assessment results in the course Machine Vision.

Course Information System (IS)

Similar to the previous course, in a generalized manner, a good accomplishment of the learning objectives is observed, with a trend towards a better estimation after the second intervention (Figure 5 and 6). In summary, it is observed that the degree of learning went from mostly acceptable to a balance between acceptable and excellent.

4.2. Intervention Assessment

The quantification of the intervention impact on the achievement of the learning objectives for the two courses can be seen in Figure 7 and 8. As already mentioned, the criteria evaluated were grouped by learning objective. The average number of students considering themselves to have achieved each characteristic to a certain degree is presented.

In summary, for the two courses, the concept of students concerning the LO achievement is either good ro excellent 90% of the time.

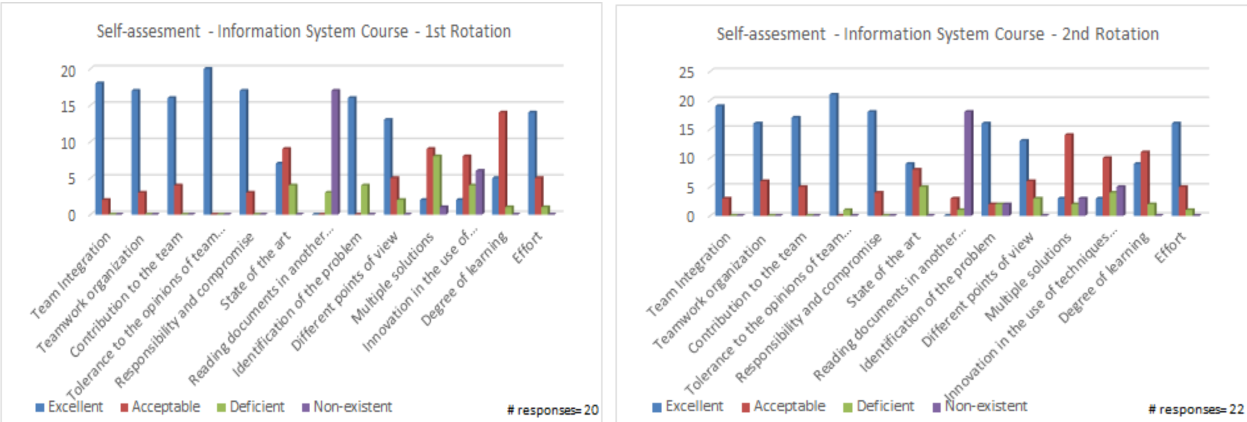


Figure 5: Self-assessment results in the course Information Systems.

Regarding the results of peer-assessment (figure 6), a tendency to a higher valuation is observed in the two highest grades.

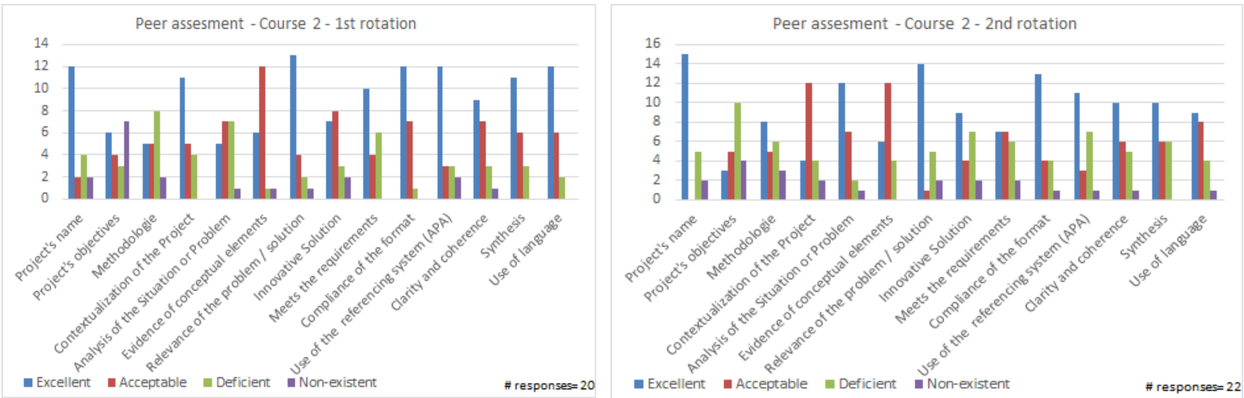


Figure 6: Peer-assessment results in the course Information Systems.

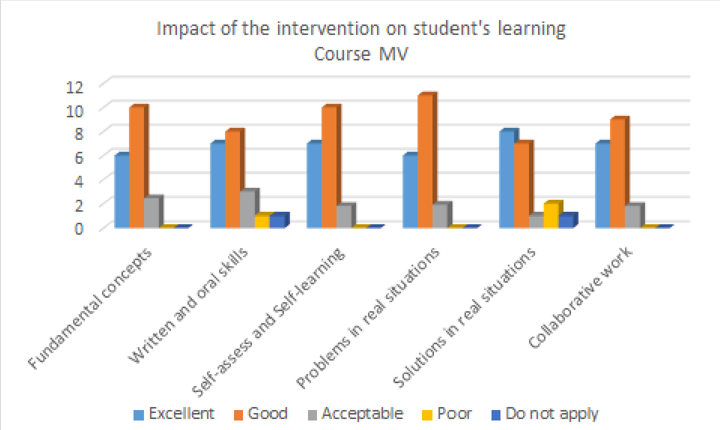


Figure 7: Intervention impact on the LO in the course MV.

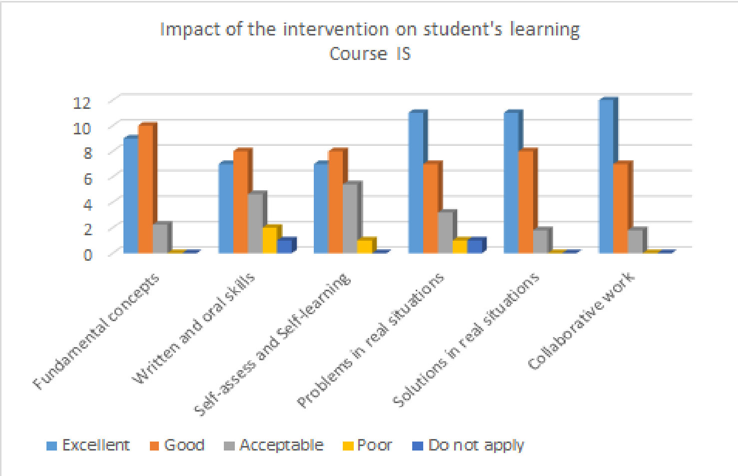


Figure 8: Intervention impact on the LO in the course IS.

As mentioned above, the students were also questioned about the effects of the intervention on the scope of the learning objectives by means of open questions. From their answers, some positive and negative aspects of the intervention were identified. The results of these questions are summarized in the following table, where the symbol '+' represents the level of positivity and the symbol '-' level fo negativity. It is evident that the project rotation methodology strengthens aspects such as self-learning and application of knowledge in different real contexts. As a negative aspect, students mentioned that the time for development was short and that there was no assistance from the teacher. Finally, 80% of the students agreed that they would like to use this methodology in another course.

Table 3: Positive and negative aspects of the Projects rotation

	MV course	IS course
Real context	++	+++
Differents points of view and ideas	++	+++
Put knowledge into practice	+	++
Use of different contexts	++	++
Promote Learning	+++	+++
State and share ideas	+++	+++
Time for the Project	-	-
Professor Assistance	-	-
Expectations on the work done	-	-
Commitment with the other group	+	-

According to the results analysis presented previously (Table 3 and Figures 3, 4, 5, 6, 7, and 8) and the observations made by the teachers, the following impacts of the intervention are identified:

One of the main contributions of the projects rotation is the **students' approach to real situations**:

> "*I consider it an enriching methodology... because we simulate a real situation where we are negotiators looking for real solutions in real companies, and... you do not choose the company you will work with...".* Student - IS course

One benefit is that it allowed students to **put into practice the knowledge** acquired in class by applying it in different contexts:

> *"... more learning spaces are generated and it forces us to demonstrate that we have understood the subject explained, as well as to look for creative solutions for the new problems that are presented to us*". Student - MV course

> *"... it is a great idea to manage the knowledge acquired in the class. Besides it is also a way of learning, innovative in my case, that makes us think and act as if we were in real life, dealing with the different organizational problems that are seen daily*". Student - IS course

Another benefit is that the projects rotation allows students to **share their ideas and points of view**, which enriches their learning processes:

> "*I liked watching the work results of other groups and interacting with classmates. It is interesting to see the ideas of the other students.* " Student - IS course

With this methodology, **appropriate self-learning environments** for students are generated:

> "*When the rotation of projects is carried out, an environment is created where the comfort zone maintained up to that point is removed and it is necessary to learn new concepts and think of solutions that may not be useful for the first project but can be very useful for the new one.* " Student – MV course

The facilitation guide (figure 2) helps teams easily **understand** the other's project and **make decisions** together.

5 Discussion

For the intervention methodology for project rotation, self and peer-assessment, four main adjustments are defined (Figure 9):

- The creation of a **meeting session between the teacher and the groups** prior to project rotation. This activity would also serve to facilitate a professor assessment activity in the future, since a single teacher cannot assess the development of all the groups' projects due to the dynamics of the project rotation itself. It would be an space between groups and within groups.
  "L*acked a little bit more communication between groups* " Student - MV course.
  "*Maybe teachers could provide support through questions and/or suggestions for better decision-making before each rotation.*" Student - IS course.
- Review of the assessment activities. The **peer-assessment** should not be at a specific moment after the rotation. Once project rotation begins there should be permanent peer assessment among groups. This peer assessment should be consolidated in a written report simulating a real organizational context. This document must be prepared after the completion of the rotation. P**rofessor assessment** is to be a permanent process. Additional, **self-assessment** is to take place before the rotation session.
- The learning objective associated with teamwork (**LO4**) must be exercised throughout the project and not at specific times. It is a critical and important factor for the development of the project.
  "*An important factor is the need to meet the expectations of other people, to know the responsibility of responding to colleagues*" Student - MV course
- A **presentation activity** of the work done by the groups is to take place at the beginning of project rotation in order to support use of the facilitation guide.

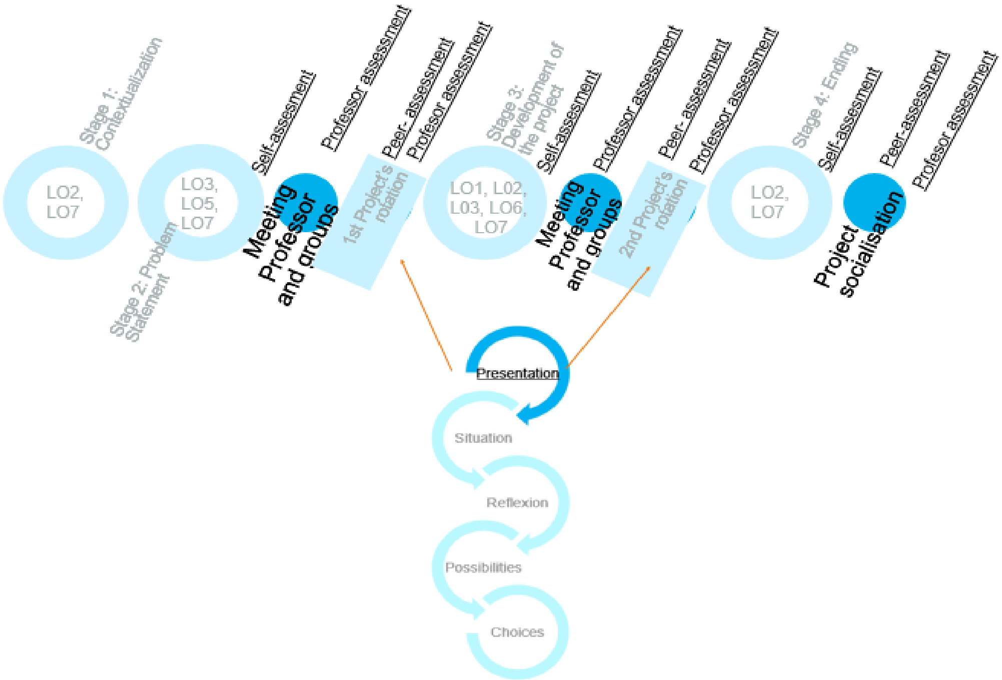


Figure 9. Methodology of intervention for project rotation, peer-assessment and self-assessment

6 Conclusions

The methodology of intervention by project rotation with peer and self assessment facilitates deep learning by the students, since besides being responsible for the realization of their own project, students must reflect on and apply concepts to the development of other projects in other contexts. These processes contribute to answering the research questions posed at the beginning of this work.

Based on the application and analysis of the proposed methodology, the following conclusions were drawn:

- The rotation activity defined by the facilitation guide forces students to formulate concise questions and to reflect upon the projects, which implies a gain in the capacity for analysis, synthesis, argumentation and negotiation.
- The exchange of projects contributes to develop the understanding and association of concepts (keys of deep learning) by applying them to the different projects.
- The rotation permit expansion of the alternatives for the development of the project, as it implies that more than one group participates, which increases the number of visions of the problem and the possible solutions.
- For a good assessment of the contribution of the methodology to the learning process, it is necessary to align the rubrics with the learning objectives. This valuation is key to defining adjustments in it.
- Factors such as obligatoriness and the students' level of studies affect their motivation and degree of involvement in the development of projects.
- In the undergraduate courses, especially the obligatory ones, additional motivation and assistance are required, compared with the postgraduate courses. Likewise, time dedicated to development of the projects must be adjusted to the type of course.
- When open problems are considered, it is important that the teacher play a grater facilitation role at the beginning, since the definition of the problem and the solution strategy is a highly complex task.
- This type of exercise raises the degree of involvement and motivation of the students in the development of the project as they appropriate the themes studied in the course to apply them in the project.
- The teacher's role in this methodology goes from being lecturer and consultant to facilitator in student learning.
- There is evidence of a strengthening in oral and written communication skills and in the achievement of learning objectives.
- This type of methodology promotes and facilitates a shift from an evaluation approach to an assessment one, since the teacher and the peers are giving feedback permanently in support of the project improvement. Students are more involved in the success of the project than in the grade assignerd at the end of the course.

As future work, it would be necessary to define rubrics in a more balanced and proper manner to assess the learning objectives by mixing quantitative and qualitative tools. Also, it would be interesting to include rigorous information collection of the professors' experiences during the process in order to contrast with results from students' feedback.

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PBL Intervention in a Power Electronics Laboratory at a Latin American University

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Abstract

In this best practice paper, the experiences with an implementation of the Problem-Based Learning (PBL) methodology in engineering courses under the power electronics program of the Faculty of Engineering – Electronic & Electrical Engineering Department– at the Universidad Nacional de Colombia are presented and discussed. This intervention consisted of changing a laboratory practice, which had the structural elements of a collaborative intervention. The learning goals, activities, rubrics of evaluation and the assessment plan of the implementation were defined. A comparison practice was developed in defined academic sessions. The results were compared in two groups of the course: one applying the PBL methodology and the other one with the usual development of laboratory practices. Four lecturers from three engineering departments developed this PBL intervention as part of the final project of a CPD training, using their academic experience to create an innovative transformation-based iterative methodology and virtual instruments in order to find out students' perception about the learning process. As a result of this experience, we also assessed each group's performance under the intended learning goals.

Keywords: PBL Implementation, Intervention, Iterative PBL, engineering courses, teacher's role

Type of contribution: Best practice.

1. Introduction: Motivation for PBL Implementation

In 2010, the *Engineering* report*: Issues, Challenges and Opportunities for Development* showed that it was necessary "to develop public and political awareness of the understanding of engineering, affirming its role ... as a driver of innovation and social and economic development" (UNESCO, 2010). In 2015, the objectives of sustainable development presented by the UN included quality education (ONU, 2016). One of the purposes of this objective was the need to facilitate the access of students from developing countries to training programs, where engineering was considered as a priority. The Faculty of Engineering of the Universidad Nacional de Colombia (The Faculty of Engineering is part to the Bogota Campus. It is the public University with the largest number of students in Colombia and recently celebrated its 150th anniversary of foundation) has become aware of its responsibility and has identified academic innovation as an alternative to respond to the necessary challenges in science and technology for the development of society.

The Faculty was the host of the 6th edition of the IRSPBL, where an innovation alternative was announced from the potential improvements arising from the Problem-Based Learning -PBL methodology. At present, the Faculty has nine undergraduate Engineering programs and comprises about 7,000 students. It has a considerable number of opportunities to develop improvement projects in the training of future engineers.

In 2018, a Continuing Professional Development (CPD) course was developed with interdisciplinary teams of engineering professors who wanted to be trained in PBL. An implementation experience was proposed in an essential element of engineering learning: Laboratory practices. In the nine programs, nearly 800 courses are offered each semester and it is estimated that 25% of them have laboratory activities in their academic structure. The first phases of transformation towards the PBL methodology can be implemented in this type of activities, where the results might not affect 100% of the course but open the way to a breakthrough.

It is considered that these changes in the teaching practice, aimed for the students' learning experience, entails a significant motivation for them. The presentation of problems in the classroom will improve their active participation within the practices, indirectly increasing their ability for teamwork and probably resulting in an improvement in their grades.

The work herein described presents the results of a PBL exercise applied in one of the electronics laboratories for electronic engineering undergraduate students and integrates the final project of our CPD.

2. Aims of the practice

The objectives of this PBL intervention in the advanced training cycle for engineering students was to answer the following questions:

- What skills should be developed in the students to improve their performance and what conclusions arise in this regard?
- What changes in teaching practice and teacher role have been found necessary?
- When evaluating courses with and without PBL intervention, are their results superior or inferior in quantitative terms?

3. Methodology

This section describes the methodology used for this intervention. The Universidad Nacional de Colombia is an autonomous institution, where it is feasible to implement Problem Based Learning - PBL as a new methodology in the courses or laboratories of the Faculty of Engineering. However, in the University traditionally there has been a great objection to the incorporation of changes, therefore, the intervention was created on an incremental application, based on what was developed in the intervention of Inglar (Inglar, 1999) cited by Kolmos (Kolmos Annette, 2008) where he describes six stages of the intervention: Contact, Contract, Preparation, Implementation, Evaluation and End.

For this first intervention, we selected the power electronics laboratory, which is part of the Electronic Engineering curriculum, being the last course in the area of Analog Electronics out of a total of 5 courses. It is issued for eighth-semester electronic engineering students out of the total of ten semesters. The course is theoretical and practical with a duration of six weekly hours of which two are Laboratory and four theoretical. The course deals with the conversion topics between the two types of alternating and direct energy: AC-DC, DC-DC, DC-AC and AC-AC. The first intervention of PBL was performed in the laboratory practice of the sixth week, which addresses the AC-DC converter.

The first intervention will allow all participants (teachers and students) knowledge in PBL concepts and methodology, and it will initiate the continuous learning that will guarantee the next experiences. PBL intervention for laboratory practice was designed considering some best-practice references from other universities (Berres Stefan, 2018). Students were involved in a task where a real problem of Power Electronics had been considered for laboratory under the teacher’s guide. This PBL intervention was designed over two months for its application in the laboratory for a week, each stage is described below.

3.1. Contact

With the support of the directors of the Faculty and thanks to the participation of the group of professors in the International course with the University of Aalborg, it was determined that the first step of the methodology should be the selection of the course or laboratory which through its current conditions will provide sufficient information to carry out the intervention. To this end, the list of courses or laboratories to be taught by the four research professors needed to be scheduled, the current data would be analysed and the course or laboratory that would provide the most information to carry out a first intervention with successful results would be selected.

The data of the course correspond to the current average of the theoretical and practical components, the number of statistically acceptable sufficient students (for the case more than 7), in order to have current guides that could be contrasted with the instruments developed for the intervention, and to be presented in at least two groups: one to apply the traditional method and the other one for the PBL intervention.

3.2. Contract

Once the group in which the first PBL intervention was applied was defined, the agreements of the participants were determined during two sessions, pointing out what the role of the teacher would be and what the criteria and skills that the students would develop would have to be. In accordance with the established objectives, the role of the teacher would be a facilitator and the students would use all their capacity to provide critical thinking, teamwork and effective communication in order to come up with an adequate solution to the problem posed.

As part of the agreement, the students would present 3 possible solution options, on which the teacher in his role as facilitator would state the pros and cons of each of them, to finally determine a simulation solution, before executing the real practice in the laboratory where it was implemented.

3.3. Preparation

Once the course was determined and agreements were made between the teacher and the students, it was necessary to divide the preparation into two: On the one hand, the teacher defined the objectives of the practice, built the new laboratory guide and the rubric that would be used for the evaluation, and on the other, the students focused on understanding the basic elements of the intervention, analysing the guide and finding an adequate solution to the problem they had to simulate before the laboratory practice.

3.4. Implementation

Each question of the 4W1H Methodology was considered (Why / What / How / When / Where). The detailed explanation is given in another section below. The implementation of the intervention was held in April, following the methodology defined, and concluded with the students' feedback and expert judgment, at the beginning of May.

3.5. Evaluation

The evaluation plan of the PBL-based pedagogical intervention in the Power Electronics laboratory includes a focus based on wh-words: Why, What, How, When and Where.

Why refers to the motivation that led us as teachers to explore PBL: achieving a better teaching-learning process (effectiveness) and an ongoing improvement of our pedagogical process. It is important to consider the motivation for this PBL experience because we want to assess whether these objectives were met.

What asks whether the PBL intervention contributes to the development of the following skills listed by Graff and Kolmos (Kolmos Annete, 2009), in this case: critical thinking, effective communication and teamwork. From these skills, we conclude three more criteria for our evaluation.
How denotes one of the instruments for the feedback of the students that participate in this PBL experience. For this purpose, we apply a survey that includes the evaluation of the two objectives:

- Engineering solution
- Soft skills development

For the last objective in this PBL intervention, we used a comparison mechanism on students' performance between the traditional method and the PBL innovation.

- Evaluation of learning objectives

When determined that we would do the survey once the lab involved a PBL approach. And finally, where was chosen by election as it is an electronic survey and we can say that the site was determined by the students when they were filling it out.

PLAN EVALUATION OF IMPLEMENTATION OF PBL INTERVENTION

4W1H	DESCRIPTION
WHY	Effectiveness (methodological approach) Continuous improvement
WHAT	Product performance
	Skills development, e.g.: ✓ Critical thinking ✓ Communication ✓ Team working
HOW	A rubrics development of PBL implementation & Intervention Expert judgment Student's feedback
WHEN	At the final stage of traditional lab session followed by PBL lab session
WHERE	Classroom Eng. Alejandra Guzman (Assessment from PBL expert)

Figure 1. Evaluation Plan for PBL Intervention

Feedback from students: A virtual assessment tool was developed to collect the students' feedback. The results are presented in the "Evaluation" section.

3.6. End

Results of the rubric and Judgment of the experts: The evaluation (assessment) of the subjects developed in practice was performed by comparing the results with another group that used the traditional guide and method. The results of the comparison are shown below.

Each experience will be a new step until a large part of the courses or laboratories of the Faculty are covered.

4. Preparation

On the part of the teachers: Define the objectives of the practice, build the laboratory guide. On the part of the students: Understand the guide, find a solution and perform the laboratory simulation.

Learning Objectives

Two (2) learning objectives were set during laboratory practice:

- Use and operation of the VRS
- Voltage regulation by feedback

With these two clearly established objectives for the control of voltages, the group defined the role of the professor in the intervention as a guide in the process. Each group of students should face and give a solution to the problems posed in the laboratory. Professor Ricardo was defined as leader of the intervention, since it was a course assigned directly from the Department of Electronic Engineering. Prior to the development of the laboratory, Professor Ricardo explained the required theory about how to use VRS and the types of ignition used in it. The detailed explanation is provided below in another section.

LEARNING OBJECTIVES

LEARNING OBJECTIVES	TEACHERS' ROLE	ACTIVITIES	STUDENTS ACTIVITIES	ASSESSMENT AND EVALUATION INDICATORS	MATERIALS AND INSTRUMENTS
Use and operation of the VRS.	Guidance It has been developed previously A basic VRS practice through a guide	Before: Explain the theory and use of the VRS. Types of ignition of the VRS. Evaluate presented solution. During : After: Validation of the results obtained and the calculated theoretical.	Before: Design, define elements to use and simulate solution. During: Test the solution. Afte⁻: Present the solution, and the results obtained. actions for each objective	Indicador 1: He understood the VRS operation. Indicador 2: He learned the VRS ignition... Examen A.	Materials: -PowerPoint - protocols - readings Instruments: - assessment - evaluation - feedback
Voltage regulation by feedback	Counselor. A control course	Before: Control Course	Before: Define type and values for the control. During: Verify operation After: Validate results. actions for each objective	Indicador 1: learned how to connect the control Indicador 2: Know how to choose the values. Examen A	Materials: -PowerPoint - protocols - readings

Figure 2. Preparation Plan for PBL Intervention

Teaching Activities: Perform the teaching and learning activities as described by Biggs (Biggs, 2003).

Rubric: Designed by establishing six (6) evaluation elements. Each criterion was quantified. The detailed explanation is provided in another section below.

#	Description	Criteria		Quantification
1	Paper Design of a voltage regulator source	Perfomance		33%
		Safety		33%
		Reliability		33%
2	Assembly of teh electronic source VRS	Does it work as was required	Yes	100%
			No	0%
3	Justification of each of the components used	All		100%
		Someone		50%
		None		0%
4	Does it work from 1 to 15 volts	Is it variable ?	Yes	100%
			No	0%
5	Output tolerance is between +/-2.5%	1% or less		100%
		From 1 to 2.5%		50%
		Greater than 2.5%		0%
6	Presentation of the written report	Clarity		33%
		Knowledge		33%
		Answers		33%

Figure 3. Rubrics for PBL Intervention

Preparation and Development of the laboratory practice: The elements required for the laboratory were built. For the intervention, new laboratory guide had to be prepared, where students no longer had the steps that solved the problem, but they had to use critical thinking and their knowledge in order to come up with a solution to the problem. The results are presented in the "Evaluation" section.

5. Results

In this section we present the results of the application of the survey covering the two first aims and the results of the application of the questions in order to evaluate the last aim: the performance improvement in the group with PBL intervention.

5.1. Soft skills development results

The students expressed their perception about the development of soft skills that as teachers we consider critical for their future professional development, such as critical thinking, teamwork and effective communication.

Team work: This skill is indispensable for professional performance. It is rated by students at an average grade of 3.5 out of 5. We could interpret that they consider teamwork as an acceptable mechanism to design and implement the engineering solution.

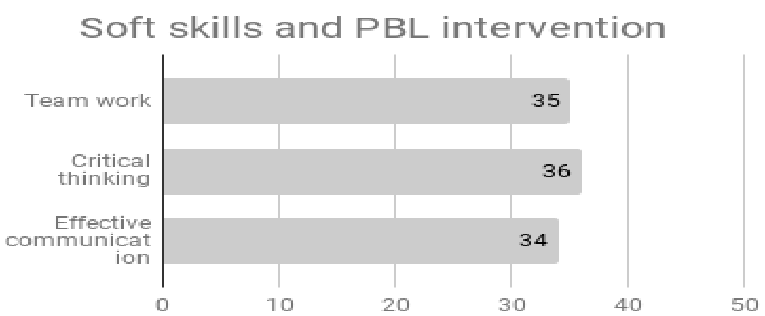

Figure 4. Results about improvements

Critical thinking: The ability to form a judgment based on the analysis of the facts is perceived by the students as being developed in a PBL practice in an average grade of 3.6 out of 5. This skill is very important for the future engineers to help the decision-making process in Engineering.

Effective communication: The ability to clearly convey a message is undoubtedly very important for the roles that engineering professionals will play in the future. Students consider in an average grade of 3.4 out of 5 that PBL practices allow the development of this skill.

5.2. Engineering Solution Results

Regarding this criterion, we will consider two aspects of our interest in the evaluation:

About the design of the solution: 72% of the students prefer that the teacher provides the design of the solution, while 28% believe that it is better for the students to prepare it. This evidenced the preference for the traditional teaching method where the teacher provides the answer for the given problem.

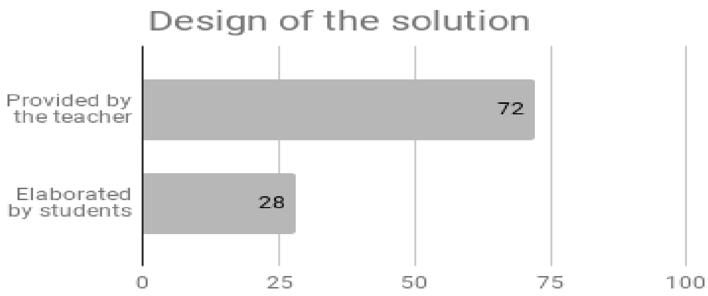

Figure 5. Results about Design of the solution

About the implementation of the solution: Regarding the implementation of the solution, they prefer again the traditional teaching method. This results from the students' greater preference for a step-by-step guide (64%) than for an implementation carried out by themselves (36%).

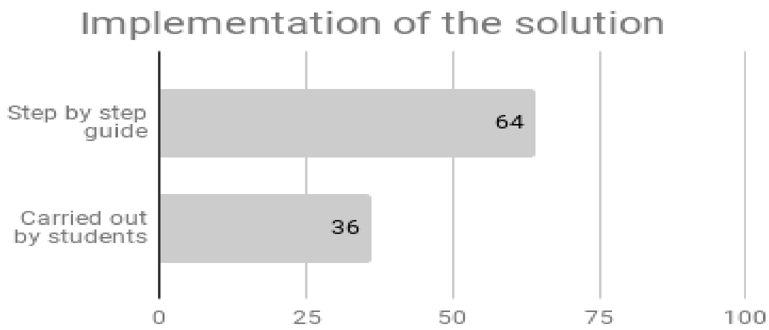

Figure 6. Results about implementation

At this stage of the engineering students' training (mid-career and further), they prefer traditional teaching. This leads us to think as teachers that we need to start the PBL approach from the first semesters, so that we can replace the traditional teaching-learning model with a more active one and with a student-rather than a teacher-based process.

5.3. Evaluation of Learning Objectives

After the laboratory session, we wanted to compare the effectiveness of the PBL Intervention related with the learning objectives. Consequently, we applied a group of identical questions to two student groups: one of them with the traditional method to the lab and the other one, the group with the PBL approach. The questions were:

For the forced switching of SCR (Silicon Control Rectifier - Thyristor):

i. Draw two forced commutation circuits by using SCR.
ii. Explain the operation of one of them.

iii. What ignition methods of SCR do you know?

The students that made the lab practice with the traditional method scored an average of 21.5, while those students that used the PBL approach ranked an average of 30.6.

The students that used the PBL approach were guided to implement a design without forced commutation. Although the questions are related to force switching, the difficulty of implementing it in the PBL approach generated greater skills in the acquisition of knowledge related to the architecture of the solution.

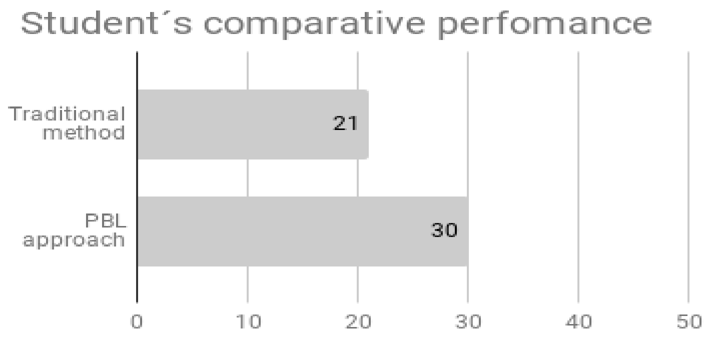

Figure 7. Results about Student´s performance

6. Reflections and Conclusions

Applying a PBL approach at a course mainly implies changing the role of teachers and students. As (Zimmerman, 2000), cited by (Kolmos, 2003), state: There are activities different than the traditional model, such as learning by solving problems in a collaborative way, with critical thinking and effective communication.

6.1. Impact of teaching activities

Teaching will no longer be provided by the traditional method, but it will involve a collaborative process among the students, with the participation of the teacher in the role of facilitator. The guides developed for the course are not made step by step anymore, but with a practical orientation where the student is an active part of the learning and the tutor is the teaching counsellor.

At the same time, each professor who incorporated the methodology in the course will have time enough until the next semester to extend the applicability of PBL according to the initial proposal. An initial effort is necessary for the construction of the rubric and other elements, that is, 20-30% additional effort to that of traditional methods. This could be evidenced in the one-week application of the proposed intervention, but it is considered only an indication that will be deeply analyzed when a greater number of interventions be made.

6.2. Competencies and skills developed by students

As teachers, we believe that Problem-Based Learning does have a significant impact on the development of students' soft skills necessary for their future role as professionals, a situation that leads us to conclude again that this approach must be addressed earlier and integrally in the curriculum.

6.3. Expansion of the PBL intervention

Since it is the first formal PBL intervention in a course of the advanced training cycle, there are several activities to develop and to find out whether this learning method results in other improvements for students. According to the iterative methodology, the intervention could be extended to a complete section of the course in order to increase the comparable data of this collaboration exercise. Then, it may be proposed in other courses and even in other public universities of Colombia.

6.4. Implementation as a pedagogical practice

It is necessary to train more teachers in each department or the career, so that each iteration of the proposed model can cover a greater number of courses, which in turn will cover a greater number of students. The latter could help to better understand the PBL implementation. It is also necessary to allocate more resources in the training and promotion of experiences that facilitate change. The mechanism would depend on the will of the directors of the Faculty, but also on determining a set of courses that allow its rapid implementation, taking as a base the theoretical-practical subjects.

6.5. Change in the assessment methods

The traditional student evaluation is simply accomplished through the grade reached in the written evaluation. However, there are different methods with PBL that can provide a greater perception of the results of the students' learning. For this purpose, the survey carried out by the student was valuable, as well as the use of very specific questions in the rubric defined for the evaluation of the learning objectives and, in general, the teacher's viewpoint of the process carried out.

6.6. Early change management

The results of the surveys made to the students show a greater predilection for maintaining traditional methods where they feel more comfortable with learning. It was evidenced that most of them look for the line of the lower effort to carry out the laboratories, since they preferred the step-by-step practices used in the traditional method, over practices where more work should be done with teacher mentoring. This shows us that it is necessary to start working with the student from the first semesters in order to promote awareness of the better results obtained with PBL.

7. Future Work

The challenge will be building 100% of the course in three iterations, with the instruments and elements necessary to apply PBL. In the first iteration, the professors will discover the potential of the methodology, the best way to apply it in the context of their course and, above all, their own fears and those of their students. In the next iteration, the professor searches for mechanisms to address and solve the previous findings. It is expected that the second iteration lasts at least four weeks (out of the 16 weeks planned), to reach a maturity degree high enough for the teacher and the student to face a third iteration in the remainder of the weeks covered in PBL. The iterations will allow the teacher to build the instruments, rubrics and other elements required according to the new course conditions.

As a strategy to prepare students, continuous lines must select at least three courses (to be developed in the same number of semesters), ensuring that the student has the same continuous improvement cycle as expected with the teacher. According to the curriculum, three subjects that complement each other in the study of knowledge are easy to identify. For example, the electronics undergraduate program could address lines such as: In the first course, the student would attend a week using PBL; then, in the second one, once per month; and finally, in the third one, the student would have to do it in 100% of the weeks.

In the future, a stronger intervention is planned on 5 practices to implement a mixed technique. According to the methodology proposed in our poster, the PBL immersion will be made through an incremental evolutionary growth, which consists of covering a greater scope each semester with the PBL intervention in several weeks, until completing the entire course, as follows: First Semester: One (1) week intervention, corresponding to one (1) laboratory guide, Second Semester: One (1) month or four (4) weeks intervention, corresponding to four (4) laboratory guides and Third Semester: Total intervention of the course, (4) months or sixteen (16) weeks, corresponding to ten (10) laboratory guides. The incremental implementation considers the following:

- Teachers interested in PBL, preferably those who have actively participated in pedagogical training in the methodology, will make a small one-week intervention in any of their courses. This first iteration would consist of determining: The topic that facilitates its initial implementation and should serve to build the minimum elements required for a solid preparation of the participants (teachers and students) for future interventions.
- The challenge will be building 100% of the course in 3 iterations, with the instruments and elements necessary to apply PBL. In the first iteration, the professors will discover the potential of the methodology, the best way to apply it in the context of their course and, above all, their own fears and those of their students. In the next iteration, the professor searches for mechanisms to address and solve the previous findings. It is expected that the second iteration lasts at least four weeks (out of the 16 weeks planned), to reach a maturity degree high enough for the teacher and the student to face a third iteration in the remainder of the weeks covered in PBL. The iterations will allow the teacher to build the instruments, rubrics and elements required according to the new course conditions.
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- At the same time, each professor who incorporated the methodology in the course will have time enough until the next semester to extend the applicability of PBL according to the initial proposal. An initial effort is necessary for the construction of the rubric and other elements, that is, 20-30% additional effort to that of traditional methods. This could be evidenced in the one-week application of the proposed intervention, but it is considered only an indication that will be deeply analysed when a greater number of interventions be made.
- Some results evidenced that students also have objection to change and show a greater predilection for maintaining traditional methods where they feel more comfortable with learning.

For the next interventions, detected improvements in the existing laboratory guides were analysed and four more practices were changed, aimed at providing students with a major role in their development and seeking to reinforce knowledge. In accordance with the result obtained from the immersion in a course and later with the participation of other professors, the scope will achieve the intervention of a line (several courses of cross-curricular form, in two or three semesters), thus, in a couple of years, the PBL intervention will be made throughout the curriculum.

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Environmental Impacts of Transportation: A problem-based -learning approach to damage and social costs of transport systems

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Abstract

Transportation is usually ranked within the first three most significant sources of environmental impacts, such as air pollution and climate change, regardless of the city or region. Therefore, there is increasing interest in promoting awareness among civil and transportation engineers about environmental and sustainability issues, and problem-based learning could effectively integrate content, skills and knowledge development requirements among students and future engineers. Within the curriculum of a lecture-based course on the environmental impacts of transportation offered to master students and last-year undergraduate Civil Engineering students at Universidad Nacional de Colombia, we designed a PBL intervention with the dual learning objective of deepening students' understanding of and developing critical thinking around the environmental damage caused by transportation. We aimed at facing two teaching challenges: 1) to support students in analyzing environmental damage though correlation and causation relationships between transport system components and health risks, using different quantitative methods; and 2) to support them in converting their analyses into informed decisions on transportation systems design and public policy. The PBL intervention covered 40% of the total course. Students worked in groups of 3 during a 6-week period. We report on quantitative and qualitative data from rubrics applied to the products of teamwork, students' self-assessment of participation and teamwork dynamics, an individual examination, and individual students' interviews. We offer reflections and insights on the PBL experience and traditional teaching of the course.

Keywords: PBL in Engineering, active learning in Engineering, teaching environmental impacts of transportation, teaching transport and sustainability.

Type of contribution: Best practice paper.

1 Introduction

Environmental Impacts of Transportation is a postgraduate, elective course offered by the School of Engineering at Universidad Nacional de Colombia to students of the Master's degree in Transportation Engineering. It was offered for the first time in the history of this postgraduate program during the first academic semester of 2018 and planned with a lecture-centered methodology to cover topics like environmental problems caused by transportation, environmental externalities, benefit-cost and decision making including environmental externalities and climate change and transportation. As the professor giving the course was, in turn, invited to take a course on the basics of Problem Based Learning (PBL), and without yet knowing she was already starting a pedagogical intervention to drastically change the class methodology, she gave the students an authentic problem in transportation to discuss, study materials to understand it, and devise solutions to it. The project was: Traffic-related pollution in Bogotá. Looking closer to trucks and buses. The students had to use different approaches to compute a traffic-related-emission inventory and devise and support public policies to control it. This authentic problem in the area of the course was a perfect opportunity to develop a whole intervention applying PBL, so as a group we decided to use it as our first attempt at implementing PBL and learn from it.

2 Theoretical Framework Title Page

The description that constructivism makes of human learning (Ordóñez, 2004; 2010a; Fosnot, 2005) indicates that people learn from their activity in the world and their interactions with others (Dewey, 1945; Piaget, 1970; Vygotsky, 1978); that learning is a long process of improving understanding and making it increasingly complex (Boix Mansilla & Gardner, 1998; Perkins, 1998; 2005; Wilson, 2005); and that learning occurs in specific contexts (Brown, Collins & Duguid, 1989), so the activities which are best suited to produce learning are authentic, related to the real world and the real activities performed by people who do daily things because they possess knowledge which they understand or because they are experts in specific areas of knowledge (Dewey, 1945; Gardner, 2004; Ordóñez, 2010a; 2010b). Different forms of PBL (Problem-based and Project-based Learning) and other active or student-centered pedagogical practices are classroom manifestations of the application of constructivist principles of learning to the design of teaching-learning environments (Savery & Dufy, 1996).

Referring specifically to PBL in higher education, Kolmos, de Graaff, and Du (2009) connect different Project and Problem-based pedagogical models through a set of learning principles, related to three different areas: a cognitive and a social areas, which evoke constructivist principles because they deal with the structural relationship between problems and projects and the contextual, experiential and collaborative nature of learning; and a contents area that relates to the relationship between theory and practice and interdisciplinary learning. But in spite of common learning theory grounds, PBL practices can vary greatly in the type of activities students are assigned to do, the organization given to collaborative work, and the way in which student performance is assessed (De Graaff & Kolmos, 2003) and can be restricted to individual courses or used throughout a whole university (Kolmos et al, 2009). In any case the activities devised for or by the students in a PBL learning environment should be organized by the teacher or the teacher and her students in a way that they align with clearly described learning objectives, as should the outcomes of these activities and the way in which they are assessed, in a way that ”the learner finds it difficult to escape without learning properly” (Biggs, no date: p.1).

3 The Intervention

Based on the initial problem the students had to study and give a solution to while their teacher was taking a course herself, we designed a PBL intervention which comprised only a learning section of the course. We defined for it the dual learning objective of deepening students’ understanding of and developing critical thinking around the environmental damage caused by transportation. At the same time we set to apply PBL for the first time in our teaching of an Engineering topic and learn ourselves in the process, through two challenging commitments: 1) to support students in analyzing traffic -related air pollution damage considering relationships between transport system components and health risks, using different quantitative methods; and 2) to support them in converting their analyses into informed decisions on transportation systems design and public policy.

During the intervention the students had to investigate and select a method to calculate a traffic emission inventory for buses and trucks in Bogota, study and propose different policies to mitigate such emissions, evaluate the cost effectiveness of those policies and the social benefits of the most efficient policy. We had a total of twelve (12) students, and they worked in groups of 3 during a 6-week period, and the PBL intervention covered 40% of the total course.

The entire class met twice a week for a 2-hour period each time. During our class meeting we implemented various active learning strategies as Socratic questioning, collaborative reading of research articles, post it parade, among other, with the purpose of guiding their work on the problem. Students presented every Friday their progress and results accomplish week. Collaboration within and among groups was encourage and took place during class meeting times. Students also reflected on their performance within their group every week. For an overview of the intervention see Appendix 1.

4 Method

According to the above theoretical framework and the way in which we organized the pedagogical intervention, we could expect students who were used to lecture-based, traditional teaching to discover new ways to learn and find challenges in the process. We then formulated the following research questions for our project:

- How can we characterize students' learning from the PBL intervention, on the basis of their performance in oral presentations, written reports, and a final oral examination?
- What differences did the students perceive between the first part of the course, based on lectures from the teacher, and the PBL experience?
- How did the students characterize their learning from the PBL experience?
- What challenges did they identify in this experience?

In order to answer the first question about the students' learning we used rubrics to assess two different oral presentations about the analysis of the problem and its solutions, one after computing the emission inventory and analyzing mitigating policy options and the other at the end of the intervention. The rubrics included criteria related to academic rigor in the handling of the content of the course and skills in talking about it and their decisions in a clear and concise way. They associated qualitative descriptions of different levels of achievement in each criterion to numeric grades.

The teacher also used similar rubrics to assess a final written report the students had to present on their work, and she gave them an oral final examination on the academic content they had to handle, also producing a numeric grade from it. We did descriptive statistical analysis of these grades and related it to the qualitative descriptions in the rubrics and a qualitative description of the students' performance produced by the teacher during the final oral test.

In order to find answers to questions 2, 3, and 4 relating to students' perceptions, we interviewed the 12 participants in the course on the last day of the intervention, asking them if they identified the change in methodology, how they described it and what advantages and disadvantages they saw in it. We categorized the views of the students pertaining to each research question.

5 Results

In general terms, we found that the students showed their learning in ways different from the traditional ones they show in tests and demonstrated that they got to understand concepts and methods they studied to an acceptable depth. They also noticed a big change in the methodology of the course, identifying the basic pedagogical characteristics of PBL, and acknowledged a different kind of learning and some advantages in working in this way. They also pointed out some problems in the methodology and expressed doubts as to the possibility of learning in this way all the time, especially, in courses where a lot of complex content has to be learned. In what follows in this section we present the answers to the research questions in detail.

5.1 Results from the Assessment of Presentations, Reports, and Final Test

During the intervention students had two group oral presentations, two written reports by group and one final oral individual examination. Improvement in the use of technical language and economic concepts was observe in all groups during the oral presentations. These reflects appropriation of concepts and deeper understanding of the problem. Grades were higher in the second oral presentation in all cases. Same trend is observed with the written reports.

The individual oral examination was consisted of four questions, two related to topics covered during the lecture-based part of the course (Concepts of externalities and economic framework for environmental resources) and two related with the topics developed during the PBL intervention (risk analysis and valuation of social benefits). Three quarters of the students performed better in questions covering the topics enclosed during the PBL intervention compare to results on questions related to topics covered trough lecture-based teaching. Overall, we report improvement on students abilities to analyze environmental impacts of transportation using a set of tools that they discovered and manage to master.

5.2 Results from the Qualitative Analysis of Student Interviews

In their interviews, all the twelve (12) students identified the change in methodology: six (6) of them described it as a change towards student autonomy or self-study and five (5) as a change towards research. One (1) student indicated that the most important characteristic of the change was more effort and personal sacrifice to learn, and only one (1) gave a negative connotation to the change, qualifying it as 'drastic' and explaining that it forced them to find their way within unknown territory. In giving details, four (4) students acknowledged that they changed to constructing their own knowledge from their own work in a project and solving a problem, two (2) of them giving a lot of importance to reaching knowledge though group feedback. One of these students gave a very engineer-like explanation of the change, in terms of flow of knowledge: from one-way flow (teacher –> students) to a two-directional relation, with knowledge flow among students and between students and teacher. Five (5) students talked explicitly about their role producing questions and doubts and/or their teacher's as collaborator, working with them to find answers and clarity.

All the twelve (12) students found advantages in the PBL methodology, even if two of them did not acknowledge those advantages in this intervention in particular or considered the traditional methodology better. Five (5) students mentioned the advantage of not depending only of one person's knowledge, the teacher's, and getting knowledge directly from different sources. Five (5) students recognized that PBL work was similar to real life work in that group work is done in professional life, finding different answers to a problem was more the case in consulting, and this type of work helped them find their way better in unknown situations. Finally, two (2) students indicated that PBL is better if one really likes the topics that are being learned, because it allows one to investigate on their own.

But the advantage the students indicated, which we thought most interesting was related to learning: ten (10) of the students indicated that PBL allowed them to develop academic and personal skills, mentioning literature research skills, skills to support ideas and to develop criteria about the solution of problems as the first ones. As to personal skills, they were all related to group work and involved learning from one another, communicating or sharing information and reaching consensus, dividing tasks consciously and supporting one another. Also ten (10) of the twelve (12) students realized that the learning they were able to do was more profound and better assimilated and is going to be more permanent than the learning they get from teachers, because they had to work more, work by themselves, and share knowledge to get it. Finally, two (2) students made it explicit that ALL of the members of the groups learned the content, implying this is not usual in traditional methodologies.

In spite of all these positive ideas about PBL, all the students mentioned challenges related to it and even sometimes expressed their view that the traditional methodology, where the teacher explains the content to be learned, is definitely better (one (1) student) or better in the case of classes which are full of new content to be understood (two (2) students). Some of the negative ideas they expressed, which can be related to this preference for traditional methodologies, refer to the fact that PBL is quite difficult if students do not have good basic understanding of necessary content (one (1) student); the fact that they do not trust the explanations given by classmates (two (2) students) or their own understanding of what they have to study by themselves (six (6) students); and the fact that they believe that what the teacher says is correct, well understood, and safe to believe (three (3) students). Six (6) students agree that the autonomous and group work in PBL takes more time, dedication and rigorous work, two (2) of them indicating explicitly that in spite of this, the result is knowledge of less content. Also, although most of the students indicated that group work had functioned well, this was a focus of complications during the PBL experience: two (2) students reported that it had taken time to get real group work to function; two (2) that there had been problems with very different possibilities to dedicate time to the necessary work; and two (2) that the challenge of listening, conceding and reaching consensus had been big; another student (1) said there had been problems because of the different levels of knowledge of the members of his group, since there was a mixture of undergraduate and postgraduate students.

6 Discussion

Related to our first challenge, which was to support student´s understanding of traffic -related air pollution damage in relation to transport system components and health risks using different quantitative methods, we consider that students developed the analytical skills of at least one of the methods that we expect them to learn. All groups were able to perform a well-designed risk analysis of traffic-related emissions. Additionally, our interpretation of the group and individual examination is that most students developed a deeper understanding of the topics covered during the PBL intervention when compared to those covered during lecture-based course. Dealing with the uncertainty of not having one right answer or one right method to use was a challenge observed on students, which represented a challenge for them when converting their analyses into informed decisions on transportation systems design and public policy. Students don't feel as secure on their knowledge gain during the PBL intervention. Even so, a discussion on how to uncertainty plays a big role in real life engineering practice was enforced. At the end, most students appreciated having this discussion in an academic setting.

Finally, the most salient interpretation we can do of the results from the students' interviews is that, in their very first experience with rigorous autonomous and group work in facing a problem/project, they acknowledge a different and better type of learning, but are still unable to dismiss the idea that covering content and receiving it directly from a person they trust as an academic authority is learning. They are just beginning to reflect on their learning and to understand it as a personal, internal process that enables them to make decisions and do things. Content is still the focus of learning for them, and they still understand it as knowledge not to be discussed and totally necessary as a basis for later application. They still need to develop a different conception of understanding, where understanding is an internal, personal process and not something acquired from others. But it is clear that this very short but authentic experience of a few weeks has opened an important window of reflection and change in their conception of teaching and learning for them.

We discovered that our students are not well prepared for critical thinking: they find it difficult and too much work to make decisions, support them with knowledge that they have really worked with and understood, organize the time to work by themselves and with others, and understand that their classmates and other people can also help them learn, nor only the teacher. They are too used to receiving; not so used to really work effectively and efficiently in learning. It really seems that changing to PBL and other active methodologies means improving our teaching, in the sense of getting better results in students' learning from our efforts. It will be challenging, though, both for us and for the students.

We also want to highlight that the experience of implementing this intervention as a group of professors was an appropriate choice. Junior professors felt supported by senior professors with experience in constructivism and PBL interventions who provided the guidance needed to the professor implementing activities in the classroom. This factor that played very well on the success of the experiment.

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Appendix 1 An overview/plan for the teaching & learning activities for the intervention

Date	Content	Phases	Class Activities	Teaching Role	Students Role	Assessment Tools	Evaluation
14/03/2018	Project Phase 1: Discussion of approaches to the problem Second Hour: Discussion on Willingness to pay and Value of statistical life	Training	First hour: Present and discuss Second Hour: Discussion on Willingness to pay and Value of statistical life	Prepare questions to activate learning during students presentations Prepare instrument to assess process Prepare questions to generate discussion on VSL an WTP Compute VSL and WTP of students	Prepare their presentation Phase 1. Readings on VSL and WTP	Instrument 1: used during Project Phase 1: How much they understand the problem quantifying emissions and different options of abatement Instrument 2: Self and Peer assessment of the PBL intervention. Fridays 10 minutes during class starting on 03/16	

Date	Content	Phases	Class Activities	Teaching Role	Students Role	Assessment Tools	Evaluation
16/03/2018	Different methods: Risk assessment, Life cycle assessment and statistical models	Clarifying and Directing	Concept map	Prepare readings Prepare questions	Read material Discuss and build the concept map of damage		Students Interview to establish a base line on how they understand the problem and topics
21/03/2018			Newspaper article				
23/03/2018	Final presentation of Project Phase 1 Project Phase 2: Teacher presentation		Student present their solution to the first phase of the problem	Questions Rubric Project 1 Design of Project 2 Assessment instrument for peer feedback	Prepare their final presentation Phase 1. Give feedback to students presentations	Evaluate Product and Process of Phase 1 using a rubric related to learning goals:	
28/03/2018	Holiday						
30/03/2018	Holiday						
04/04/2018	Different methods: Risk assessment, Life cycle assessment and statistical models	Training	Presentation of project development - phase 2	Process assessment tools	Prepare presentations of process development	Assess how much students understand the problem of environmental damage and the tools to assess damage	
06/04/2018			Papers and cases	Prepare readings Prepare questions	Read and analyze cases and research articles		
11/04/2018	Different methods: Risk assessment, Life cycle assessment and statistical models	Support	Presentation of project development	Process assessment tools	Prepare presentations of process development	Assess how much students understand the problem of environmental damage and the tools to assess damage	
13/04/2018			Papers and cases	Prepare readings Prepare questions	Read and analyze cases and research articles		
18/04/2018	Final Presentation of the project	Evaluation	Student present their solution to the second phase of the problem	Prepare questions and Evaluation tools	Give feedback to students presentations	Evaluate Product and Process of Phase 2 using a rubric related to learning goals	
20/04/2018	Oral examination			Design rubrics	Prepare for the oral Examination		Individual oral examination to compare to the base line

Old Brick Warehouse Re-Start Project

Inheritance of Memory—Regeneration By Students of a Historic Building Damaged by the Kumamoto Earthquake in 2016—

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Abstract

This paper describes students learning process with PBL. The aim was to focus their attention on a concrete outcome from an earthquake. The learning experience was not structured and was intended to be a self-directed educational process. Confronted with real problems, students were expected to attain valuable educational goals through enhancing motivation. This PBL project was related to an old brick warehouse damaged in the Kumamoto earthquakes in April 2016. We describe the project and present the results of a questionnaire by the students about their leaning experience, as well as competencies developed through involvement with people affected by the earthquake. The Kumamoto Earthquake (magnitude 7.3), damaged a warehouse located near the students' college. It was constructed in 1921 and had been used by residents for various community activities. After the earthquake, the authorities intended to demolish the building in agreement with the owner. However, determined to preserve and create a memory legacy of the historic building, students decided to implement the "Re-Start Project." They proposed creating a pocket park having benches made of bricks from the demolished warehouse. In collaboration with residents, a plasterer, municipal officers, and teachers over a period of ten months, students were able to complete the project. Despite the strained circumstances that followed the earthquakes, students remained highly motivated, acted on their own initiative, and experienced deep satisfaction with the completion of the project. Participating residents also learned much about the nature of future-oriented community development. Through various exchanges with stakeholders, students gained new knowledge for the optimal solution to a specific situation. Solving a "problem" caused by an earthquake brought innovative learning approaches that have never been tried previously.

Keywords: Kumamoto Earthquake, motivation, self-directed learning, architectural design, residents' participation

Type of contribution: best practice paper

1 Introduction

The aim of this paper was to clarify the educational effects of a problem-based learning (PBL) project related to the damage caused by natural disasters such as earthquakes. Such situations are usually non-structured and ill-defined, and they confront a student with the task of having to find solutions to a specific problem. In doing so, students develop certain competences and deepen their own awareness about what they are inquiring into. After completing the PBL project, the students can also evaluate their learning achievements and understand the process of finding solutions to a problem which involves the residents of a local community. One of the challenges of introducing a PBL project is keeping students highly motivated. The high motivation of the students leads to increased depth of learning. PBL projects produce the following two effects. One is the influence on the student's own learning process which results in high academic performance. Secondly, other people who participate such a project also experience deep learning; in the latter case, the social effect of PBL becomes a catalyst experience for future-oriented development and desirable changes in the local community. This paper reports how the PBL project's outcomes are not limited to the initial proposal, but by also working on actual construction proposals the students deal with earthquake reconstruction developments. In addition, for the application of the lessons learned through the present study to other cases, the results are considered by examining the "Role of the student," "Role of the teacher," "Cognitive Focus," "Metacognitive Focus," “Role of the problem,” and “Problem Information,” which seem to have affected the motivation of students.

2 Outline of “A New Engineering Education Program with a Local Community as a Classroom”

Since 2001, our Department of Architecture and Civil Engineering has been implementing “A New Engineering Education Program with a Local Community as a Classroom.” It is designed for students’ active learning to help them develop as engineers who will understand not only scientific technology, but also local history and culture, and who can see problems from the residents’ point of view. Students confront real life complex problems by collaborating with a local community. Through workshops involving residents and experts, students participate in discussions with stakeholders in the affected areas and propose appropriate solutions. A conceptual diagram of the PBL process is shown in Figure 1. From 2001 to 2016, there have been 99 projects carried out in the Architectural Design classes at our Institute.

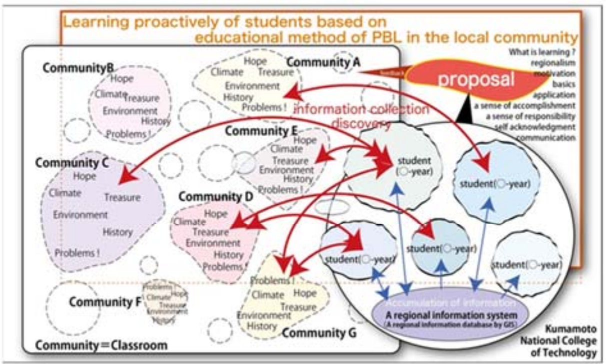

Figure 1: Concept diagram of Students’ positive learning with a local community

3 Old Brick Warehouse Re-Start Project

3.1 Old Brick Warehouse

The damaged old red brick warehouse was built in 1921. It is the only port warehouse remaining in HINAGU Onsen Town, which developed into a seaport area. In Japan, the period during which brick buildings were constructed was very short, only about 60 years from 1864 to around 1923. The warehouse architecture indicates that the structure was erected during the latter part of the brick building period. Yatsushiro City had been renting the warehouse from the owner, and various local groups have used it as a base for community events held in the area. Students at the National Institute of Technology, Kumamoto College, Yatsushiro have also being utilizing the site as a place to learn about brick building and renovation planning. Thanks to this background, students can also learn about topics closely related to regional history and culture.

3.2 Earthquake Damage

The second Kumamoto Earthquake on April 16, 2016, had a magnitude 7.3. At the Hirayama Shinmachi observation point, the nearest to the warehouse, the Japanese seismic intensity scale was the fifth strongest degree. Part of the pediment of the red brick warehouse was damaged, as shown in Figure 2.

Figure 2: The red brick warehouse right after the earthquake

3.3 The Story of the Project

Figure 3 shows the different roles of students, stakeholders, residents, experts, and administrators. The history of this PBL project can be divided into three stages. The first stage entailed the discussion to preserve the whole warehouse through seismic reinforcement. In the second stage, demolition was decided by the owner and the students initiated the Re-Start Project. This consisted of the students developed an alternative plan, i.e. to build a red brick pocket park and submitted their proposal as an entry in an architecture design contest. The third stage of the project was the construction of the park in collaboration with residents. Nine students from sophomores to the fifth school year participated. Immediately after the earthquake, two students in the fifth school year in the Architectural Design class had proposed the preservation plan for the historic red brick warehouse.

(1) The First Stage: Discussion about preserving the whole red brick warehouse

For preservation of the entire warehouse, the students proposed multiple methods such as seismic reinforcement and its utilization after preservation was completed. In response to a request to offer a partial preservation plan instead of preserving the whole building, the students came up with an appropriate plan. In the first meeting, the discussion's main themes concerned safety issues, securing budget, effective utilization and management of the warehouse. From the second meeting on, the participants came to be divided into two groups, one was those who wanted to preserve the warehouse and the other group consisted of people in favour of demolishing the damaged building. Then in July 2016, the municipal administration and the owner decided to demolish the warehouse using public dismantling funds, one financial support system set in place after the earthquakes. That decision brought the first stage of the proceedings to an end.

Figure 3: Students propose multiple methods to preserve at the meeting

(2) The Second Stage: Alternative proposal; "Re-Start Project"

However, the students did not abandon their idea of restoring the warehouse and the "Re-Start Project" was developed. This proposed that, after the demolition of the warehouse, the reconstruction should be implemented in five stages. These included plans to use bricks as part of the wall construction and building a bench for surrounding the open space (Figure 4). A prototype was built by the students (Figure 5). When asked about the feasibility of realizing the proposed plan, the Deputy Mayor offered to cooperate.

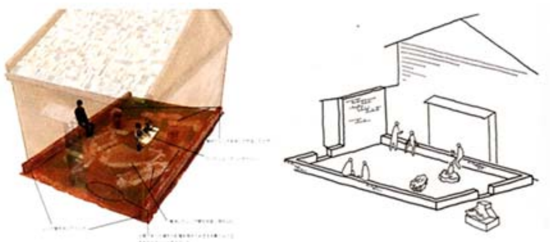

Figure 4: Alternative plan; red brick pocket park using the bricks of demolished warehouse

Figure 5: A prototype of bench by laying bricks

(3) The Third Stage: Workshops in cooperation with residents

Aanother meeting was held in February 2017. The participants agreed to form the "Re-Start Project Group of the Old Red Brick Warehouse." Securing temporary storage for the dismantled warehouse bricks, determining the quantity of bricks that would be required, subsidy application for securing financial resources, construction methods, and other concerns were also addressed. The agreement of the owner of the warehouse was then obtained for the proposed plans. After trials by the student group, the first collaborative construction workshop was held on May 7, 2017. A total of 20 workshops were held until completion of the project in February 2018. There were 327 participants in total. The purpose of this PBL project was to preserve the memory of the brick warehouse as evidence

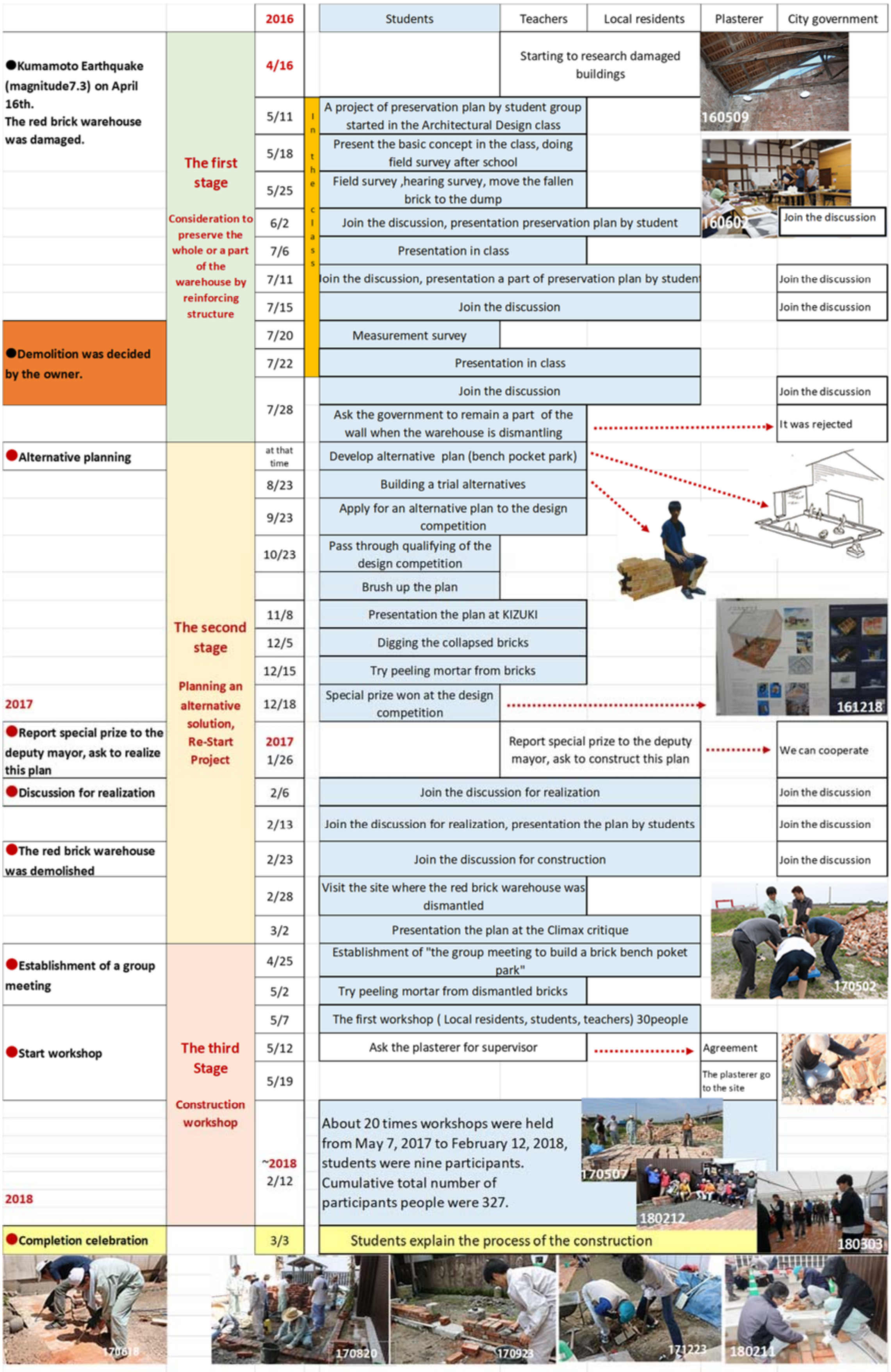

Figure 6: The story of the Re-Start Project

of a regional culture, history, and industry. As a result, the bench in the new pocket park reminds people of old red brick warehouses and brick walls. The park is expected to be used as an event venue and as a town walking spot as well as being a place for residents to relax.

Figure 7: Workshop

Figure 8: Finished brick bench park

4 Learning Experience and Competencies Developed

To assess students' learning experiences and the competencies they had developed, a questionnaire survey was held after the project was completed. There were open-ended questions about motivation, the learning process and lasting impressions. The information about what competencies were acquired was elicited through closed-ended questions.

4.1 Learning Experience Questionnaire

(1) What motivated you to take part in this project?

Fifth grade students in the Architectural Design class had worked on preserving the old red brick warehouse shortly after the earthquake. Their motivation for preserving the warehouse was high. Also, as motivation for participation, they wanted to support the community's recovery from the earthquake damage by working with residents, and they wanted to gain experience in supporting the recovery. It is considered that their motivation depended largely on the tense situation prevailing immediately after the earthquake, and also on their innate ability to recognize and understand that the damage caused by the earthquake might have individual and personal implications for themselves.

(2) What did you learn through this project?

Many students pointed out that they learned the importance of horizontal. "Horizontal" is one of the most important basic elements in architecture. It seems that hands-on experience made the students understand its actual importance in architecture design.

(3) What made the biggest impression?

Students were impressed by the plasterer's technique, great enthusiasm and responsibility as an expert, and gained a new respect for his social role. Students would not have been able to experience such thoughts unless they had worked with the plasterer. Furthermore, the students were surprised how many residents participated in the project.

(4) What was the difference between making a project proposal as a way of student

involvement from a proposal until completing an actual construction project?

Fifth-year students valued the importance of their proposal for being based on cost and construction feasibility. They also stated being deeply impressed that the proposal was implemented. However, they themselves had been involved in carrying out the construction. This lasting impression could hardly be gained without experiencing the actual construction.

4.2 Competencies They Think They Develop

The average of eight participating students is shown in Table 1. “Own initiative” and “specialization” had high average scores. “Own initiative” shows high motivation. Most students did not wait for instructions at the worksite but understood the work that they had to do. Regarding the high average for "specialization," it is thought that, for example, experiences of kneading mortar and laying bricks may be linked to increasing a student’ knowledge of such techniques. “Consensus formation,” “information gathering ability,” and “leadership” are relatively low with three points. The “information gathering ability” score is high among upper grade students and low among the lower grades. Lower grade students have not yet developed information gathering capability. It is thought that information gathering capability will be formed through the experience of encountering diverse stakeholders in actual experiences like this project.

Table 1: Competence developed from this activity and newly acquired skills

Basic capability	Examples of actions that can be taken if a basic ability is acquired ◎5：I was able to execute all the action examples ○3：I was able to do a part of the action example ×1：I was not able to do the action examples	Average score
Communication skill	I was able to listen to the opinions of others and show my opinion. I was able to take basic actions to make a good human relationship.	4
Consensus formation	I was able to take part it the discussion. I was able to understand the background and goals of discussion and activities.	3
Gathering Information	I was able to gather information trough website, books, resources and the stakeholders etc. I was able to use information that takes into consideration copyright and personal information.	3
Own initiative	I was able to understand what kind of behavior is required. I was able to practice the roles and behaviors required for me.	5
Responsibility	I was able to understand the roles and responsibilities required of me. I was almost able to practice the roles and responsibilities required of me.	4
Teamwork	I was able to communicate with the collaborating members and participate in activities. I was able to practice my role cooperatively.	4
Leadership	I was able to understand the goals and ideals of the activities. I was able to form a cooperative relationship with participants.	3
Ethical values	I was able to understand social rules on activities. we were almost able to take actions conforming to social rules.	4
Specialization	I was able to understand what kind of expert knowledge and skills are necessary. I was able to make use of specialized knowledge and technology.	5

5 Comparison of Past Active Learning Projects and This Project

Our Kumamoto college; National Institute of Technology basically has a lecture-centred traditional curriculum. In our department, as mentioned above, practical "projects with a local community as a classroom" are held mainly for the Architectural Design classes. Focusing on the finished projects, they can be classified into four types as shown in Table 2. This classification is based on Linda Tourp & Sara Sage, 2011. The past active learning projects are shown, and the main features of the present project are compared with them.

Table 2: Comparison of instructional strategies in our Department of Architectural and Civil Engineering learning system

TYPE OF INSTRUCTION	ROLE OF THE TEACHER	ROLE OF THE STUDENT	COGNITIVE FOCUS	METACOGNITIVE FOCUS	ROLE IN THE PROBLEM	PROBLEM	INFORMATION
A: Project of lower grade class	As expert: ・Direct thinking ・Evaluates students As consultant: ・set the environment ・Advises	As expert: ・Direct thinking ・Evaluates students As consultant: ・set the environment ・Advises	Students synthesize received knowledge and individuality in the solution of problems within curricular context	Problem-solving process learned is applied to problems, not necessarily independently	As a student: learns about things outside personal experience or "over there"	・Moderately structured ・Presented as a strategy to develop effective learning behavioral	・Some is organized and presented by instructor ・Learners collect the necessary information themselves, but they are not necessarily voluntary
B: Project of higher grade class working until proposal	As expert: ・Direct thinking As collaborator: ・Learn together ・encourage	As problem solver: ・Crafts divergent solutions ・Active	Students synthesize received knowledge to bring resolution to problems in a way that meets the conditions that they themselves set forth	Problem-solving process learned is applied to problems. ・Independently	As a stakeholder: ・Immerses in the situation, learning about events "here"	・ill-structured ・Presented as a situation within which a compelling problem is yet to be defined	Little is presented by instructor without students identifying a need to know. Most is gathered and analyzed by students
C: Realized Project	As expert: ・Direct thinking As collaborator: ・Learn together ・encourage ・involve a variety people	As problem solver: ・Crafts divergent solutions ・Investigates and resolves problem from the inside	・Students synthesize received knowledge to bring resolution to problems in a way that meets the conditions that they themselves set forth ・Based on the request of the owner, consideration such as how to use, cost, workability and maintainability etc. is required	・The eminent pressure of the lived experience activates prior learning ・Students develop strategies to enable and direct their own learning	As a stakeholder: ・Immerses in the situation, learning about events "here" ・interaction of variety people	・ill-structured ・Presented as a situation within which a compelling problem is yet to be defined	Little is presented by instructor without students identifying a need to know. Most is gathered and analyzed by students
This project D: Realized Project, and students work from planning to construction in the situation of immediately after earthquake	As expert: ・Direct thinking As collaborator: ・Learn together ・encourage ・involve a variety people As a responsible person: ・Take on responsibility	As participant: ・Actively grapples with the complexity of the situation ・Investigates and resolves problem from the inside	・Students synthesize received knowledge to bring resolution to problems in a way that meets the conditions that they themselves set forth ・Based on the request of the owner, consideration such as how to use, cost, workability and maintainability etc. is required ・Experience of practical skill	・In shortly after the earthquake ・The eminent pressure of the lived experience activates prior learning ・Students develop strategies to enable and direct their own learning ・Experts such as teachers, craftsmen and architects models and coaches, as needed and inspire students	As a stakeholder: ・Immerses in the situation, learning deeply about events "here" ・interaction of variety people ・Experience great pleasure	・ill-structured ・Presented as a situation within which a compelling problem is yet to be defined ・the "problem" of the area under the situation of tension shortly after the earthquake	Little is presented by instructor without students identifying a need to know. Most is gathered and analyzed by students

5.1 Past Active learning Projects

A： Proposal of Ogawa Town for recovery from the Kumamoto earthquake；Architectural Design and Drawing class for 3rd grade; Lower grade students project

This is a project aimed at revitalizing the shopping street by the renovation of a ”Machiya" and the utilization of the land which became vacant land after the Kumamoto earthquake. Students created a plan after understanding the historical background of Ogawa Town and current problems through field visits and interviews with residents. The Students made a presentation of their proposal to the residents at a Machiya in Ogawa Town (Figure 9).

Figure 9: Project of Ogawa Town at Machiya, final presentation

B： Traditional craft; Miyaji Japanese Paper Project; Architectural Design class for 4th and 5th grade; Senior grade students projects

Main theme is "Making with local area, making with people." The student team himself decides the concrete theme under the big theme. The team focused on the fact that the traditional craft; Japanese paper craft continued for 400 years form a beautiful many waterways landscape of the area and proposed how to continue it to the next generation.

Figure 10: Japanese paper project, discussion with in the students’ group

C：Hospital Gallery Project; a realized project which was proposed by students

The Hospital Gallery Project was implemented as one extracurricular activity in 2012. Advanced Course students of the National Institute of Technology, Kumamoto College, took the lead. Many stakeholders participated in the project, i.e. doctors, nurses, office staff, and high school students who were members of the photography club at their school. Their pictures were to be exhibited at the gallery. A mock-up model was created, it was brought to the display site, and its essential features were confirmed (Figure 11).

Figure 11: Confirming by mock-up model

5.2 Difference between the past active learning projects and this project

The biggest difference was having to perform this project in the environment that followed the earthquake and under strained circumstances. The students maintained high motivation throughout the project and a lot of stakeholders participated as well. In addition, the students not only proposed the pocket park plan that would use the red bricks of the demolished warehouse, but they themselves also participated in the construction in cooperation with local residents. In past projects, there was none where students themselves participated in the actual construction in cooperation with many stakeholders.

6 Conclusion

As in this PBL project, “problems" caused by natural disasters can be presented as a situation within which complex ill-structured outcomes are said to have a high educational impact for PBL. Also, such problems touch a students' heart. In the present instance, the warehouse owner, many residents and the administration sympathized with the Re-Start Project, which was realized through mutual cooperation. The students retained high motivation, acted on their own initiative, and experienced deep satisfaction after completion of the project. The residents who joined this project also learned much and presented an opportunity for future-oriented community development. In addition, under the prevailing circumstances immediately after the earthquake, relevant information was provided in rapid order, which learners had to collect, select from, and utilize at their own discretion. Students could not but act as the person concerned. Furthermore, as an interactive learning effect occurs among various experts in a community, students were motivated to learn as engineering candidates. Furthermore, through dialogues with many stakeholders, students acquired the new knowledge that the “Re-Start Project” was an optimal solution to a rather complex situation. Approached this way, solving the "problem" caused by the earthquake yielded valuable innovative experiences that could never have never been attained by previous PBL projects.

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How do engineering students in a group-based learning environment maintain and build motivation to learn?

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Abstract

This paper explores engineering students' motivation to learn. The study is conducted in a problem-based learning (PBL) environment and investigates students' interest in group-based collaborative learning. Little research has considered motivation in groups, such as what actually takes place and what is required to maintain motivation when collaborating and learning together. This paper thus investigates how engineering students in a group-based learning environment maintain and build motivation to learn. The ultimate purpose of the paper is to inform student groups and teachers within engineering education of the possibilities and pitfalls of collaborative motivation.

The paper first presents the theoretical framework used to interpret the data collected: a macro-level framework of motivation research on young adults. At a group level, the theoretical framework identifies three different types of interactions in groups: liquidating, maintaining or evolving ways of interaction, with an add-on of identified strategies that seem to either support or inhibit motivation in collaborative learning.

Empirically, the study is based on recorded real-time action of student groups in collaboration and interaction, subsequently analysed through the application of the framework and motivational strategies. Having divided the student groups into the three types of interactions, the dominating motivation strategies within each type are identified and discussed.

Keywords: Collaborative learning, motivational strategies, liquidating, maintaining and evolving ways of interaction, engineering education

Type of contribution: Research paper

1 Introduction

1.1 Current research about motivation in groups

Very little (if any) research exists regarding motivation in groups within engineering education. Indeed, a search of peer-reviewed articles, written in English from the year 2000 onwards and within the combined areas of motivation, group work and learning (or any relevant synonym of these, see Figure 1), generated on 28 November 2017 yielded only 209 articles in the appropriate databases of Eric, Scopus and the Danish Research Database. Closer scrutinisation reduced the number of articles to 16, of which two were relevant for this paper, both written by the same author. The lack of research regarding motivation in groups is intriguing given the fact that most engineers spend their working lives solving problems in teams, and learning how to regulate motivation consequently seems to be an important part of group collaboration skills.

Search String

("Achievement Need" OR "Learning Motivation" OR motivat* OR demotivat* OR "motivation regulation" OR incentive OR engagement OR "student* motivation" OR "student* engagement" OR "group motivation" OR "team motivation" OR "motivation techniques")

AND ("team work" OR "teamwork" OR "group work" OR "groundwork" OR "group collaboration" OR "group cooperation" OR "team based learning" OR "project based learning" OR "problem based learning" OR "collaborative learning groups")

AND ("student learning" OR "students learning" OR "Socially shared learning" OR "Educational learning" OR "student learning setting" OR "student* learning setting " OR "adult learning" OR "learning situations" OR "educational context")

Figure 1: The search string with relevant words used on 28 November 2017.

The research presented in this paper takes a first step into this important area.

1.2 Research question of this paper

The aim of this paper is to answer the following question: *How do engineering students in a group-based learning environment maintain and build motivation to learn?* The ultimate purpose of the paper is to inform student groups and teachers within engineering education of the possibilities and pitfalls of collaborative motivation. Thus, the objective is to inspire groups to take self-reflective action as well as to merely understand the dynamics of motivation in groups.

We will answer the question by first conceptualising relevant motivational strategies (as well as demotivating strategies) that groups apply when working. Second, we will apply this conceptual framework to specific cases of group collaboration, thereby illustrating how groups maintain and build motivation. To the extent that the empirical data inform our theory, we will discuss this while developing and illustrating a theoretical framework in practice as the principal aim.

2 Relevant theory regarding motivation in groups

2.1 A motivational model for young adults

In general, two dimensions exist in terms of young people's motivational learning universe: the specific learning context in which learning takes place and the larger societal context (Sørensen *et al* 2013). If these two dimensions are combined, four spheres of interest can be identified regarding the motivation of young people. See Figure 2.

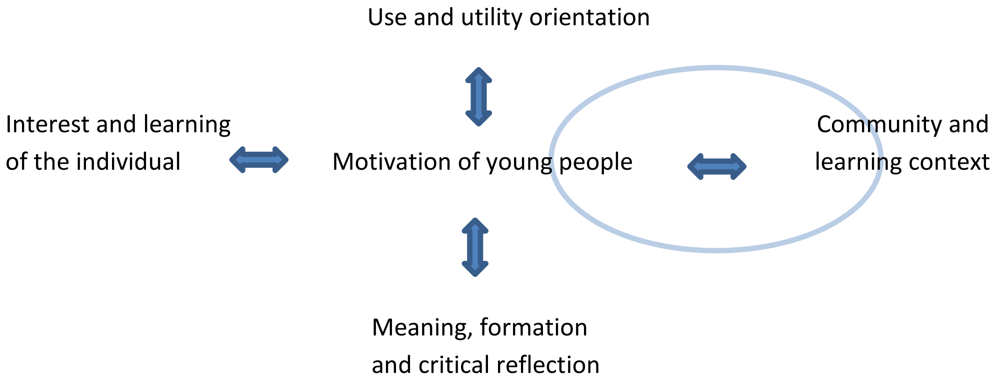

Figure 2: Two relevant dimensions when studying the motivation of young adults. After Sørensen *et al* 2013.

The vertical dimension – the societal axis – concerns the purpose of educating young people and the societal task of the educational system. To what extent is motivation created through utility- and use-oriented teaching, and to what extent is meaning, formation and critical reflection important? On the horizontal axis is the extent to which motivation either springs from the experiences, preferences and interests of the individual young adult, or alternatively from the specific community and learning context available. In this paper, we are specifically interested in how motivation works in groups, which is why our focus is on the relationship between the motivation of young adults and group work in a problem-based learning university setting. This implies that we are less concerned with inner motivation, empowerment and the specific interests of individuals in the group. Rather, we want to understand motivation as a result of social relations and meaning-producing systems in their social and cultural context (Sørensen *et al* 2013). This also suggests that motivation by utility (diplomas, grades and relevance in a future work setting) or formation (perspectives and knowledge exceeding what the young adults think they might need) will not be specifically addressed; they will be acknowledged only implicitly as a function or asset of a particular group-related motivational strategy.

In order to understand how motivation works in groups in a particular learning setting, we will first introduce a basic model of how to understand social interaction in a group from a developmental point of view. We will then connect this understanding with six motivational strategies that approach how groups facilitate or hinder motivation. The broader learning context is problem-based learning and will be described further in relation to the case selection and methodology.

2.2 Relational dynamics

Broadly speaking, there are three ways of being in a relationship with another person: liquidating, maintaining and evolving. It is the quality of the collaboration, especially the contact and the response, that determines the outcome (Mourier *et al* 2008). All three kinds of dynamics are present in the group: the total relational dynamics between the individual members constitute the collaborative culture of the group. This can alter, both daily and over time, the kinds of dynamics that prevail. Table 1 illustrates important characteristics of the three types of relational dynamics and a more explicit example of what is required in order for an evolving relational dynamic to take place.

A situation involving a difference of opinion, perspective, emotion or way of handling an issue is a situation in which it is possible to detect the kind of relational dynamic at hand. How a group in a socially shared learning situation responds to differences is central to the way individuals develop and learn with and from one another.

In terms of liquidating dynamics, the focus is often on negative issues: what went wrong, who is to blame and why. Aggressive power struggles and arguments with a winner and loser are salient. To ignore responses is a significant part of the liquidating dynamic. Rules and control predominate instead of personal engagement and responsibility. Consequently, people in the group withdraw, expectations and roles become locked, and over time aggression becomes silent. A drainage culture with scapegoats is established and the potential to grow, learn and inspire is liquidated (Mourier *et al* 2008).

In maintaining dynamics, a basic lack of contact operates, in accordance with the saying that it is better to be silent than to argue. To the extent that things are said, they are stated indirectly. Clashes are ignored and the desire to say “no” is suppressed. Not only are responses ignored, they are avoided altogether and the level of anxiety is high. Self-sacrificing behaviour often occurs and individuals try to fit in without attending to their own emotions or needs. People are not willing to risk themselves or invite changes. Lack of development prevails.

Table 1: Three basic types of relational dynamics. Developed on the basis of Mourier *et al* (2008, p.86).

	Liquidating	**Maintaining**	**Evolving**	**Example: Evolving**
Norm	Difference is a problem	Difference is equalised	Difference is opportunity	Curiosity/Recognition
Handling	Rules	Pseudo-consensus	Collaboration	Mirror /Contain
Response	Error-focus	None	Engaged	Excited/Positive
Confrontation	Attack/defence	Ignore/suppress	Nurtured	Identify/Acknowledge
Resolution	Backward	Standstill	Forward	How to go ahead?
Responsibility	Avoidance	Sacrifice	Action	Who does what?
Sense of reality	War	Denial	Acceptance	
Mood	Aggression	Anxiety	Vitality	
Motto	Me, not you	You, not me	You and me	

Evolving relational dynamics create a lot of energy and vitality (Mourier *et al* 2008). Where individuals dare to retain their diversity, distinctiveness and integrity conflicts are bound to materialise in the open. Conflicts with the underlying agenda that everyone involved is expected to move on together characterises this dynamic, along with a profound belief that the other has something to offer even if I do not completely understand it in the here and now. There is no predetermined truth, merely an imprecise feeling that something new can be created by curiously identifying and scrutinising differences. Groups like this are often marked by significant goals and expectations, large amounts of individual responsibility and considerable mutual involvement. It is you and I together in a coordinated dance marked by vitality, acceptance and initiative.

For groups to truly thrive and develop, a substantial degree of the relational dynamics needs to be within the evolving area. In the following section we will more specifically consider six motivational group-based strategies that visualise particular ways of regulating motivation in collaborative learning.

2.3 Group-based strategies to regulate motivation

Previous research (Jarvela *et al* 2007) has identified six important motivational strategies that are available to groups in higher education in order to regulate motivation while collaborating. Five of these strategies encourage motivation and the other (self-handicapping) undermines it. They are illustrated in Table 2.

Groups encounter different socio-emotional challenges when they collaborate (Jarvela & Jarvenoja 2011), such as challenges related to personal priorities (e.g. different goals), work and communication (e.g. different styles of interaction), teamwork (e.g. differences in commitment), collaboration (e.g. different understandings of a task) or external constraints (e.g. different family situations). In other words, differences arise and require the group to regulate them. Jarvela and Jarvenoja (2011, p. 354) define motivational regulation as follows:

Motivational regulation includes thoughts and behaviours through which students act to initiate, maintain, or supplement their willingness to start or to make an effort toward completing academic activities.

Table 2: Motivation regulation strategies in a socially shared learning situation (Jarvela *et al* 2007).

Regulation strategy	Definition	Example
Social reinforcing	Students' identification and administration of reinforcements influencing their motivation and shaping their joint behaviour.	The students make reciprocal suggestions of how to plan the poster. Kalle suggests an idea and Mari adds *"Why don't we add…".* The other two support the plan.
Socially shared, goal-oriented talk	Students using goal-oriented dialogue: thinking about various reasons for persisting with or completing a task.	The students discuss which topic to take for poster-task. "*Let's take the topic "metacognition". That is also a good choice concerning the exam".*
Interest enhancement	Increases aspects of students' intrinsic motivation or situational interest while completing an activity.	*"This is a brilliant idea!"* The students express concrete examples to increase joint interest: *"I can describe my example…".*
Task structuring	Reducing the possibility of off-task behaviour by structuring a task or the environmental conditions.	In a situation where students have difficulties with making progress, one student says *"Let's make a list of the five most important points".*
Self-handicapping	Manufacture of obstructions before or during a task that renders performance difficult.	*"This text is so complicated" or "The other group have a much better poster than we have".*
Efficacy management	Students' ability to monitor, evaluate and control their expectations, perceptions of competence, or self-efficacy.	*"The task is not easy and this group is not working well"* or *"The discussion today has been productive. We progressed well!"*

This research highlights the practice of regulating motivation in a socially shared learning situation regardless of the relational dynamics and ultimately the collaborative culture of the group. We will use all three basic relational dynamics and the six motivational strategies to analyse our empirical cases. The cases are introduced next.

3 Case selection and methodology

3.1 A case design of eight first-year groups

Empirical data were collected at two first-year Engineering and Science study programmes at Aalborg University, Denmark, in the autumn semester of 2017. One is the study of biochemistry, environmental techniques and biology, and the other is the study of techno-anthropology. They were chosen due to availability and because they each represented the ends of a continuum running from hard scientific and engineering education to the softest kind of engineering education. They also differed in size. The former study programme included a total of 31 groups and approximately 200 students, whereas the latter comprised five groups and about 35 students. In each study programme, four groups were identified for observation, written feedback and interview. The groups either volunteered or were asked to participate during data-gathering events. In this way, we tried to avoid systematically biased groups, and maximised the chances of finding very different group dynamics within the field of Engineering and Science. With a total data set of eight groups we in no way strived to be representative; we merely aimed to open up a variety of group dynamics.

3.2 Inquiry into the motivational dynamics of each group

Each group was asked to participate in three kinds of activities. All three activities were videotaped for subsequent observation. First, the groups were asked to select and go through a narrated, cartoon case of a fictional demotivated group situation. The case could comprise a single member challenging the working culture of the group, i.e. a group with a common work-related issue such as abortive data or a heated argument between two group members; common situations that in some way challenged the motivation and drive of the fictive group. The challenges were in line with the challenging categories developed by Jarvela and Jarvenoja (2011), mentioned in section 2.1. Attached to the case were a number of questions upon which the the eight groups were instructed to reflect. This activity provided a window into the relational dynamics of the groups while allowing us to see how they motivated themselves to undertake the assignment.

The group members were then asked separately to write down the day their group was most motivated and why. Their individual written answers were collected by email. This activity was also videotaped to reveal an initial discussion amongst the group members regarding the day they chose and why. The questions here were taken from Hein (2013), who has developed an individual-based motivational theory of highly educated people working primarily in creative and complex working environments. This activity was used to offer a window into a more direct reflection and discussion of the groups' motivational behaviour as experienced by the individuals.

Finally, the eight groups were interviewed about their individual answers and asked to discuss their answers with the interviewer present. They were also asked to reflect upon a day on which they were least motivated and why, as well as their experiences of discussing the fictive case. The interview guide for this part was partly developed on the basis of Hein, and partly on the design of the activity as a whole. This activity essentially provided us with the opportunity to follow up on some of the individuals' answers and enabled us to ask additional questions about their motivational strategies.

Five different people conducted the interviews, including the two authors of this paper.

3.3 Data analysis approach

All of the videos were watched by the two authors with the theoretical framework as the analytical framework for observation. On this basis, all eight groups were defined as belonging to one of the three relational dynamics, and three extreme cases were selected for more detailed analysis of the motivational strategies they most commonly used and how this would be manifested; one within each of the main relational dynamics categories to exemplify the three types of evolving, maintaining and liquidating categories (Flyvbjerg 2006). The results of the data analysis are examined in the following section.

4 Case analysis

4.1 The evolving relational dynamic

The group consists of four male students and two female students. There is a relaxed atmosphere, featuring lots of laughter while coffee and tea are served. The relational dynamic in the group can be categorised as evolving and the motto of this group could be you and me. They state that '*the basis on which we work and how we are: everyone has to agree*', and '*it doesn't matter who writes how many pages, it is also about contribution in the discussion and sharing in the writing process'*. The prevailing norm is recognition of differences as opportunities. They are, somehow a heterogeneous group and they seem to be aware of this. Nevertheless, although they have built trust, one of the female students claims, '*I'm not good at teamwork; I'm very much retaining*'. Yet, this seems to be a joint group issue: *'We as a group should be much better at inviting you, and asking "What do you think?"'*. In their responses they are engaged and positive. The female student continues, *'If you're already out of a group, you cannot ask for help, but if you feel you're welcome, you can ask for help*'. The overall sense of reality appears to be acceptance. Later, the same student says, '*I'm usually the one who is out-of-the-group; now, in this group, I'm not, because they are very good at having me: I can easily fall out!*' The confrontation dynamic applied in this group is nurtured: they seem to care for and encourage the growth and development of one another.

The group starts by aligning understandings of the assignment, and continues by choosing a group member to take notes. The students apply the motivation regulation strategy of task structuring: '*Will someone take notes?'… 'Shall we?' … 'We should not only think about it?' ... 'I will take notes'*. One of the female members volunteers for the task, all members agree, and they continue. Motivation is also regulated through efficacy management: '*We are ahead of the semester!*'. The achievement of milestones makes sense of success: '*We meet in the group every day; we do not just meet to do nothing. It is constructive and something that we need each other for … We have really good planning, and there is nothing about the project that is not being discussed!*' The group member taking notes continuously contributes to the discussion, but to a lesser extent. However, several times the group breaks from discussing: '*We just have to break and hear if Maria gets her words in*'. The group makes sure she is being heard even though she is busy taking notes.

The group continuously shapes its joint behaviour through applying social reinforcing motivation regulations. This is the most prevailing motivation strategy of the group. The members constantly make reciprocal (mutual) suggestions and build on each other's ideas such as '*yes …*', '*as you said …*', '*as Maria said before* …', '*I agree …*'. The communication has a natural flow, to which everyone contributes. They are extremely good at continuing and building on each other's arguments without interrupting and always in a positive and relaxed manner.

On several occasions the group displays the motivation regulator socially shared, goal-oriented talk. They discuss what is important in the assignment and how it relates to the dynamics in their own group. Different things are mentioned. One member emphasises the code of conduct and they all support and add to the key issues in relation to this code.

4.2 The maintaining relational dynamic

The group consists of two male students and three female students. The environment is serious and the students are very polite. They each have individual water bottles – no shared coffee and tea – but the atmosphere is nevertheless relaxed.

The group contains a female student who is not taking part in the discussion. Before commencing is an initial game, a form of task structuring, regarding the responsibility of being the session moderator. One of the females is given the task of ensuring that everyone is engaged, and she immediately turns to the female who is not taking part in the discussion and asks whether she has any comments, which she does not. The quiet group member contributes very little and only when directly asked, which is seldom. The group does not address the issue. Throughout the assignment, they reproduce the reality of the four active group members.

The most talkative female says, '*There are no stupid questions in here, at all!*' and so everyone laughs. '*There is a good atmosphere, and you are not afraid to talk about anything*'. One of the male students continues, *'When we arrive at conclusions and everyone agrees ... a joint decision that everyone contributes … it is satisfactory*'. Their means of confrontation appears to be to ignore, even though they claim that all decisions must be taken by the group as a whole. It is clear that the group is aware of the challenge represented by the non-participating member but they do not address the issue. They refer to '*We*': '*We have accomplished*', '*We act as a group'*. Nevertheless, they are unable to address the non-participation of the individual group member or to devise a means of including her. Therefore, the way in which they handle the resolution of differences can be characterised as standstill. Overall, the relational dynamic in the group can to some extent be regarded as maintaining, since the reality of the group, as far as the silent member is concerned, is denial.

The four active group members apply a social reinforcing strategy, where they build upon each other's ideas and arguments through dialogue, akin to the evolving case description. They also describe how they apply task structuring through playing Uno to determine the moderator of the session. They describe situations of interest enhancement: '*When it's been really cool … when you've gone home with a really cool feeling ... that's when you've started out disagreeing, and then in some way you have compromised, discussed and worked ... and then agreed and reached a point where everyone is feeling good: that's a bold feeling'*. The group relational dynamic has the potential to become evolving – it reveals vitality – but the group must be a whole before it can reach its full potential.

4.3 The liquidating relational dynamic

The group consists of three male students and two female students. There is no laughter; the group is very quiet. One of the male students wears sunglasses during points of the session, and is seated with his back to one of the female students. The relational dynamic in the group can be categorised as liquidating, the mood is aggression and the confrontation is attack and defence. '*It's not to pick on you, but one day you came with a hangover and were destructive; the rest of us were prepared to work … 'This is also something that concerns you! It was the day you came and said you did not practise for the oral exam: it was really demotivating for us too'*. Considerable focus is placed on errors and the reality in the group seems to be war. There is no happiness, jokes or smiles.

Social reinforcement, the motivation regulator most commonly used in the two cases above, is only sporadically used, and only between the two female students. At the beginning of the session, pauses punctuate the dialogue, and when group members speak, they tend to speak simultaneously without listening to one another. Social reinforcement is not prevailing: on the contrary, they seem to be trapped in an evil circle and they disagree on everything. '*You also have to give the individual room'*, '*Then you just have to cut through*', '*Not everyone can*', '*They need a moderator*', '*Do we need a moderator in our group?*' '*I don't think so!* '*I do'*. There is a lot of mismatch in the group.

Furthermore, the group demonstrates a tendency to self-handicap. '*This is one of our first projects, that's why it's shit'*. '*We are doing our best, why don't you*?' '*I have to say that this group work does not reach my full potential; it does not get out the best in me'*.

They end up discussing the group's internal issues. They decide to extend the day with a meeting in which they feel they must discuss their project because they lack the 'red thread': they have the same problem as outlined in the assignment! But apparently, they see the 'red thread' as being their main problem and seem to overlook how their treatment and motivation of each other constitutes a major issue.

5 Discussion

5.1 The research question revisited

The aim of this paper has been to answer the following question: *How do engineering students in a group-based learning environment maintain and build motivation to learn?* To this end, we have developed a theoretical framework primarily consisting of three types of relational dynamics and six motivational regulating strategies. We have tested the feasibility of this framework by applying it to a data set of eight groups that encapsulate these three cases. Indeed, we have used the three cases to illustrate the relative merits of the three different types of relational dynamics and the six motivational regulation strategies. Critical reflection regarding the design of the investigation underlines that it is a pilot study involving only a small sample of cases. It does not explore all of the available strategies and relational dynamics in full. As such, the conclusions of the study do not offer a full picture, hence more research is advisable.

With these critical remarks in mind, our ultimate purpose have been to inform student groups and teachers within engineering education of the possibilities and pitfalls of collaborative motivation and to inspire groups to take self-reflective action regarding the motivational habits of the group, rather than leaving this to chance. In the following section we will comment on our results and demonstrate how this information can be utilised by student groups and supervisors.

5.2 Summing up the results as concerns the cases

In terms of the ways in which engineering students maintain and build motivation to learn, it is interesting to acknowledge that the evolving dynamic appears to be most relevant in nurturing an environment for learning. The evolving dynamic case highlighted a group of students who have shaped a common norm of recognition and curiosity through an overall sense of acceptance as they express their appreciation for each other. This was most clearly reflected in the statement, 'I'm usually the one who is out-of-the-group; now, in this group I'm not, because they are very good at having me'. This dynamic of recognition and acceptance offers a strong basis for collaboration and action, in which group members benefit from diversity in terms of experiences, expertise, knowledge, skills and competencies. In contrast, the group that applied a maintaining relational dynamic ignored its internal differences or acts as if such differences are equalised as expressed as 'We', 'We have accomplished', 'We act as a group' even when the group was cognisant that a group member was not participating. This sense of denial suppresses an open and trusting collaboration, which may affect the learning environment and benefits of group work. The third group, which was caught in a liquidating relational dynamic, found themselves in a downward spiral in which differences constitute a problem that must be combated with aggression and attack, as exemplified by 'It's not to pick on you, but…' and 'There is also something that concerns you'. Considerable attention is paid to errors, and the reality of the group seems to be conflict, which does not stimulate a learning environment.

The motivation regulation strategies applied by the students correlate with the relational dynamics. This means that some strategies (for instance social reinforcing and task structuring) are more prevalent in the evolving case, less so in the maintaining case and predominantly absent in the liquidating case. In contrast, self-handicapping represents a regulation strategy that was witnessed in the liquidating case, as expressed in 'This is one of our first projects, that's why it's shit', but not in the other two cases. In applying motivation regulation, students use different strategies, which can have positive or negative impacts on their learning environment.

5.3 Possibilities and pitfalls of collaborative motivation

In terms of informing students and supervisors, it seems crucial to be aware of the relational dynamics and motivation regulation strategies that students can utilise as a compass to ensure that appropriate dynamics and strategies flourish. One recommendation could be to recognise differences as opportunities by being curious about diversity and actively seeking differences as inspiration for learning. A further recommendation could be to use it diagnostically. For instance, if the group becomes aware that social reinforcing strategies are used increasingly seldom whereas self-handicapping strategies begin to emerge, it is a sign that evolving dynamics and motivating strategies must be re-engaged.

The conceptual approach developed and used in this context is clearly of utility. In research beyond this paper, the conceptual approach can be used to describe and understand motivational dynamics, although it still exists in an early stage, necessitating a more nuanced understanding of concepts such as evolving and maintaining and liquidating group dynamics.

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Contribution of Project Based Learning to the Development of Engineering Competencies – Industry Perspective within the GCC region

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Abstract

The effectiveness of utilizing Project Based Learning (PjBL) has already been investigated in various regions and contexts. However, the effectiveness of PjBL for the countries of the Gulf Cooperation Council (GCC) is largely limited to anecdotal evidence.

The purpose of this study is to identify from the perspective of managers of engineers within the GCC region, first, the importance of common engineering competencies, second, the contribution of PjBL in developing them, and third, the contribution of traditional teaching in developing these competencies.

Questionnaire-based interviews with 92 managers of engineers are carried out and descriptive as well as inferential statistics (Wilcoxon test) are applied.

It is found that fifteen of sixteen competency elements show a statistically significant difference regarding the contribution of PjBL versus traditional teaching. Fourteen competency elements are developed predominantly by PjBL, whereas only one competency element is developed predominantly by traditional teaching. The twelve most important competency elements are perceived to be developed predominantly by PjBL.

The analysed industry perspective may encourage engineering educators in the GCC region, and in regions with a similar socio-economic context, to utilize PjBL for developing the identified ‘PjBL-supported competency elements’, and, to utilize traditional teaching for developing the identified ‘teaching-supported competency element’.

This study is part of an ongoing research effort related to PjBL in the GCC region.

Keywords: Project Based Learning, PjBL, PBL, engineering competencies, industry perspective, GCC.

Type of contribution: research paper.

1 Introduction and Background

The effectiveness of Problem Based Learning (PBL) approaches has been investigated in numerous contexts and different settings over the past decades (e.g. De Graaff & Kolmos, 2007). There are differences between the various PBL models and approaches (e.g. Savin-Baden, 2007), and Problem-Based Project-Organized Learning (Garcia, Bollain and Del Corral, 2011) seems to be the common approach within engineering education in the countries of the

Gulf Cooperation Council (GCC). Since engineering educators and industry representatives in this region prefer the term Project Based Learning (PjBL), it is used throughout this paper.

Although many studies related to PjBL neglect that the overall goal of students' learning is the development of a set of complementary and interrelated graduate attributes (also called student outcomes) to prepare students for the world of work (Patria, 2012), some studies have used graduate attributes as a framework to analyse the effectiveness of PjBL. For example, Ulseth & Johnson (2015) used graduate attributes to compare graduates of an engineering program that utilized PBL with graduates of engineering programs not utilizing PBL. Other studies used graduate attributes for student exit surveys and employer satisfaction surveys (e.g. Christoforou *et al.*, 2003; Ramadi *et al.*, 2016). For the present study, Engineers Australia's sixteen competency elements for Engineering Technologists (EA, 2017) are used as a framework, since they represent the graduate attributes for engineering technology programs accrediated by Engineers Australia. These are similar to graduate attributes listed by other engineering accrediting bodies (for example, the student outcomes of ABET - Abet.org, 2014), and they cover all essential skills and attributes of an engineering graduate, identified in an earlier study (Nguyen, 1998) as distinct elements of competency. A summary of these competency elements is shown on Table 1.

Table 1 Competency areas and competency elements

COMPETENCY AREA / Competency Element
1. KNOWLEDGE AND SKILLS
1.1. Theory based understanding of the underpinning natural sciences
1.2. Conceptual understanding of mathematics, numerical analysis, statistics, etc.
1.3. In depth understanding of specialist knowledge areas
1.4. Discernment of current knowledge development, such as new methods and materials
1.5. Knowledge of contextual factors such as business, culture, laws, etc.
1.6. Understanding of the scope, principles, accountabilities of contemporary engineering
2. ENGINEERING APPLICATION ABILITY
2.1. Application of established engineering methods to problem solving
2.2. Application of engineering techniques, tools and resources
2.3. Application of systematic synthesis and design processes
2.4. Application of systematic approaches to the management of projects
3. PROFESSIONAL AND PERSONAL ATTRIBUTES
3.1. Ethical conduct and professional accountability
3.2. Effective oral and written communication
3.3. Creative, innovative and pro-active demeanour
3.4. Professional use and management of information
3.5. Orderly management of self and professional conduct
3.6. Effective team membership and team leadership

The purpose of this study is to identify the industry perspective in the GCC region regarding the importance of these competency elements, the contributions of PjBL, and traditional teaching in developing these competency elements. The effectiveness of PjBL in the GCC region is largely limited to anecdotal evidence. Ramadi *et al.* (2016) suggested that country specific research may help to gain a better understanding of the skills required of engineers in that country, and this study is contributing to filling this gap related to the GCC region.

It could be argued that alumni of a PjBL engineering program in the GCC region are in a better position to judge the contribution of PjBL versus traditional teaching in developing these competencies. However, there is only a relatively small number of 'PjBL alumni' in the GCC region who have been employed for a sufficient amount of time in order to make informed judgments. Some engineering educators hold that PjBL has advantages in preparing graduates for their initial work assignments, but that traditional teaching is better preparing them for a long-term engineering career. Managers of engineers with several years of experience and line responsibility for subordinates are arguably in a better position to provide a realistic judgment. Furthermore, earlier studies (e.g. Rumberger & Thomas, 1993; Vermeulen, 2006) suggested that career success should be measured by two dimensions, i.e. the objective/extrinsic and the subjective/intrinsic dimensions. The same is true regarding the perception of the importance of graduate attributes, and, the contribution of PjBL versus traditional teaching to develop these graduate attributes. This study is providing the 'objective/extrinsic' dimension within the GCC region. Last, but not least, approaching industry in order to learn about their perspective regarding graduate attributes and the potential of PjBL versus traditional teaching, leads to a desirable 'side effect', namely strengthening of the strategic partnership between engineering education and industry.

2 Research Questions and Methodology

The research questions for this study areas follows:

1) What is the perceived importance of the sixteen competency elements in relation to requirements at engineering workplaces?

2) Is there a statistically significant difference between the perceived contribution of PjBL versus traditional teaching in developing the sixteen competency elements?

3) Which competency elements are developed predominantly by PjBL and which competency elements are developed predominantly by traditional teaching?

In order to answer these questions, the following methodology has been applied. Questionnaire based interviews have been carried out with managers of engineers in Kuwait, a country typical of those found in the GCC region. Only managers actively involved in supervision and leadership of engineers were approached based on personal contacts of a group of 92 engineering students. The standardized questionnaire, the provided introduction to PjBL versus traditional teaching, as well as the requirement of providing contact data of the interviewees for possible follow-up on answers, contributed to comparable survey conditions while ensuring reduced bias in selecting interviewees. The questionnaire covered the sixteen elements of competency shown on Table 1, and the managers were asked to rate them on a 5-point Likert scale regarding, first, their importance (very unimportant to very important), second, regarding their perception of the contribution of PjBL in developing these competencies (very little to very much), and third, regarding their perception of the contribution of traditional teaching in developing these competencies (very little to very much).

Before managers were asked to rate the latter two aspects, the difference between PjBL and traditional teaching was explained to them with the help of the simplified comparison shown on Figure 1. The simplification was necessary because of the managers' limited background regarding PjBL and the time constraints for carrying out the interviews. However, the explanation included the main characteristics of PBL (Barrows, 1996).

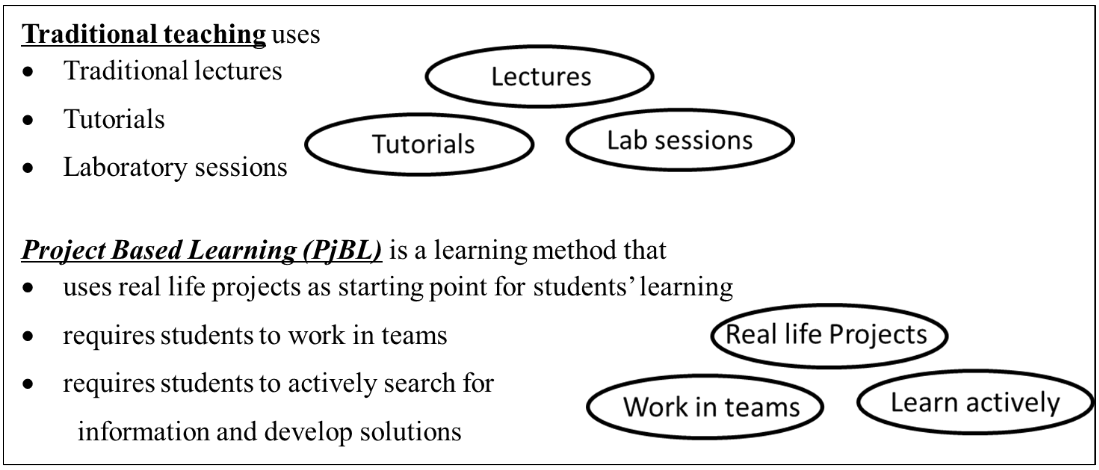

Figure 1 Simplified comparison PjBL versus traditional teaching

A simplified and pointed explanation of PjBL versus traditional teaching becomes even more important due to the concerns that have been raised among educators in the GCC region, that utilizing graduate attributes for exit surveys or employer satisfaction surveys have limited impact on teaching and learning because of cultural differences, limited constituency involvement and teaching in a non-native language (Bordia, 2001; Christoforou & Yigit, 2008).

In addition to collecting managers' perception on the importance of the competency elements, as well as the contribution of PjBL versus traditional teaching in developing these competencies, demographic data has been collected and is shown on Table 2.

Table 2 Demographic data of respondents

Variable	Answer	#	%
Education			
	Bachelor	73	80
	Master	17	18
	Ph.D.	2	2
	Total Education	92	100
Position			
	Upper management	37	40
	Lower management	55	60
	Total Position	92	100
Industry			
	Petroleum	32	35
	Construction	40	44
	Manufacturing	5	5
	Telecommunication / Electrical	15	16
	Total Industry	92	100
Sector			
	Private	35	38
	Public	57	62
	Total Sector	92	100
Size of Organization			
	<10	6	6
	10-100	30	33
	>100	56	61
	Total Size of Organization	92	100
Industrial experience [average years]		12.7	

The analysis of data includes descriptive statistics to answer research question one and three, as well as inferential statistics to answer the second research question. For the inferential statistics, the Wilcoxon test was chosen (Cohen *et al.*, 2011) since the same group of respondents was actually evaluating two different aspects, i.e. the contribution of PjBL and traditional teaching in developing the sixteen competency elements. The test converts the scores to ranks for both aspects, before it evaluates if the number of times the score of one aspect (e.g. PjBL) is significantly different from the score of the other aspect (e.g. traditional teaching). Since the scores are converted to ranks, it does not require a normal distribution of scores (unlike *t*-tests). The level of significance alpha was set to 0.05.

3 Results

The results related to the first research question, i.e. the importance of elements of competency, are reflected by the Mean and Standard Deviation (SD) and are shown in column two of Table 3. In addition, the Mean and SD related to the contribution of PjBL and traditional teaching (second and third interview question) are shown in column three and column four.

With a Mean of 4.7, 'Ethical conduct and professional accountability' (3.1) and 'Effective team membership and team leadership' (3.6) were perceived as the most important competency elements. With a Mean of 4.6, 'Effective team membership and team leadership' (3.6) is also the competency element which is perceived as being developed most by PjBL. With a Mean of 4, 'Conceptual understanding of mathematics…' (1.2) is the competency element which is perceived as being developed strongest by traditional teaching. These results will be further discussed in the discussion section below.

Table 3 Descriptive statistics (Mean, SD) of competency importance, PjBL and traditional contribution

COMPETENCY AREA Competency Element	**Importance**		**PjBL**		**Traditional**	
	Mean	SD	Mean	SD	Mean	SD
1. KNOWLEDGE AND SKILLS						
1.1. Theory based understanding…	4.1	0.9	3.7	1.0	3.9	1.0
1.2. Conceptual understanding of mathematics…	4.2	0.8	3.6	1.0	4.0	0.9
1.3. In depth understanding…	4.5	0.7	4.1	0.9	3.6	0.9
1.4. Discernment of current knowledge…	4.3	0.7	4.3	0.8	3.2	1.0
1.5. Knowledge of contextual factors…	3.9	0.9	4.1	0.9	2.7	1.1
1.6. Understanding of accountabilities…	4.5	0.6	4.2	0.8	3.4	0.9
2. ENGINEERING APPLICATION ABILITY						
2.1. Application of established engineering…	4.4	0.7	4.4	0.8	3.2	1.0
2.2. Application of engineering techniques…	4.3	0.7	4.3	0.8	3.2	1.0
2.3. Application of systematic design…	3.9	1.0	4.1	1.0	3.6	1.0
2.4. Application of systematic management…	4.2	0.7	4.3	0.8	3.1	1.0
3. PROFESSIONAL AND PERSONAL ATTRIBUTES						
3.1. Ethical conduct…	4.7	0.5	4.2	0.9	3.2	1.2
3.2. Effective oral and written communication…	4.5	0.6	4.4	0.7	3.4	1.1
3.3. Creative, innovative and pro-active…	4.3	0.8	4.2	0.8	3.0	1.1
3.4. Professional use of information…	4.3	0.7	4.2	0.7	3.3	1.1
3.5. Orderly management of self…	4.2	0.7	4.3	0.7	3.3	1.0
3.6. Effective team membership…	4.7	0.6	4.6	0.6	3.2	1.1

The difference between the contribution to developing competency elements by PjBL and the contribution to developing competency elements by traditional teaching is shown by the results of the Wilcoxon Test as shown on Table 4. Statistically significant differences between PjBL and traditional teaching were found for all competency elements, except competency element 1.1 'Theory based understanding of the underpinning natural sciences…' ($Z=-1.356$, $p=0.175$). The competencies were ranked by importance (most important to least important) and the ranking is shown on Table 5. The results will be discussed further in the following discussion section.

Table 4 Difference between PjBL and traditional teaching

COMPETENCY AREA Competency Element	**PjBL**		**Traditional**		**Wilcoxon**	
	Median	SD	Median	SD	Z	*p*
1. KNOWLEDGE AND SKILLS						
1.1. Theory based understanding…	4.0	1.0	4.0	1.0	-1.356	0.175
1.2. Conceptual understanding of mathematics…	4.0	1.0	4.0	0.9	-23.558	0.000
1.3. In depth understanding…	4.0	0.9	3.0	0.9	-23.558	0.000
1.4. Discernment of current knowledge…	4.0	0.8	3.0	1.0	-3.142	0.002
1.5. Knowledge of contextual factors…	4.0	0.9	3.0	1.1	-23.558	0.000
1.6. Understanding of accountabilities…	4.0	0.8	3.0	0.9	-23.558	0.000
2. ENGINEERING APPLICATION ABILITY						
2.1. Application of established engineering…	5.0	0.8	3.0	1.0	3.557	0.000
2.2. Application of engineering techniques…	4.5	0.8	3.0	1.0	-23.558	0.000
2.3. Application of systematic design…	4.0	1.0	4.0	1.0	-23.558	0.000
2.4. Application of systematic management…	4.0	0.8	3.0	1.0	6.511	0.000
3. PROFESSIONAL AND PERSONAL ATTRIBUTES						
3.1. Ethical conduct…	4.0	0.9	3.0	1.2	-23.558	0.000
3.2. Effective oral and written communication…	5.0	0.7	3.0	1.1	-23.558	0.000
3.3. Creative, innovative and pro-active…	4.0	0.8	3.0	1.1	3.945	0.000
3.4. Professional use of information…	4.0	0.7	3.0	1.1	-23.558	0.000
3.5. Orderly management of self…	4.0	0.7	3.0	1.0	-23.558	0.000
3.6. Effective team membership…	5.0	0.6	3.0	1.1	4.579	0.000

Table 5 Ranking of Competencies by Importance (most important to least important)

Rank	**Competency Element**	**Importance**		**PjBL**		**Traditional**	
#		Mean	SD	Mean	SD	Mean	SD
1	3.6. Effective team membership…	4.7	0.6	4.6	0.6	3.2	1.1
2	3.1. Ethical conduct…	4.7	0.5	4.2	0.9	3.2	1.2
3	3.2. Effective communication	4.5	0.6	4.4	0.7	3.4	1.1
4	1.6. Understanding of accountabilities	4.5	0.6	4.2	0.8	3.4	0.9
5	1.3. In depth understanding…	4.5	0.7	4.1	0.9	3.6	0.9
6	2.1. Application of established engineering…	4.4	0.7	4.4	0.8	3.2	1
7	3.4. Professional use of information…	4.3	0.7	4.2	0.7	3.3	1.1
8	3.3. Creative, innovative and pro-active…	4.3	0.8	4.2	0.8	3	1.1
9	2.2. Application of engineering techniques…	4.3	0.7	4.3	0.8	3.2	1
10	1.4. Discernment of current knowledge…	4.3	0.7	4.3	0.8	3.2	1
11	3.5. Orderly management of self…	4.2	0.7	4.3	0.7	3.3	1
12	2.4. Application of systematic management…	4.2	0.7	4.3	0.8	3.1	1
13	1.2. Conceptual understanding of mathematics…	4.2	0.8	3.6	1	4	0.9
14	1.1. Theory based understanding…	4.1	0.9	3.7	1	3.9	1
15	2.3. Application of systematic design…	3.9	1	4.1	1	3.6	1
16	1.5. Knowledge of contextual factors…	3.9	0.9	4.1	0.9	2.7	1.1

4 Discussion

In order to facilitate the discussion of results presented in the previous section, the competency elements have been ranked based on the Mean of their importance, from the most important to the least important competency element (Table 5). The competency element 1.1, 'Theory based understanding of the underpinning natural sciences…', rank 14 (row shaded), will not be discussed further since it was shown in the previous section that the difference was not statistically significant.

Of the remaining fifteen competency elements, only one competency element, namely 'Conceptual understanding of mathematics…', rank 13, was perceived as developed stronger by traditional teaching than by PjBL. The finding here confirms results of previous studies (e.g. Cohen-Schotanus *et al.* 2008; Schmidt, Vermeulen, and van der Molen 2006) which found that PjBL led to higher graduate competencies. The exception of the competency element 'Conceptual understanding of mathematics…' seems to confirm a common perception among engineering educators who see difficulties in developing mathematical concepts through PjBL (e.g. Jaeger, 2018). However, the rank of the importance seems to contradict a common perception among engineering educators who usually emphasize the importance of mathematical concepts for subsequently taught subjects of the engineering curriculum. The managers of engineers here do not rate high importance to this competency element.

The twelve most important competency elements, i.e. rank one to twelve, are all perceived to be developed stronger by PjBL than by traditional teaching. They include all competency elements of the competency area 'Professional and Personal Attributes', as well as three out of four competency elements of the competency area 'Engineering Application Ability' and four out of six competency elements of the competency area 'Knowledge and Skills'.

The first three most important competency elements, namely '3.6 Effective team membership and team leadership', '3.1 Ethical conduct and professional accountability' and '3.2 Effective oral and written communication' belong all to the competency area 'Professional and Personal Attributes'. For the managers of engineers these competency elements are more important than knowledge and skills or application abilities. This might be related to challenges resulting from the multi-cultural context within the GCC region as well as the fact that most engineering work in this region is carried out using English whereas many engineering students are more confident in Arabic (Findlow, 2001).

Based on the comparison between PjBL and traditional learning (c.f. Methodology section), many managers of engineers expressed their strong support for PjBL. The data presented here shows that they perceive PjBL to be more effective in developing most of the competency elements. However, their perception may have also been influenced by their own experience as students (all were exposed to predominant traditional teaching approaches) as well as the competency level of graduates they receive from most educational institutions. Many managers expressed dissatisfaction with the competency level of graduates which is in line with previous studies. For example, Ramadi *et al.* (2016) showed that engineering professionals in the MENA (Middle East and North Africa) region felt that recent engineering graduates were below industry expectation in any of the skill areas considered in their research. The managers of engineers interviewed here perceive PjBL as a learning approach which has potential to improve the level of most competency elements.

5 Conclusion

As part of an ongoing research effort to understand better the potential and the challenges of PjBL in the GCC region, managers of engineers have been interviewed regarding their opinion of the importance of sixteen elements of competencies, the contribution of PjBL in developing these competencies and the contribution of traditional teaching in developing these competencies. Of the fifteen competencies with a statistically significant difference between PjBL and traditional teaching, fourteen are more effectively developed by PjBL than by traditional teaching. The twelve most important competencies are all developed more effectively by PjBL. These findings present a strong case for utilizing PjBL in engineering education at educational institutions in the GCC region, and engineering educators in this region should be encouraged to utilize PjBL in order to meet better industry expectations by improving the level of competencies of engineering graduates. Future studies will allow comparisons of the industry perspective with the perspective of engineering educators and the perspective of engineering alumni in the GCC region. Finally, the effectiveness of PjBL as preparation for further education, possibly in a context that uses predominantly traditional teaching, needs to be investigated.

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Pilot testing of an instrument to measure self-directed learning in a problem-based learning environment

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Abstract

In preparing higher education students for life-long learning, there is a requisite to develop students who are equipped with eminent levels of motivation towards learning. In addition, it is envisaged that such students should have the ability to plan their learning, communicate effectively, engage in collaborative learning and monitor themselves whilst they are active participants in the learning process. These attributes collectively form the construct termed self-directed learning. This study reports on the development of a survey instrument to measure students' self-directed learning abilities in a problem-based learning environment. The pilot study surveyed 316 first-year polytechnic students, including engineering students who were undertaking full-time diploma studies. Students voluntarily participated in the online survey consisting of 55 items. The items were developed based on an extensive literature review that spanned across various attributes critical to the theory of self-directed learning, including learning motivation, planning, collaborative learning, interpersonal communication and self-monitoring. Exploratory factor analysis was employed to reduce the number of items and establish a factor structure. The findings provided strong empirical support of the emergence of four factors, namely, (a) learning motivation, (b) planning, (c) self-monitoring, and (d) collaborative cum interpersonal communication. Furthermore, there is no major distinction between the way students perceive collaborative learning and interpersonal communication in a typical problem-based learning environment.

Keywords: Problem-based learning, self-directed learning, exploratory factor analysis, instrument development.

Type of contribution: Research paper.

1 Introduction

As educators in institutes of higher learning, such as polytechnics, we are faced with the veracity of inculcating a spirit of lifelong learning amongst our students as we prepare them primarily for the 21st century workforce. This requires us to play an important role in ensuring that the students develop the mind-set to continuously learn as well as to recognise and use resources to this end. Attributes such as self-directedness are crucial in helping students become lifelong learners (Lee, Tsai, Chai & Koh, 2014). In progressive pedagogical approaches, like problem-based learning (PBL), students are compelled to take on more accountability for the learning process. Consequently, there is an underlying prerequisite to develop self-directed learners where learning is predominantly underpinned by the PBL pedagogy.

The challenge is to measure self-directed learning amongst students when learning happens in these distinctive settings.

Prior to this study, the authors endeavoured to measure self-directed learning in polytechnic students in the PBL environment by adapting items from established survey instruments produced by Cheng, Kuo, Lin, and Jane, (2010) and Lee *et al*., (2014). The results indicated the lack of an important factor, namely, self-monitoring (Periasamy & Vedamuthu, 2017). This together with an apparent dearth of survey instruments to measure self-directed learning among learners in the PBL environment, prompted the authors to create and pilot a new survey instrument.

This pilot study was guided by the research question: What are the different dimensions of self-directed learning in a PBL environment?

2 Literature Review

2.1 Conceptualisation of Self-Directed Learning

In the literature, there are several definitions for self-directed learning and as with most constructs there appears to be no definite, accepted definition. This study draws upon the definition provided by Knowles (1975) as several other studies related to this definition have produced reliable scales and instruments. Self-directed learning is defined by Knowles (1975, p.18) “as a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, implementing appropriate learning strategies, and evaluating learning outcomes”. Some may interpret self-directed learning as an individualistic or independent activity. Brockett & Hiemstra (1991, p.11) purport that “it is a mistake to automatically associate self-directed learning in isolation or learning on an independent basis”. Garrison (1992) provides further support of this conception. Research shows that leaners learn through a high degree of collaboration with teachers and peers, contrary to the notion that learning takes place in isolation during self-directed learning. Collaboration is an integral part of self-directed learning where participants describe their own learning process, to accomplish their learning goals (Donaghy, 2006). During this collaboration, a learner acquires knowledge through his or her own effort by deciding on who to collaborate with and what to learn from that collaboration. PBL with its distinctive student-centred nature furthers SDL skills in students through many aspects, but not limited to, students discerning information and knowledge gaps, generating their own hypotheses or learning concerns, students’ individual engagement with knowledge, the critical assessment of resources, choosing who to collaborate with, and the application of new knowledge to the problem.

There is sufficient evidence in the literature to accentuate the importance of using instruments to measure self-directed learning in a variety of settings, both generic and domain specific. Some well-known examples include the self-directed learning readiness scale developed by Guglielmino (1977) and more recently, the self-directed learning readiness scale for nursing education (Cheng, *et al*., 2010). Guglielmino’s (1977) self-directed learning readiness scale has been widely used given its early establishment in the field. It was also used to explore self-directed learner readiness of medical students studying in a PBL setting, for example, Soliman and Al-Shaikh (2015). However, the reliability of this scale has been refuted in some studies by Field (1991), and Hoban, Lawson, Mazmanian, Best and Seibel (2005). Consequently, it was disregarded for this study.

2.2 Construction of an Instrument to Measure Self-Directed Learning

The researchers interpreted the definition of self-directed learning, as purported by Knowles (1975) and Cheng *et al*., (2010), to be an instrument comprising five domains, namely learning motivation (LM) which is associated with 'diagnosing their learning needs'; planning (P) with 'formulating learning goals' as well as 'implementing appropriate learning strategies'; self-monitoring (SM) with evaluating learning outcomes; collaborative learning (CL) with identifying human and material resources for learning. The interpersonal communication (IC) domain is related to dialogue and discussion skills, which is a necessary interpersonal skill to enhance self-directed learning in the PBL environment.

3 Methodology

3.1 Context of the Study

The participants were students enrolled in first year polytechnic full-time diploma studies, including the engineering discipline. The diploma programmes are facilitated using student centred learning approaches, which comprises PBL, cognitive apprenticeship, interactive seminars, and project-based learning. These teaching approaches are anchored on seven principles of effective teaching and learning, which focusses on self-directed, collaborative and reflective learning.

Data was collected from first year full-time diploma students towards the end of their semester 1 lectures. The students volunteered to participate in the study on self-directed learning with the understanding that they could withdraw at any stage. Students were assured of confidentiality and they gave their consent before completing the online survey questions. The sample size was 378. After cleaning the data and removing those deemed unusable, the sample size reduced to 316.

3.2 The Survey Instrument

Two researchers with background in psychology, statistics and PBL framed the survey questions. All ratings were made on Likert 5-point scales and ranged from 1 (strongly disagree) to 5 (strongly agree). Some of the items were adapted from Lee *et al*., (2014) and Cheng *et al*., (2010). The number of items for each domain together with some exemplars is given in Table 1.

Table 1: Five domains of self-directed learning.

Domain	Exemplars (Survey Items)	Number of items
Learning motivation	I am eager to learn new information	7
Planning	I am able to choose strategies to reach my learning goal	9
Self-monitoring	I check to see if the strategies I am using are helping me to learn	16
Interpersonal communication	I learn the content better through my communication with peers	18
Collaborative learning	In class, my classmates and I actively work together to help each other understand the material	5

The 55 Items were developed to emphasise the aspect of self-directed learning specifically in the context of the PBL settings. These include but are not limited to: 'I am a good listener during team discussion; I am

able to speak clearly when I discuss with team-mates; I try to listen for the meaning when someone is talking; I learn the content better through my communication with the lecturer; in discussions I am able to see things from others point of view; I use feedback from previous work to focus on the gaps in my learning; I check to see if the strategies I am using are helping me to learn and I am able to monitor how well I am learning when I work with others'.

3.3 Methods

SPSS version 23 was used to analyse the data. The minimum amount of data for factor analysis was satisfied with a final sample size of 316, providing a ratio of over 5 cases per variable. The items listed in Table 2 were removed as their kurtosis was more than 3.

Table 2: Items removed due to effects of kurtosis.

Item	Description
SM3	I seek assistance when I know I cannot tackle the challenges I face
SM7	I am aware of why it is important to learn new information
IC6	I believe that communication will help improve my learning

Exploratory factor analyses involving principal axis factoring with the direct oblimin Kaiser Normalisation rotation was used to reduce the items. This method was chosen because the major purpose was to identify the latent factors. The factorability of the 52 items was examined and some well-known criteria for the factorability of a correlation were used, detailed as follows. There were 4 items which revealed too low correlations of below .3 with at least 46 other items, and these were removed from subsequent analysis. The items are in Table 3 below.

Table 3: Items removed due to low correlations.

Item	Description
IC13	I am not afraid that people will get angry with me if I disagree with them
IC14	I let my peers finish talking before reacting to what they say
IC7	I use examples to explain what I am talking about
IC8	I am a good listener during team discussion

The Keiser-Meyer-Olkin value of sampling adequacy was .931 which was well above the recommended value of .6 and also Bartlett's test of sphericity was significant. The diagonals of the anti-image correlation matrix were all above .9, indeed over the usual recommended value of .5. The communalities were above .3 except SM6: 'I am able to correct mistakes', which was subsequently removed. The above serve to confirm that each item shared some common variance with other items. With these overall indicators, factor analysis was deemed to be suitable with these 47 items. After removing item SM6, the factor analysis was rerun a few times with 1 or 2 items being removed at each run due to low communalities of below .3. The items removed are reflected in Table 4 below.

Table 4: Items removed due to low communalities.

Item	Description
P7	In class, I experiment with different approaches or strategies to solve problems
SM6	I am able to correct mistakes
P3	I am able to rank my learning from most important to least important
IC18	I am able to communicate effectively through social media
IC17	I am able to communicate effectively through written messages
IC2	I am able to communicate messages effectively when writing

An inspection of Catell's (1966) Scree plot revealed a break after the fifth component. Principal axis factoring of the data revealed the presence of nine factors with eigenvalues more than one. Solutions for three, four, five and six factors were each examined using principal axis factoring and oblimin rotations of the factor loading matrix. The four-factor solution was preferred because of its theoretical support as well as the difficulty of explaining the fifth and subsequent factors. Finally, items with loadings of below .4 in each of the four factors were removed and are reflected in Table 5.

Table 5: Items removed due to low loadings in each factor.

Item	Description
P6	I know how to find information to help in my learning
SM11	I can explain the concepts I have learnt to another person
SM8	I check to see if the strategies I am using are helping me to learn
SM14	I am able to monitor how I learn for the examinations
SM5	I can recognise accurate work
SM16	I am able to monitor how well I am learning when I work with others
IC1	I am able to communicate effectively during oral presentations
IC4	I learn the content better through my communication with the lecturer
LM7	I will not give up learning because I face some difficulties

In summary, out of the pool of 55 initial items, 23 were removed as per analysis and the remaining 32 items formed the survey instrument.

4 Results and Discussion

The 4-factor model with initial eigenvalues explained 30.86%, 7.39%, 6.22% and 5.08% of the variance respectively, totalling 49.55%. The finalised pattern matrix for this study, using principal axis factoring with the direct oblimin method of extraction is in Table 6.

Table 6: Results of Exploratory Factor Analyses

Items	Factor			
	Learning Motivation	Collaborative	Planning	Self-monitoring
SM2. I learn on my own when I am	.63			

confident that I can tackle the challenges I face			
LM1. I am eager to learn new information	.56		
LM4. My successes inspires me to continue learning	.53		
LM2. Regardless of the results or effectiveness of my learning, I still like learning	.49		
LM3. I strongly hope to constantly improve and excel in my learning	.49		
SM1. I apply what I know to understand new information on my own	.43		
LM6. I enjoy finding answers to the questions	.41		
CL2. In class, my classmates and I actively share ideas and information		.85	
CL3. In class, my classmates and I actively work together to learn new things		.77	
CL4. In class, my classmates and I actively discuss the ideas we have about things we are learning		.70	
CL5. In class, my classmates and I actively talk about what to do during group work		.67	
CL1. In class, my classmates and I actively work together to help each other understand the material		.65	
IC9. I find it easy to talk to others in class		.57	
IC3. I learn the content better through my communication with peers		.56	
IC5. I am able to speak clearly when I discuss with team-mates		.54	
IC10. I am able to express my ideas even when they differ from those around me		.43	
P8. In class, I make plans for how I will study			.73
P5. I am good at managing my learning time			.72
P9. In class, I try to check my progress when I study			.65
P4. I am able to follow my own plan of learning whether I am in the classroom or on my own			.65
P2. I am able to choose strategies to reach my learning goals			.50

SM9. I check to see if I need to try something different to improve my learning	.48	
LM5. My failures inspires me to continue learning	.44	
SM4. I use feedback from previous work to focus on the gaps in my learning	.43	
SM15. I know my strengths and weaknesses on how I learn with others in a team		.54
IC15. I am able to tell the difference between what a person is saying and what he is feeling		.48
IC16. In discussions I am able to see things from others point of view		.45
IC12. I am able to accept constructive criticism from others in class		.43
IC11. I try to listen for the meaning when someone is talking		.42
SM10. I can apply what I have learnt to different situations		.38
SM13. I know what content I need to work on in order to do well in the examinations		.35
SM12. I apply what I know to understand new information with the help of the worksheet, peers or lecturer		.32

Most of the items in Table 6 had loadings which are greater than .4, demonstrating that the latent variables can be measured by the items. The three items with lower than 0.4 loadings are acceptable given the large sample size, they can also be re-worded for future use. Items that were originally planned to be within respective domains loaded on different domains after rotation. SM2 loaded highly on the learning motivation factor and justifiably so as learning motivation and success is related to confidence. As for SM1, if students perceive that what they are learning is relevant and can be applied to new learning situations, then they will find learning meaningful and this will contribute to increased levels of learning motivation. The loadings for the collaborative cum interpersonal communication factor were high, as expected, since these are dominant in the learning culture of a PBL classroom. The items IC9, IC3, IC5 and IC10 on interpersonal communication loaded strongly with collaboration. This can be justified since these are actions of working with someone and can include groups, e.g. team-mates and peers. SM9 loaded with the factor of planning and this is reasonable as it is similar in nature to P9. SM4 can be regarded as a planning item because feedback can be used to plan the action that one needs to take, which in this case is to decide the gaps in learning that needs to be addressed. IC15, IC16 and IC11 links with SM15 as self-awareness creates empathy. As for IC12, by willing to accept constructive criticism, one is able to observe and evaluate one's behaviour, which is self-monitoring.

The Cronbach's alpha measure of reliability was used for each of the factors and these values, ranging between .777 and .887, were substantial as illustrated in Table 7. This implies that there is a good measure of internal consistency, indicating that the items within the scales measures what it intends to measure.

Table 7: Reliability measures.

Domain	Cronbach's alpha
Learning motivation	.777
Planning	.842
Self-monitoring	.802
Collaborative learning and Interpersonal communication	.887

5 Conclusion

The survey instruments in the literature on self-directed learning appear to have limited transfer to the settings underpinned by the PBL pedagogy. Hence this pilot study was undertaken to create a survey instrument to explore self-directed learning in polytechnic students when learning takes place in PBL settings. The items were developed around the main constructs of self-directed learning, which are, learning motivation, planning, collaborative learning, interpersonal communication and self-monitoring. Exploratory factor analysis was employed to reduce the number of items from 55 to 32 items and thereby establish a factor structure. The findings provided strong empirical support of the emergence of four factors, namely, (a) learning motivation, (b) planning, (c) self-monitoring and (d) collaborative cum interpersonal communication. The reliability of these four factors were established, however future research is needed to examine the validity of this instrument.

Furthermore, there is no major distinction between the way students perceive collaborative learning and interpersonal communication in a typical problem-based learning environment. This could be because in a PBL context, students are engaged predominantly in communication only when they are collaborating with their peers and lecturers in class. Either we could combine these two dimensions together or reword the items to keep them separate.

It is envisaged that this study has the potential to influence curriculum developers to transform both curriculum and, learning and teaching approaches with the aim of developing self-directed learners who are prepared for the demands of the workplace in the 21st century whilst engaging in lifelong learning.

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Characterization of learning strategies used by engineering students of the Universidad Nacional de Colombia

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Abstract

Since 2016, the Faculty of Engineering of the Universidad Nacional de Colombia, began the process of formation of teachers as agents of change to facilitate the implementation of a bottom-up strategy with the aim of not only promoting the transformation of pedagogical practices towards those centered on the student, but also the application of the problem-based learning methodology. The aim of this work is to characterize the learning strategies currently used by our students, as one of the preliminary steps of the change strategy. A self-report questionnaire called MSLQ-Col was applied. This questionnaire allows to identify nine learning strategies that students may use to facilitate their study tasks: rehearsal, elaboration of ideas, organization of ideas, critical thinking, metacognition, management of study time, study environment control, peer learning/help seeking and effort regulation. More than 500 randomly selected students answered the questionnaire in order to obtain a sample representing the nine engineering programs of the Faculty and students belonging from the first to the fifth year. As a result, it was determined that the strategy reported by students as the most used is the *Study Environment* and the strategy reported as the least used is *Organization of Ideas.* Additionally, the different factors that make up the questionnaire and its relationship with demographic variables such as sex, Grade Average Point, belonging to a research group, type of school (public or private) from which students come, and employment status were also analyzed. The analysis of the results will be useful in defining the change strategy that should be developed in order to implement Problem Based Learning methodologies in the Faculty.

Keywords: Learning Strategies, Self-Regulated Learning, Motivated Strategies for Learning Questionnaire – Colombia (MSLQ-Col), Engineering Education.

Type of contribution: research paper

1 Introduction

Since 2016, the Dean´s office of the Faculty of Engineering of the Universidad Nacional de Colombia, initiated an ambitious process to promote the transformation of educational practices and methodologies towards those student-centered, such as active learning and problem based learning. This effort requires the combination of top-down and bottom-up change management strategies. The top-down strategy is "mainly focused on training of the individual faculty member to develop her teaching and learning methods and skills, mostly with the goals of making reflective *teachers*" (Kolmos et al., 2016, p. 403); the bottom-up strategy is represented by the changes made for teachers at the course level (Kolmos, 2010). These management strategies require diagnosis of how the students regulate and direct their learning processes when the goal is to implement educational practices student-centered. It has been found the self-regulated learning (SRL) plays a key role in the PBL learning processes

(Loyens et al., 2008). SRL encompass tasks such as goal setting, metacognitive, regulation of resources for learning and, learning monitoring and evaluation (Pintrich, 2004). These tasks can be carried out through learning strategies that students can apply when they are studying (Ramírez, 2017). Effective learning strategies allow students to process the subject matter in a deeply level. Deeper level processing is necessary in learning environments like PBL because learners have more responsibility to control what they learn and how they learn it (Loyens et al., 2008).

This characterization work seeks to explore how the students of the Engineering Faculty of Universidad Nacional de Colombia self-regulate their learning processes. Specifically, it was explored:

- What learning strategies are used by the students of the Faculty of Engineering?
- What is the relationship between the learning strategies applied by the students and the sex, grade point average, belonging to a research group, public or private type of the school from which students come and employment status?

The reflection and analysis of the answers obtained with this work could be useful to apply the top-down and bottom-up management strategies to implement PBL in this Faculty.

2 Learning strategies

Learning strategies can be defined as all operations or mental activities that the student can implement to facilitate the acquisition of certain knowledge (Curotto & Yuni, 2004). The learning strategies construct is based on the self-regulated learning theory (Panadero, 2017). This theory includes fundamental variables that influence learning processes as cognitive, metacognitive, motivational and behavioral aspects. A way to explore the learning strategies employed by students is using the self-report questionnaires; some examples of these questionnaires are: The Motivated Strategies for Learning Questionnaire, MSLQ (Pintrich et al., 1991), and Learning and Study Strategies Inventory, LASSI (Weinstein at al, 2002). The MSLQ Colombian version (MSLQ-Col) is a questionnaire for engineering students based on MSLQ. MSLQ-Col was adapted and validated by Ramírez et al. (2016) in order to explore motivational aspects and learning strategies employed by engineering students.

In this study the MSLQ-Col was used, specifically, the items of learning strategies scale. The learning strategies explored were:

- **Cognitive learning strategies**: It refers to those that help the student to create new knowledge based on their previous experience. These involve short-term memory, the organization of information, as well as the elaboration of ideas.
- **Metacognitive learning strategies**: These allow the student to plan what they want to learn, observe their performance and thus adjust their actions or rethink the object of study. The student "*controls their learning process using metacognitive strategies such as planning, self-regulation, evaluation, checking, criticism and monitoring*" (Hernández & Camargo, 2017).
- **Resource management strategies**: These strategies allow the students to manage different resources adequately that they have available to carry out their learning processes. These strategies include management of study time, study environment control, peer learning/help seeking and regulation of effort.

3 Methods

3.1 The student sample

The Faculty of Engineering offers nine undergraduate programs in which 6800 students are enrolled. The present study was descriptive-transversal type; the sample was acquired at random. They were 531 students who participated in this research, enrolled in 23 disciplinary subjects from the nine undergraduate engineering programs and they were randomly selected. Table 1 shows the distribution of the sample in the programs of the Faculty, Table 2 shows the distribution of the sample by sex and Table 3 shows the distribution of the sample by age.

Table 1: Distribution of the sample in the nine engineering programs.

Program	Frequency	Percentage (%)
Agricultural Engineering	39	7.3
Civil Engineering	58	10.9
Systems and Computer Engineering	106	20.0
Electrical Engineering	65	12.2
Electronics Engineering	57	10.7
Industrial Engineering	70	13.2
Mechanical Engineering	31	5.8
Mechatronics Engineering	72	13.6
Chemical Engineering	33	6.2
Total	531	100.0

Table 2: Distribution by sex.

Sex	Percentage (%)
Female	14.3
Male	85.7
Total	100.0

Table 3: Distribution by age.

	Age (years)
Average	21.4
Minimum	16
Maximum	38
Sample	531

3.2 Process

The Motivated Strategies for Learning Questionnaire, colombian version (MSLQ-Col) was digitalized to achieve easy access by students in the computer rooms arranged in the institution, by mail and other electronic devices. Within the questionnaire (MSLQ-Col), answered by 531 students, variables such as sex, the public or private nature of the school of origin were investigated, as well as if the student has a job, if he/she belongs to a research group and the Grade Point Average, in order contrast these variables with the learning strategies used by students.

3.3 The Motivated Strategies for Learning Questionnaire (MSLQ-Col)

The Motivated Strategies for Learning Questionnaire (MSLQ-Col) (Ramírez *et al.*, 2016) is made up of 75 items divided into two scales: motivation and learning strategies. These scales work in a modular way, that is, they are independent of each other in their application. Given the interest on learning strategies for this work, only the second scale consisting of 45 items will be used, with an average application time of 20 - 30 min. The scale of learning strategies groups the actions that facilitate the student to create new knowledge (cognitive strategies), to plan what they want to know, observe their performance and thus adjust their actions (metacognitive strategies) and to manage different resources in order to carry out learning processes (resources management strategies). MSLQ-Col score for each learning strategy is a Likert scale from 1 to 7. The student selects “1” if the item does not apply for him and student should select “7” if the item apply entirely for him. Table 4 shows the MSLQ-Col factors related to learning strategies.

Table 4: Factors of MSLQ-Col.

Factor	Description
F1	Peer learning/help seeking
F2	Critical thinking
F3	Management of study time
F4	Effort regulation
F5	Elaboration of ideas
F6	Organization of ideas
F7	Memorization
F8	Metacognition
F9	Study environment control

4 Results

The analysis of the questionnaire and the relationship for variables studied was done with the SPSS software, running non-parametric statistics, due to the nature of the variables to analyse and the size of the sample.

4.1 Results regarding demographic variables

Tables 5, 6, 7 and 8 show the results found about the regarding demographic variables: grade point average (GPA), the belonging to a research group, the type of the school and employment status, respectively.

4.2 Learning strategies results

From the answers of students reported through MSLQ-Col it was found the use level of each learning strategy by students. A score near to “1” means low use level of the strategy, on the other hand, a score near to “7” means a high use level of the learning strategy.

Table 5: Students´ Grade Point Average.

	Grade Point Average (0.0 to 5.0)
Average	3.74
Minimum	3.0
Maximum	4.8
Sample	477

Table 6: Belonging to a research group.

	Percentage (%)
No	90.2
Yes	9.8
Total	100.0

Table 7: Private or public school.

	Percentage (%)
Private	52.5
Public	47.5
Total	100.0

Table 8: employment status.

Currently working	Percentage (%)
Yes	34.7
No	65.7
Total	100.0

Figure 1 shows the average score for learning strategies evaluated with the MSLQ-Col and Table 9 shows the standard deviation for each strategy. Results indicate that the least strategy used by students is *Organization of ideas* (score: 3.61), that refers to the abilities that students have to organize the content study in class, through sketches or diagrams in order to facilitate his/her own learning. On the other hand, the strategy most used by students is *Place and study environment control* (score: 5.39), which refers to assigning an ideal space to study the contents. However, the average score for all strategies that make up the questionnaire is 4.50, which shows a uniform distribution with a high average trend in the sample evaluated.

4.3 Relationship between demographic variables and the learning strategies

All demographic variables (sex, GPA, research group, type of school and employment status) have at least one significant relationship with learning strategies considered by the MSLQ-Col. Table 10 shows the level of significance (p-value) for relationships that were found statistical significant.

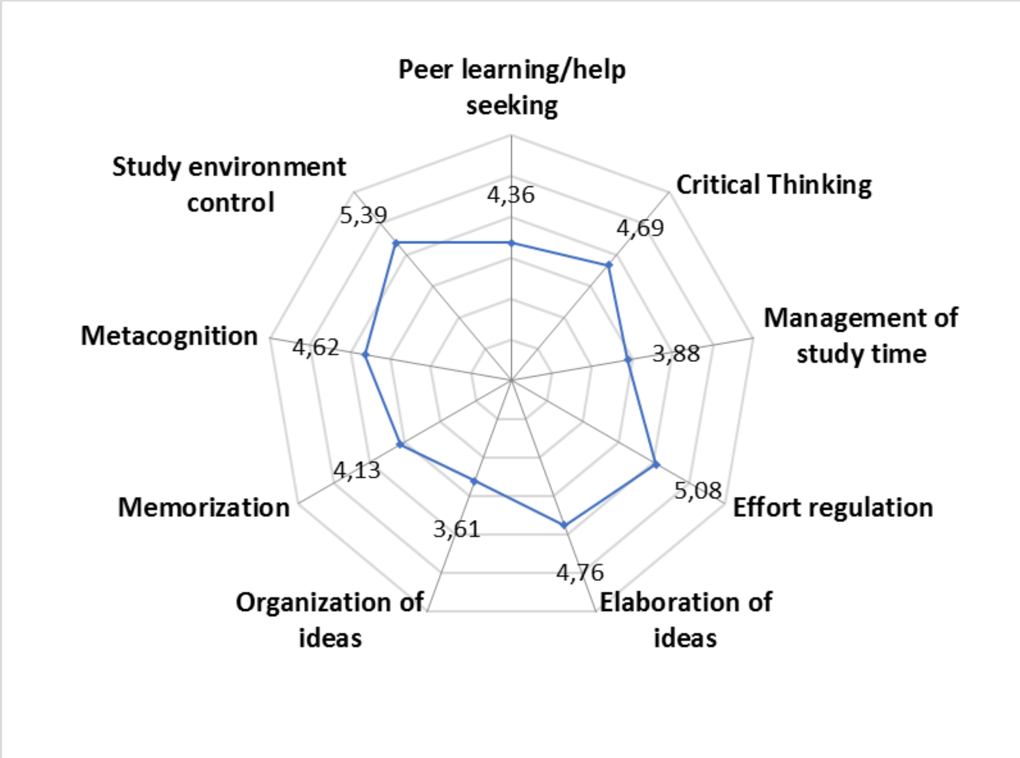

Figure 1: Average score for learning strategies evaluated with the MSLQ-Col.

Table 9: Standard deviation of the average score for each learning strategie evaluated by MSLQ-Col.

	F. 1	F. 2	F. 3	F. 4	F. 5	F. 6	F. 7	F. 8	F. 9
Standard Deviation.	1.42	1.00	1.34	1.18	1.32	1.51	1.34	1.08	1.28

Table 10: Level of significance for relationship between demographic variables and learning strategies. *(p-value)*

	F1	F2	F3	F5	F6	F8
Sex					0.000	
GPA	0.000		0.002			
Research group					0.016	
Type of school	0.002					
Employment status		0.017		0.040	0.020	0.035

The specific relationships found were:

- Women have a better performance in F6, organization of ideas, than men.
- Students with high GPA report a greater use of the strategies of F1 and F3, peer learning/help seeking and management of study time. That is to say, the students may obtain better academic performance if they know how to work as a team in order to learn and if they know how to manage their study time.

- Students who belong to a research group have a high performance in F6, organization of ideas strategy.
- Students from private schools do greater use of F1, peer learning/help seeking strategy, than those who come from public schools.
- Students who are working obtain a better performance in factors 2, 5, 6 and 8 than students who are not currently working. These learning strategies are critical thinking, elaboration of ideas, organization of ideas and metacognition.

To do the GPA analysis, these were divided into the ranges shown in the Table 11.

Table 11: GPA ranges.

Low	3.0 – 3.4
Medium	3.5 – 4.3
High	4.4 – 5.0

The effort regulation, memorization and study environment control learning strategies did not present significance relationship with demographic variables studied.

5 Analysis of results

The results of this research indicate that study environment control is the learning strategy most used by engineering students of Universidad Nacional de Colombia. It has been found that is important to control the environment conditions of study place in order to focus in the study tasks. On the other hand, it also has been found the organization of ideas and management of the study time are the learning strategy least used. The organization of ideas through sketches or diagrams implies rigorous cognitive process and facilitates the learning by mean of associative knowledge (Peña, 2013). In PBL, students must study relevant literature related to the problem or the project that they are working on, before the next tutorial meeting with the facilitator (Loyens et al., 2008). Additionally, the management of the study time is fundamental in PBL because students require planning and monitoring their study activities. Therefore, it is pertinent to consider this results in order to propose changes at the course level (bottom-up strategy) because students need to know how to apply strategies to organize the ideas extracted from the literature read and manage their study time before a PBL implementation.

The goal of the analysis about the relationships between demographic variables and learning strategies was to explore if some personal conditions would be to affect the use of learning strategies. A very relevant result of this analysis was the relationships found between employment status variable and some learning strategies. Students who are working obtain better performance in critical thinking, elaboration of ideas, organization of ideas and metacognition than students who are not currently working. These learning strategies are related to the deep learning approaches; this means when student is working may be more likely to use learning strategies in order to learn significantly. This could be because the students have the possibility to find relationships between formal learning in the university and informal learning in the job. To be aware of these relationships could motivate at students to learn deeply (Guile & Griffiths, 2010). For the concerns of this article, this result suggests that could be interesting to include, in each working group of PBL, students who currently have a job. They could contribute to other peers with relevant point of views about how to study deeply.

Other relevant result was the relationships found between GPA and study time management and peer learning/help seeking strategies. These strategies are related to the resources management. In other words, the students can obtain a better GPA if they use effectively their study time, program their study tasks and seek help or support from their study partner. These relationships have been found in other surveys (Esgerra & Guerrero, 2010). Additionally, these relationships constitute the basis to develop teaching methods (top-down strategy) in order to facilitate at students the use of these learning strategies to improve their GPA. As well, these learning strategies should be taught to students before the PBL implementation because both are fundamental in the PBL learning processes (Loyens et al., 2008).

Finally, it was found that the organization of ideas strategy is more used by students who belong to a research group or students with active work status or female students. These results may be because students that is working or belonging to research groups can establish relationships between the knowledge addressed in class and the knowledge they need to do their work. This situation could arouse the interest of students, and motivate them to take better notes and organize the information (Rioseco & Romero, n.d.; Ramírez, 2017). It is important to remember that organization of ideas was the learning strategy least used by all participant students.

6 Conclusion

This characterization work allowed to answer two research questions: what are the learning strategies used by students of the Engineering Faculty of Universidad Nacional de Colombia? And what are the relationships between the learning strategies employed by the students and the sex, Grade Point Average, belonging to a research group, public or private type of the school from which students come and working status?

The results of this research will be useful to answer questions like what should be have in account in order to implement PBL methodologies in the Faculty? This characterization of the current state the learning strategies used by students could be the basis for top-down and bottom-up management strategies in this Faculty. These management strategies seek to promote the transformation of educational practices and methodologies towards those student-centered like PBL.

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The Significance of Problem Analysis for Critical Thinking in Problem-Based Project Work

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Abstract

In this paper, we argue that the problem analysis inherent to problem-based project work is important for students' possibilities for developing competencies for critical thinking. Problem-based learning, PBL, is often described as an effective approach for fostering critical thinking. However, less often does research offer explanations for *why* this should be the case. In this paper we argue that the problem analysis in problem-based project work constitutes a space conducive for learning how to think critically. In particular, we argue that a problem analysis may be understood as an argument with a specific purpose namely to clarify why it is relevant to ask the question posed in the problem statement.

We show how the purpose of the problem analysis is more than to provide a formal space for introductory remarks in student reports. Rather, the problem analysis is intended to offer students opportunities for reflecting on the relevance of the identified problem. We further demonstrate how the problem analysis can be understood as an argument and that in this sense, the problem analysis is both a process and a product serving dual interrelated purposes. In the former sense, because it requires a particular kind of questioning or mindset leading to a *process* of problem analysis which provides an an opportunity for learning how to think critically. While in the latter sense, the *product* resulting from this process, i.e. the finished problem analysis along with the resulting problem statement, function as textual manifestations demonstrating the quality of students' competencies for critical thinking. Consequently, the fact that students are required to identify and define the problems themselves serves to reinforce the potential of doing a problem analysis to foster the development and/or improvement of students' competencies for critical thinking.

Keywords: Problem analysis, critical thinking, problem-based learning, problem-based project work

Type of contribution: Conceptual paper

1 Introduction

It is not difficult to find research that documents the positive effect of problem-based learning on a number of parameters such as motivation, self-direction, and collaboration just as many authors seem to agree that problem-based learning is well suited to facilitate the development and/or improvement of students' critical thinking skills (Stefanou, Stolk, Prince, Chen, & Lord, 2013; Bell, 2010; Hmelo-Silver, 2004; Dochy, Segers, Van den Bossche, & Gijbels, 2003). Nevertheless, problem-based learning is a contested concept in the sense that it may be practiced in different learning spaces with different intentions regarding what students are expected to learn and today there are numerous strategies for implementing problem-based learning (Graham, 2017; Servant, 2016). Each of these approaches stresses different aspects of problem-based learning and each of them is suitable for different purposes (Barrows, 1986; Helle, Tynjälä, & Olkinuora, 2006).

At Aalborg University problem-based learning is understood and practiced in accordance with the Aalborg PBL model. Because the Aalborg PBL model involves project work, it is also known under the epithet problem-based project work (Aalborg University, 2015). This particular version of problem-based project work adheres to the basic principles accepted as typical of most forms of problem-based learning in that it has the authentic problem as the point of departure for learning, and so like most kinds of problem-based approaches to learning, in the Aalborg PBL model, the problem is considered the starting point for the learning process and determines the direction and focus of everything that follows (Kolmos, Fink, & Krogh, 2004). Similar to other forms of problem-based learning, the Aalborg PBL model requires students to rely on collaboration in groups. Furthermore, students must direct their own learning, and groups are supported by a supervisor (Aalborg University, 2015). Finally, the Aalborg PBL model requires students to identify and formulate the problem themselves. Thus, before students can even embark on addressing a given problem, they need to work towards actually identifying the exact problem they will address in the project. In this phase, students must argue for the relevance of the problem they have chosen via a so-called problem analysis.

We use the description of how problem-based learning is practiced at Aalborg University to illustrate and exemplify how problem analysis may function as a way of facilitating the development and/or improvement of students' competencies in critical thinking in general. In line with these ideas, the purpose of the paper is not to try to answer the question about *whether or not* problem-based learning facilitates the development and/or improvement of students' competencies in critical thinking. This has already been well established in the research literature (Stefanou, Stolk, Prince, Chen, & Lord, 2013; Bell, 2010; Hmelo-Silver, 2004; Dochy, Segers, Van den Bossche, & Gijbels, 2003) Rather, our mission here is to explore the reasons *why* and *how* problem-based project work and in particular the work leading to the problem analysis might have this effect.

Thus, the research question we seek to answer in this paper is:

> *How* and *why* does problem analysis in problem-based project work facilitate the development and/or improvement of students' competencies for critical thinking?

While Aalborg University is certainly not the only university in the world to use problem-based learning as its main pedagogical approach, for our present purposes, we take our point of departure in a description of how problem-based project work is practiced at this particular institution. It follows that, in the present paper, when we refer to problem-based project work and discuss the potential merits of this pedagogical approach, we base our contentions on the principles that inform this particular version of problem-based learning. Even though this particular point of departure might seem to limit the range and application of our conclusions to a very specific local institutional context, we believe that the crux of our argument could prove useful and valid for thinking about how to enhance students' competencies for critical thinking in other settings.

The paper is structured into six sections each of which serves to advance our argument about the function and significance of the kind of problem analysis found in problem-based project work in relation to the development and/or improvement of students' competencise for critical thinking. Following this introduction, we proceed to describe how and why the concern with critical thinking has become so important that the concept now seems to permeate a great deal of educational discourse and debate. Next, we clarify our understanding of what a problem analysis is, characterizing it as both a process and a product. This leads us to the fourth section in which we argue how thinking of problem analysis as an argument may serve to further elucidate what it is about problem analysis that may contribute to the development and/or improvement of students' competencies for critical thinking. In section five we present our arguments about the connection between problem analysis and critical thinking, stating that the process of writing the problem analysis opens possebilities for students to develop their competencies for critical thinking, and how the product of the finished problem analysis, serves as a textual manifestation of the students' competencies. Finally, in section six we conclude the paper by offering some alternative perspectives and opportunities for further research.

2 Critical Thinking

Critical thinking is highly valued among national governments, educators, and employers alike (Abrami, Bernard, Borokhovski, Wade, Surkes, Tamim, & Zhang, 2008; Johnston, Mitchell, Myles, & Ford, 2011; Siegel, 1980). Higher education, no matter the particular discipline, is expected to contribute positively to the development of students' competencies for critical thinking. Some authors have even suggested that critical thinking should be considered the overriding aim of education in general and of higher education in particular (Kilby, 2004; Siegel, 1980; Siegel, 1990; Bailin & Siegel, 2003; Roth, 2010).

From the point of view of employers, the rationale behind this idea is that graduates with competencies in critical thinking will be better able to add value to the organizations that will eventually employ them. Because these organizations are competing in the context of a global marketplace that is constantly changing, they need employees who are able to adapt to the ever-changing demands brought on by technological innovations as well as social and political change (Behar-Horenstein & Niu, 2011). Since critical thinking is thought to be a highly transferable skill that may be employed across different knowledge domains, employees who are competent in critical thinking will be better equipped to deal with the challenges posed by a working environment characterized by continually changing conditions. Similarly, governments are keen on the idea because it is assumed that individuals, who are competent critical thinkers, are likely to become responsible citizens (Davies & Barnett, 2015; Siegel, 1980). Recently, however, concerns have been raised about students' lack of competencies for critical thinking (Sin, Jones & Wang, 2015; Gijselaers, 1996; Kek & Huijser, 2011). This raises the question of how institutions of higher education can best facilitate the development of students' competencies for critical thinking.

As a consequence of the focus on critical thinking, interest in new and innovative approaches to teaching and learning such as problem-based learning that may be able to facilitate the development and/or improvement of students' competencies for critical thinking has increased. Researchers have acknowledged that problem-based learning can have a positive effect on the development of students' competencies for critical thinking cf. e.g. Tiwari, Lai, So, and Yuen (2008), Maudsley and Strivens (2000), and Margetson (1997) just to mention a few. According to Kek and Huijser (2011), the main reason why problem-based learning facilitates the development of critical thinking is that

> […] it explicitly and actively engages students in a learning and teaching system, characterised by reiterative and reflective cycles of learning domain-specific knowledge and doing the thinking themselves. At the same time, students are guided and coached by the problem-based learning

> teacher, who models critical thinking skills in the acquisition of the domain-specific knowledge (p. 329).

Although the term 'critical thinking' is widely employed in the literature, there seems to be a notable lack of agreement among different stakeholders, not least among scholars, about how the concept of critical thinking should be understood (Thomas & Lok, 2015) and the concept is rarely explicitly defined (Thorndahl & Stentoft, in submission). As a result of this lack of consensus and definitions, institutions of higher education that are supposed to ensure that students are adequately equipped with the competencies for critical thinking are confronted with a number of problems the most important being how to effectively create educational pratices which ensure the development of these competencies.

In this light and to avoid unnecessary confusion, we find it necessary to explicitly state how we understand the concept of critical thinking not least to ensure that readers are aware of the premises on which we base our conclusions and to allow for the evaluation of our overall proposition that problem analysis fosters critical thinking.

Instead of conceiving of critical thinking as something that can be measured in absolute terms, that is, as something one is either able to do or not, we suggest that it might be more fruitful to think of critical thinking as a more fluid concept. In other words, we agree with McPeck (2017) when he asserts that "[l]earning to think critically is in large measure learning to know when to question something, and what sorts of questions to ask" (p. 7). In this paper, we use the following description of critical thinking:

> [Critical thinking skills and dispositions] are brought to bear in identifying a problem and its associated assumptions; clarifying and focusing the problem; and analysing, understanding and making use of inferences, inductive and deductive logic, as well as judging the validity and reliability of the assumptions, sources of data or information available (Pithers & Soden, 2000, p. 239).

In this description of critical thinking it is clear how it is not simply an end result but rather entails complex and multiple actions and processes which, as we shall see below, we can recognise in the problem analysis in problem-based project work.

3 The nature and function of problem analysis in problem-based project work

In accordance with Holgaard, Guerra, Kolmos, and Petersen (2017), we understand the problem analysis as "[...] the process of identification, analysis, and formulation of a problem" (p. 1070). Thus the purpose of the problem analysis is not merely to provide a formal space for opening statements and introductory remarks. Rather, the problem analysis in problem-based project work is intended to afford students opportunities for reflecting on the relevance of the identified problem and for assessing the validity of the argument that leads to the articulation of the problem statement. Thus, the problem analysis is the project's point of departure. As such, the production of a problem analysis provides students with a particularly favorable opportunity for analyzing the background of the problem that eventually is to be defined and articulated in the problem statement. Analyzing the background of the problem involves, among other things, the selection and discussion of relevant literature on the topic of the project and requires students to relate to the kinds of solutions that it might be appropriate to investigate further. For a more thorough description of the processes involved in the problem analysis phase of problem-based project work see Holgaard et al. (2017).

Based on the description of the nature and function of problem analysis presented above, it follows that the term 'problem analysis' has a double meaning: On the one hand, it can be used to refer to the concrete texts students include as introductions in their finished project reports, and in that sense, it may function as a product. On the other hand, the term can also be used about the work students do prior to presenting the finished text and in that sense, it may be characterized as a process. In a sense, this double meaning of the term is further reflected in the fact that problem analysis serves dual purposes. While the first purpose is to promote the development of the question that is to become the problem statement, the second purpose is to explicate why the problem statement which students eventually arrive at is relevant and makes sense from a scientific point of view. Even though these two purposes may appear to be so closely related that it might seem pointless to try to distinguish one from the other, we insist on the importance of discriminating between them because doing so allows us to think about the function and significance of problem analysis in a novel way.

The first thing we wish to suggest in this regard is that instead of thinking of problem analysis as a means to an end, it might prove more productive to think of problem analysis as an end in itself. Thus, as mentioned above, problem analysis in problem-based project work is meant to afford students opportunities for reflecting on the relevance of the identified problem and for assessing the validity of the argument that leads to the articulation of the problem statement, i.e. in effect for developing their competencies for critical thinking. In that sense, in and by itself, problem analysis is not merely a means for *acquiring* critical thinking. Rather, it may be said to *constitute* a kind of critical thinking as such. Hence, asking students to go through the process of problem analysis and to draw up a textual product based on this process is equivalent to asking them to think critically about the underlying assumptions and implications of their project. In the following section, we will elaborate on this point by presenting the idea that the the problem analysis can be thought of as an argument in keeping with Toulmin's understanding of this concept.

4 Problem analysis as argument

If we reduce the problem analysis to its essential components, we find that the problem analysis may be thought of as an argument that is meant to justify the relevance of the problem statement. According to Toulmin (2003), an argument in its most basic form contains three distinct but related components: (1) a claim, (2) some data, that is "[...] the facts we appeal to as a foundation for the claim" (p. 90), and (3) one or more warrants to justify the connection between the claim and the data. If we imagine that our claim that it is relevant to ask X is challenged by someone, we would be expected to respond by presenting the particular facts we appeal to as the foundations for our claim. Toulmin calls these facts data. Data may be used to answer the question: What have you got to go on? Therefore, one thing that needs to be presented in the problem analysis are the facts that support the original assertion or claim that it is relevant to ask X. Having presented data to support our claim, Toulmin contends that one may encounter another challenge in the form of another question: How do you get there? According to Toulmin (2003) to answer this question

> […] we must bring forward not further data, for about these the same query may immediately be raised again, but propositions of a rather different kind: rules, principles, inference-licences or what you will, instead of additional items of information (Toulmin, 2003, p. 91).

These functions are of course implicit in the process of producing a problem analysis. Students do not have to make the structure of their argument explicit in order to produce a good problem analysis but implicitly, these are the questions they are intended to ask themselves and the answers they provide determine whether their problem analysis makes sense/works/is any good and whether it constitutes solid or not so solid critical thinking.

In this connection, it is important to stress, in keeping with the idea that problem analysis may be understood as an argument that contains three interrelated components, that the specific contents encompassed within these components is never merely of a generic kind. Rather, it is always topic-specific cf. e.g. McPeck (2017) who states that

> […] a minimal condition for understanding a good reason in any field is that one understands the full meaning of the specialized and often technical language in which such reasons are expressed. That is, an understanding of the semantic content of a field-dependent proposition is a prerequisite for its assessment (pp. 23).

Considering the problem analysis in light of this particular perspective, it becomes clear why it is considered an important part of the kind of student-centered problem-based project work that is carried out at Aalborg University. Moreover, this idea also touches upon the next issue we will discuss, namely, what it is about problem analysis that fosters a space conducive for the development and/or improvement of students' competencies for critical thinking.

5 The significance of problem analysis for developing critical thinking

According to Hanney and Savin-Baden (2013) e.g., "[t]he initial, innovation stage of the model is a discovery or problem analysis phase which foregrounds the development of critical thinking and creative problem-solving skills as an embedded component of a project's process" (p. 13). Surprisingly, however, Hanney and Savin-Baden (and other authors as well) make no effort to elaborate on their reasons for believing that this is in fact the case, just as they do not explain in more detail *what* it is about problem analysis more specifically that promotes the development and/or improvement of students' competencies for critical thinking. The question then arises, *how* and *why* does problem analysis in problem-based project work facilitate the development and/or improvement of students' competencies for critical thinking?

Returning to the point made in section 3 about how the problem analysis may be seen as both a process and a product, we argue that in the former sense, it requires a particular kind of questioning attitude or mindset. We take our point of departure in an understanding of the concept of critical thinking similar to that suggested by Pithers and Soden (2000) who stress the importance of posing questions rather than providing answers:

> [When involved in problem-based learning] students are required to establish what the main issues are within the problems, how the problem might be resolved, how any proposed resolution might be evaluated and what knowledge they need to interrogate before they can construct a way forward (p. 247).

In keeping with this understanding of the relation between problem analysis and critical thinking, we contend that problems and their associated assumptions are identified by posing relevant questions to the field of research. Examples of these relevant questions, could be the 5W1H questions (why, what, who, where, when and how). These questions provide an overview of the problem field, where the why question addresses the relevance of the problem, the what helps us to conceptualize the problem, the who enables us to identify the different stakeholders, the where identifies the local context of the problem, the when addresses the literature on the field, and the how helps us to identify the problems to be addressed (Holgaard et al., 2017).

Returning to Toulmin's view on the argument, the 5W1H questions can help us to identify the claim, data and warrants relevant for the problem statement. This is precisely the reason why the emerging *process* of the problem analysis functions as a favorable opportunity for learning how to think critically while the *product* resulting from this process, i.e. the finished problem analysis along with the resulting problem statement, function as textual manifestations bearing witness to the extent and quality of students' competencies for critical thinking, i.e. for their abilities to pose relevant questions.

6 Concluding remarks and further research

Above we have presented a discussion of the role and significance of problem analysis as it unfolds in problem-based project work where students are required to design the problems themselves and we have argued how developing a problem analysis may offer students possibilities to also develop their competencies for critical thinking.

Stated briefly, the argument we have presented may be expressed in the following way: The problem analysis inherent to the kind of problem-based project work that takes place at Aalborg University in Denmark and elsewhere, may be described as an argument for why it is relevant to ask the question posed in the problem statement. This argument has three components: (1) facts, (2) data, and (3) warrants. Importantly, these three components are not just generic in nature, rather they are subject-specific. The question that originates as a result of problem analysis, constitutes the problem statement in the form of a particular kind of question, that is "the right sort of question", cf. McPeck (2017), based on the content of the problem analysis.

Therefore in conclusion, problem analysis may be thought of as both a process and a product serving dual interrelated purposes. In the process because it requires students to adopt a particular kind of questioning attitude or mindset, the emerging *process* of problem analysis functions as a favorable opportunity for learning how to think critically. Here students learn and practice how to ask relevant questions in order to legitimize the relevance of the problem by questioning the underlying assumptions and inferences that inform the problem. On the other hand, the *product* resulting from this process, i.e. the finished problem analysis along with the resulting problem statement, function as textual manifestations bearing witness to the extent and quality of students' competencies for critical thinking i.e. for their abilities to pose relevant questions.

To complicate things further, there will also be an internal negotiation by the group members of what the problem is. As mentioned earlier, the projects are often written in groups. Small-group work that is characteristic of problem-based learning has been shown to foster critical thinking: "Insofar as small-group work embraces psychotherapeutic principles (listening, tolerating hostility), and focuses on process not results, it develops critical thinking by challenging schemata and attitudes with change" (Maudsley & Strivens, 2000, p. 540). The ability to put into writing or otherwise explicitly articulate one's argumention by connecting the components of the argument that constitutes the problem analysis also influences students' competencies for critical thinking. Thus if students are unable to articulate their argument for why it is relevant to ask the question posed in the problem statement, in a way that makes it intelligible to others, then, in effect, there is no critical thinking. This line of thinking follows from a particular understanding of critical thinking not as something confined to the mind of the individual but rather as a social practice.

To enhance the value of the conclusions provided by this paper, a relevant next step would be to verify the conclusions empirically. This could be done by employing ethnographically inspired methods to gain an idea about what critical thinking and problem analysis look like "in situ". To the authors' knowledge, there does not exist any ethnographic research with this focus. Furthermore, it could contribute to a clarification of what the notion of critical thinking actually entails in the students' local practices.

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Towards a Taxonomy of Tacit Knowing in Context of Project-Oriented Problem-Based Learning in the Engineering Sciences

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Abstract

Michael Polanyi is often quoted as the origin of the term *tacit knowledge*, but in his main work on the topic, *The Tacit Dimension* (1966), he mostly discusses the concept of "tacit knowing". The latter formulation points towards a certain type of directedness towards knowledge, rather than the piece of information which is known. This is important, because, as will be argued in this paper, examples can be identified, where there is more than one way to tacitly know a piece of so-called tacit knowledge. The paper argues initially for the relevance of a taxonomy with respect to tacit knowing in context of the problem-based learning processes involved in student projects in the engineering sciences. Different types of tacit knowing are then distinguished with a view to discussing how the conditions for externalization of tacit knowledge depend on the type of tacit knowing involved. Special attention is given to whether tacit knowing is fully internalized (i.e. automatic) or conscious, whether it only becomes conscious gradually, e.g. in the face of possibilities for action (the tacit knowing involved in "situated normativity"), or if it takes the form of immediate pattern recognition, and whether what is tacitly known is known by an invidual or by a group, collectively.

Even though Polanyi's original discussion covered a much broader range of knowledge types, the paper restricts its use of the term tacit knowledge to cover a type of practical knowledge or know-how, which arises in a non-verbalized manner in the practitioner. This reflects the most common use of the term in the fields of engineering.

Keywords: tacit knowledge classification, tacit knowledge acquisition, tacit knowledge sharing, PBL, engineering education

Type of contribution: conceptual paper.

1 Introduction

All educations at Aalborg University (AAU), where the author of this paper is employed, utilize a project-oriented problem-based learning format. The format has the students working on semester projects, typically in a student group, in parallel with the course modules of the education, within a certain theme fixed by their study plan. Among other things, the semester projects are expected to showcase the skills of the students in evaluating their own work process as such. Whereas the students are given vocabulary for articulating their developments in relation to formulated learning goals (either in their study plan or in a project-specific learning contract for the group), they are presently not given many distinctions that may help them describe their developments with respect to the more 'freely' emerging practical experience they gain e.g. while working on physical or digital models, measurements or other more 'hands-on' work. This is, naturally, not that big a problem for educations that remain in the realm of theoretical analysis, but especially for engineering educations, finding ways to discuss one's learning through pratical experience is, as will be argued shortly, highly relevant for various reasons. Practical experience is, however, not always easy to externalize (to use the vocabulary of Nonaka & Takeuchi 1995, 64-67), i.e. express in words or other means of communication. The focus on this challenge has lead researchers in the field of knowledge management to speak, broadly, of not yet externalized information or skill as *tacit knowledge*, even though there are considerable differences with respect to what the individual researcher counts as truly tacit knowledge (more on this in section 3). This paper considers the feasibility of introducing a taxonomy with respect to different ways of knowing something within the spectrum of so-called tacit knowledge, and its possible utility in a PBL-based engineering education.

2 The Relevance of Discussing Tacit Knowing in Context of a PBL-Based Engineering Education

There are at least two reasons why it is relevant to point engineering students in a PBL-based setting towards reflection on what they have gained from practical experience. One has to do with the engineering student's typical affinity for solution-oriented work, the other has to do with what is expected of the graduated engineer in professional life. We shall look at the two reasons one at a time.

2.1 Problem-Based Processes Are Often Solution-Oriented

Even though student projects are supposed to be problem-driven, in reality, they often become product- or, more broadly, solution-oriented. The PBL process is supposed to start from an initiating problem, which the students explore in a problem analysis, leading to suggestions for routes a solution to the problem could take, but the project then typically proceeds to actual work on a solution or aspect thereof, e.g. work on physical or digital models, an actual prototype, testing in a lab or other kinds of measurements etc. It is very easy for the solution-oriented student to quickly get caught up in the latter kind of work that is more 'hands-on'. Knowing well that they are assessed on their abilities to work on well-defined problems, students who have skipped directly to the practical dimension of their project tend to spend time later in the process justifying their practical choices, so as to make it look like the choices are the result of a preceding problem analysis. (The author here speaks from experience with supervision or co-supervision of so far 69 student groups spanning four different fields of engineering and a design-oriented education within media technology.) Apart from being detrimental to the student's ability to actually analyze a problem without the bias of personal preferences for the solution, this way of handling the experience gained in practical work also steers the student away from understanding the nature of that experience: There might be important insights to be gained from reflecting on how a practical solution has been shaped by e.g. personal intuitions (what 'feels right' – which of course prompts the question, "why does that feel right?"), preconceptions (e.g. of what have we seen other people do before), the physical work environment, or, perhaps more importantly, the social work environment (do some students e.g. steer away from an aspect of the work due to unaddressed issues with the rest of the group?) In turn, articulating these insights, may provide additional angles to incorporate in a revised problem analysis, and thus also be of help to the 'traditional' PBL process. As will be discussed further in section 6, engineering students (at least at AAU), currently lack a theoretical framework for thinking about their own informal learning. Providing them with one may guide them towards discovering, and possibly externalizing the knowledge or skill they have gained via practical experience.

2.2 Preparing Engineering Students for Professional Knowledge Management

Recent decades have seen an increased emphasis on organizations as driven by the knowledge they produce and maintain (exemplified e.g. by Nonaka & Takeuchi 1995) and therefore an increased focus on knowledge management. In this connection, the question of how to accurately handle (so-called) tacit knowledge has gotten renewed attention (consider e.g. the review of no less than 146 references on the topic by Hao et al. 2017). This tendency is also apparent in accounts of knowledge management in the field of engineering: Examples can be found in systems engineering (Stapleton et al. 2005), software requirements engineering (Mohamed 2010), civil and mechanical engineering (Penciuc et al. 2013), and the field of construction (Zhang and He 2016) to name a few. The question of how tacit knowledge can be shared among professionals, documented and developed, is relevant for almost any profession or organization dependent on preserving its own know-how in the future. This includes, perhaps especially, highly teamwork-dependent fields, where a lot of knowledge and skill is not externalized on a daily basis, due to time constraints. If we assume that an education should somewhat reflect the professional reality that graduates enter, an engineering education should help student develop skills in handling not just already formalized knowledge, but also knowledge informally acquired through experience, such as what is typically labeled tacit knowledge.

3 Tacit Knowing vs. Tacit Knowledge

Within the field of knowledge management, opinions differ as to if and how tacit knowledge is capable of being externalized. The differences seem to simply reflect differences in application of the term "tacit knowledge": Some consider tacit knowledge strictly tacit, with the consequence that sharing such knowledge is also a tacit process, where people simply show each other e.g. how a procedure is carried out (see e.g. Stapleton et al. 2005). Others consider tacit knowledge partially capable of being captured in words, characterizing tacit knowledge sharing as a mixture of verbal and non-verbal communication – this goes for Nonaka & Takeuchi's much cited account (1995) as well as specific approaches in terms of "communities of practice" (see e.g. Khuzaimah & Hassan 2012). Others still rely on tacit knowledge being something fully externalizable (to use the vocabulary of Nonaka & Takeuchi 1995, 64-67), while discussing formal settings for tacit knowledge sharing, such as web forums (Penciuc et al. 2013, Mohamed 2010) or social media platforms (Amidi et al. 2015). What all of the references above, their differences aside, agree on, is the subject matter of the knowledge labeled "tacit": know-how acquired through practical experience, and which is at least not *initially* externalized. One might, however, also say that in all instances where the term "tacit knowledge" is employed, there is an element of *tacit knowing* at some stage, whether the involved "knowledge" is eventually externalized or not. Curiously, Michael Polanyi, who is often quoted as the origin of the term, rarely uses the exact phrasing "tacit knowledge" in his main work on the topic, *The Tacit Dimension* (1966). Instead, for the first third of the book, he speaks, exactly, of "tacit knowing", thus pointing towards a certain type of directedness towards knowledge, rather than the subject matter of the knowledge itself. (In fact, his discussion covers a much broader spectrum of knowledge types than merely practical know-how, e.g the mechanisms involved in facial recognition (Polanyi 2009, 5) and the bodily 'know-how' of conditioned reflexes (Polanyi 2009, 8-9).) Picking up and extending on Polanyi's terminology, this paper will discuss what to include in a possible taxonomy of ways of tacitly knowing something. This is important, because, as will be argued, examples can be identified where there is more than one way to tacitly know a piece of information, and the conditions for sharing and externalizing a piece of – at the outset – tacitly known information (broadly construed) may depend on how the information is tacitly known.

4 Factors Affecting Tacit Knowing

When trying to distinguish different types of tacit knowing, as well as the conditions for sharing or externalizing the involved knowledge, there is a number of questions it is relevant to ask:

1. Is the knowledge/skill internalized?
2. How has the involved piece of knowledge or skill been learned?
3. Is the knowledge/skill only activated in specific kinds of situations?
4. Is the knowledge/skill individual or collective (i.e. in a group)?
5. How does the knower access the knowledge/skill?

Ad (1): If a skill or piece of information is internalized, it becomes something that a person does or applies automatically, without lending much thought to it. Exactly what happens in the brain or nervous system, when especially an acquired physical skill becomes part of our motor system, is outside the scope of this article (see Epstein (2016) for a discussion of two views of what happens to the brain in general during a learning process). What matters here is that once internalized, knowledge can be very difficult to externalize again. First you have to become conscious of the knowledge (again), and secondly you have to figure out a way to express it, none of which is easy, if you have not thought or talked about the knowledge for a long time.

Ad (2): An internalized skill or piece of information can, however, be more or less difficult to externalize, depending on how it was learned in the first place. Skills that we are born with or which emerge in early infancy, can be practically impossible to explain to others, because a person rarely remembers the process of learning those skills. Externalization is, presumably, easier if the person does remember the learning process, but can still be quite difficult if the knowledge has been acquired by mimicking what others do, or internalized from one's own, practical experiences. When a person, however, gets verbal or written instructions on how to do something, e.g. drive a car or swim, and subsequently internalizes these instructions, we have an instance of internalized knowing, but where the knowing stems from explicitly shared knowledge. Because of its origin in explicit knowledge, this type of internalized knowing is easier to re-externalize, because a vocabulary for describing the actions should be there in the first place.

Ad (3): Not all kinds of tacit knowing are cases of internalized knowing. In many cases, working on something can be a completely conscious process, but without being articulated by an 'inner voice' in the person's mind. Philosopher Erik Rietveld (2008) labels this type of action as "unreflective", by which he refers to the absence of reflection in the traditional, verbalized, written, or otherwise language-bound form. Among Rietveld's own examples are the soccer player who sees an opening and reacts to it by running in a specific direction (Rietveld (2008, 131) extending on an example from Merleau-Ponty (1942/1983, 168-169)), and the craftsman, e.g. a carpenter, making adjustments to a construction he is working on with his hands. (Rietveld (2008, 20-21 and 38), extending on an example from Wittgenstein (1978, 7-13)). The author of this paper has previously constructed a related example in context of a symphony orchestra performance (Frimodt-Møller 2010, 63): In a situation where the different instrument groups are not completely synchronized with respect to tempo and articulation, a violinist in the front row of her group might recognize the possibilities of trying to follow, respectively, the rhythm or articulation of the other violin group, the cellos, the woodwinds, the perhaps slightly exaggerated marked beats of the conductor, the total auditive output of the orchestra etc. In all of the mentioned examples, we might say that the actors involved are, to borrow Rietveld's (2008, 20-21) terminology, "moved to improve" on a situation by the *affordances*, i.e. the apparent possibilities for actions in a specific situation. Rietveld (2008, 40) speaks of "situated normativity" as referring to "the normative aspect of unreflective action in context; of embodied cognition in skillful action". Unpacking this formulation a bit, one could say that knowing what to do when faced with specific affordances entails knowing specific norms for how to respond to these affordances, a knowing that can be tacit. I.e. one might have a kind of visual, auditory or kinesthetic 'blueprint' for how to do something successfully that one compares with the situation at hand. With respect to externalization and knowledge sharing, the advantage of the type of tacit knowing inherent in situated normativity over internalized tacit knowing is exactly that it is already a conscious process – the route to externalization is simply shorter than one where the subject first has to reflect on what has been internalized. The process of finding a sensible vocabulary, or rather, language for articulating one's thoughts during the action itself to others afterwards, is, however, not always simple. Sportsmen and musicians quite often have such languages (which enable them to discuss what could be done better in a different game or performance). With respect to craftsmen or engineers, however, it seems that the existence of such a language varies with the need to discuss a piece of work that has been done.

Ad (4): All of the previous examples have been formulated from the perspective of an individual. It is, however, also possible to envision the *collective* knowledge of a group as presenting instances of tacit knowing. Holgaard et al. (2004) distinguish between two variants of collective "tacit knowledge", namely "culturally embedded" and "formally embedded" knowledge (ibid., this author's translation). The former is so deeply embedded and taken for granted that the members of the group are not really conscious thereof, and thus not engaged in externalizing the knowledge. The latter is represented by the type of knowledge that the group does not lend much thought to in their daily practice, but have a language for when communicating with outsiders. Following the distinctions presented in relation to (1) and (3) above, culturally embedded knowledge could either fall in the category of internalized tacit knowing or in the category of tacit knowing of norms, for which the group does not yet have a language, whereas formally embedded knowledge falls in the category of tacit knowing of norms inherent in situated normativity, for which there is an existing language for externalization. In any case, it may be speculated that the possibility of establishing such a language is higher in a group of people, because members of a group have the option of discussing an issue verbally with each other, whereas an isolated individual does not.

Ad (5): There may be still different kinds of knowing within the greater category of tacit knowing involved in the case of "situated normativity". As an example, in a previous study (Frimodt-Møller et al 2015), the author observed how a specific model designer at LEGO® Group had gained a level of knowledge and skill with respect to building physical LEGO® models, which enabled him to design new models digitally only, without having to make the physical counterpart. The model builder stated that with his many years of experience, he was able to see whether a construction would be solid enough, without having to hold a physical model in his hands. Interestingly, *every* other interview subject in the study (and studies that preceded it within the same overarching research project) who was working as a designer for LEGO® Group, expressed the need to have a physical model to work on, in order to understand what worked and what did not. The experienced model builder was able to *see* and quickly identify the properties of a possible construction, whereas other designers had to *touch and feel* the objects in order to understand the same information. (In the study, the authors used the term tacit knowledge to describe the know-how of the more experienced model builder only. If, however, one applies the terminology of the present paper, all of the designers in the study were in fact engaged in some kind of tacit knowing.) Both types of designers were, undoubtedly, engaged in very conscious design processes, being aware of what they were doing, yet they differ in terms of the way they access their (more or less) tacit ideals, values, schemata etc. with respect to which designs work and which do not. The relationship between what could possibly be identified as *pattern recognition*, referring to the tacit knowing of the experienced model builder, and the more body-dependent knowing of the typical designer, and which is preferable over the other, is a delicate issue, which will be treated in greater detail in the next subsection.

4.1 Differences in Modality for – and Swiftness of – Information Access

It is an open question whether the example of the experienced model builder at LEGO® Group is truly an instance of pattern recognition, but there are plenty of other examples in the literature to draw on: Leonard & Sensiper (2011) give the example of how nurses learn to recognize patterns and little signs in patient behavior, which results in them having a quite solid intuition of what is wrong with a patient, but without being able to justify their knowledge in the same way a trained physician is. Engel (2009) similarly addresses the importance of visual recognition of patterns of symptoms within medical disciplines such as radiology, pathology and dermatology, and furthermore discusses how this tacit know-how is built via experience. To extend on Engel's point, it makes sense that the ability to recognize patterns depends on prior exposure to patterns or a large number of occurrences of various events, which allows the practitioner to identify emergent patterns.

The tacit, but conscious knowing of the fact that a pattern is present (e.g. on a series of x-ray images) or that something fits into a pattern (e.g. when one instantly recognizes that the reason for a construction being fragile in one place lies in a problem elsewhere in the construction) is built via tacit learning, and therefore very difficult to externalize directly, due to the challenges cited in connection with (2) in the main section above.

Strictly speaking, conscious pattern recognition may be viewed as a large-scale instance of being "moved to improve" something, i.e. the person recognizing the pattern is moved to improve several things at the same time, and, conversely, recognizing a few concrete possibilities for action in a particular situation may be viewed as a minimal form of pattern recognition. In other words, the thought processes of both types of designers in the LEGO® Group example could be described in terms "situated normativity". Regardless of the fluid boundaries between the two types in terms of (tacit) awareness of norms, the two represent different ends of a spectrum, which differ radically in the way they engage with a piece of knowledge: A type of knowing in which awareness of pieces of information gradually emerges in a step-by-step manner when someone is working on e.g. a physical model, and a type of knowing, where the same pieces of information are immediately accessed as part of a bigger pattern. Another difference is, obviously, the modality for information access, which is in one case the body – more specifically, the hands, and in the other case the visual domain.

All types of practical know-how tacit can be imagined as instances of tacit knowing within a bodily or spatial modality – e.g. knowing how to make a certain type of setup run smoothly can be something that a person mainly accesses via his or her hands. Conversely, all types of tacit knowing, internalized as well as conscious, have examples in the visual domain. Even in the case of internalized tacit knowing, one may instantly know how to do something, triggered by the stimulus of what something looks like. As for pattern recognition, one might imagine other patterns than visual ones, e.g. the sounding patterns, which a skilled composer is able to instantly recognize and categorize in terms of tonality, meters, voices etc. Whether it makes sense to conceive of kinesthetic pattern recognition beyond the smaller-scale recognition of a 'blueprint' for an optimal movement in a specific situation, is an open question.

Logically, the modality via which tacit knowing takes place should not influence the ability to externalize or otherwise share the involved knowledge. This ability seems to depend mainly on how the tacit knowing has emerged (i.e. if there has been a tie to externalized knowledge in the first place), how conscious a person is of the tacit knowing involved, and whether the person has a language for externalizing the involved knowledge. The degree of swiftness with respect to how knowledge is accessed makes a much more important difference for the externalization process. Theoretically, it is easier to construct an explanation of why something holds, if the knowledge involved has been accessed in a step-by-step manner, because this process of knowing could be translated to a step-by-step description. Having recognized a greater pattern in one go, the knower may have difficulties taking it apart in a description. Thus, on one hand, pattern recognition is perhaps the most impressive and refined level of tacit knowing, one can attain, but at the same time, externalizing the involved knowledge can, theoretically, be extremely difficult compared to other, less refined types of conscious tacit knowing.

5 The Basic Problem of Externalization

Of course, the process of representing previously tacit knowledge in verbal or written language is, in any case, not merely one of finding accurate 'names' or 'tags' for the experiences the knower is aware of. Rather, the knower is attempting to build a new structure in written or verbal language that may convey some of the same insights as what was tacitly known. Any language structure, however, emphasizes certain elements of what is talked/written about and hides or downplays other. E.g. translators regularly run into challenges where a term or type of structure in one language simply does not have a counterpart in another language, and where the underlying concept therefore has to be characterized in a completely different way, if at all possible. (Whether there is an objective reality, which the different languages can refer to, is a classic philosophical debate outside the scope of this paper.) The 'focus' of any existing language means that important parts of what is tacitly known may be left out, when an attempt is made of formalization of this knowledge, especially if the practitioners involved stick to the vocabulary and theoretical framework they are already familiar with. The very reason, however, why philosophers are able to have a debate on whether formal or daily language can accurately capture human experience or not, is exactly the human ability to point out phenomena for which there are no existing terms or ways of talking about. In other words, it is, at least theoretically, possible that a practitioner might be able to extend on or build a language that can assist him or her in characterizing his or her experiences, and which emphasizes the parts of these experiences that were relevant for the practitioner before the process of verbalization began.

Does the risk of important insights getting 'lost in translation' entail that we should ideally refrain from providing students or practitioners in general with a framework, such as a taxonomy, within which they can discuss and categorize their own processes of tacit knowing? Even if this is the case, as educators working within a certain time frame, it is also our job to steer students in a different direction, if we observe that they are spending too much time on something we deem irrelevant to their learning process in a given context. Thus, if students are relying too much on traditional theories of learning when characterizing their own processes of tacit knowing, it may still be relevant to at least show them an example of a different framework for discussing these processes.

6 Towards a Taxonomy of Tacit Knowing

The traditional theories of learning that engineering students at AAU are provided with during their education are, typically, Kolb's (1984) learning cycle and Bloom's taxonomy (see e.g. Armstrong 2018). Both models have some space for discussing tacit knowing, but at a low level of explanatory detail. In Kolb's cycle (and Cowan's (1998) related spiral diagram), all types of tacit knowing seem to be delegated to the learning stage "experience", with the rest of the cycle concerned with how to reflect on this stage and eventually form hypotheses for further testing resulting in new experiences. Bloom's taxonomy, at the outset, considers learning as a generalizable process of taking up information, and thus does not distinguish between different types of knowledge as such, but only different ways of learning one kind of knowledge. Further, the examples employed to explain the taxonomy typically focus on explicit learning, such as reading a text and engaging with it in more and more refined ways. If we try to use the taxonomy to describe a tacit learning process, we cannot do so without substantial changes to the descriptions of the levels: For instance, the level *Applying* needs to be reimagined to account for special kinds of applying, as most tacit knowing is already tied to some kind of practical application. *Analyzing* and *Evaluating* have to be broadened to encompass the tacit "moving to improve" of the carpenter (see the discussion in section 4), rather than just formal analysis and evaluation. With all the tweaking needed, it may thus be more fruitful to build a new taxonomy for tacit knowing from the bottom.

The different attributes that instances of tacit knowing can have, as discussed in section 4, could be combined in different constellations to define different types of tacit knowing. Whether or not a list of such types should be ranked, and in that case, according to which criteria, is an open question. Generally speaking, tacit knowing can get a lot of tasks done faster (by removing the need for formal reflection in order to get the job done), and can, especially in the case of pattern recognition, steer e.g. a project team towards a solution faster. In context of an engineering education, however, evaluation of student skills is still very much tied to the explicit knowledge displayed by the students. When constructing a taxonomy of tacit knowing for student use, it might therefore be desirable to rank externalizability over the amount of information tacitly known. If we accept the hypothesis that collective forms of tacit knowing have more favorable conditions for externalization than individual ones (as suggested in section 4), the following ranking of types of tacit knowing might be considered (1 being the highest ranking):

1. Internalized knowing from explicitly shared knowledge – collective version
2. Internalized knowing from explicitly shared knowledge – individual version
3. Tacit knowing involved in pattern recognition – n/a for the collective
4. Tacit knowing inherent in situated normativity – collective version
5. Tacit knowing inherent in situated normativity – individual version
6. Internalized knowing from tacitly shared knowledge – collective version
7. Internalized knowing from tacitly shared knowledge – individual version

The ranked list deliberately leaves out differences with respect to the modality of information access involved in tacit knowing, as this is assumed not to have influence on externalizability (as discussed in section 4.1) Also, the ranking assumes that all types of tacit knowing, except the one involved in pattern recognition, can be envisioned for both the group and and the individual. The group may have internalized routines for carrying out various tasks, and these routines may emerge tacitly or from explicit agreements. With respect to tacit knowing inherent in situated normativity, the group can indeed have highly developed abilities in collective, tacit decision making or problem solving (think e.g. of the team of craftsmen working on a standard construction), activated gradually while facing the different aspects of the problem at hand.

7 Conclusion

In this paper, we have considered the relevance of a taxonomy of tacit knowing, and what it might look like. It is certainly possible to construct a taxonomy with respect to different types of tacit knowing, and it is theoretically possible that such a taxonomy could help students become aware, through discussion, of their own initially tacit knowledge acquired through individual work, as well as in the (group) project-oriented problem-based learning process. Whether the discussion of possible attributes of tacit knowing in section 4 is exhaustive, and whether the ranking of types of tacit knowing suggested in section 6 provides a useful taxonomy, are, however, topics for further research.

Given the emphasis within PBL-based engineering educations on learning good teamwork skills, it is tempting to jump to the conclusion that collective tacit knowing is more desirable than individual tacit knowing. On the other hand, because of the possible emergence of "culturally embedded" knowledge, a project group may become so 'aligned' in their way of thinking, that they do not get to practice the verbalization of their own work within the group (via the need to further each other's understanding of an issue). It is also important to remember that there is a synergy between individual knowledge and collective knowledge: In the case of e.g. pattern recognition, individual tacit knowing can provide an invaluable resource for the group that an individual with this skill is part of.

Empirical studies are needed to elucidate how tacit knowing emerges in a student project group, which types of tacit knowing are the more frequent in this context and why, and whether the hypotheses with respect to externalizability are correct. It is also a question for further research whether an increased focus on tacit knowing could lead students to awareness and characterization of the intuitions underlying choices made at the 'hands-on' level of a solution process.

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Application of revised Bloom's taxonomy and Kaizen lean manufacturing principles in distance problem based engineering teaching

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Abstract

Applying the "Problem Based, Project Organized Learning (PBL)" in South African tertiary engineering education is extremely challenging, and more so for distance education where the use of communication technology is essential. The authors conducted three studies on a significant sample of University of Technology students, according to which 51% of the students leave high school computer illiterate. This trend is worrying as computer literacy is absolutely essential for distance education. The poor high school teaching results in an extremely low through-put rate, of about 8 – 9 % at tertiary education level. To fix the problem as from 2020 the University of South Africa (UNISA) will introduce a new set of engineering qualifications which will be assessed using the Outcome Based Education (OBE) principles. To this end the best suitable learning progression is based on Anderson and Krathwohl modified Bloom's taxonomy (Anderson and Krathwohl, 2001), whereby the skills in the ***Cognitive*** *(knowing / head)*, and the ***Psychomotor*** *(doing / hands)* domains are commonly used in engineering education (Dave, RH, 1975). The different layers in Anderson and Krathwohl classification, show a serial structure where the knowledge is presented in a progressive manner from simple to complex, as prescribed by the South African National Qualifications Framework (NQF). Based on over 30 years of engineering teaching experience, the authors believe that for a "best practice" engineering distance education there are two basic principles: quality learning material developed for OBE assessment considering revised Bloom's taxonomy, where critical thinking on a particular topic is essential and simplification of the knowledge transfer methodology adapting the very successful Kaizen principles in lean manufacturing to engineering education.

Keywords: Distance education, Revised Bloom's Taxonomy, Kaizen principles

Type of contribution: Best practice paper.

1 Introduction

The challenges to ensure fair access across the whole spectrum of the society to engineering education are multi-faced, and not unique to South Africa. Because the laboratory work and the industry connection is absolutely essential for engineering education, the students pursuing an engineering career need extra resources and time as compared to any other professional fields.
South Africa is one of the signatory of the three international accords pertaining to tertiary engineering education, namely: Dublin, Sydney and Washington accords respectively. The South African engineering qualifications are under international scrutiny so implementing a quality engineering education through distance education is most challenging. As the main distance education institution the University of South Africa (UNISA) can be classified as a "mega university" with 350,551 students in 2017, out of which about 10,000 are engineering students. The first major problem of the current engineering qualifications is the industry placement of the students for work integrated learning (WIL), and the second one is the throughput rate which is extremely low (about 8 – 9 %) as the UNISA students are working and learning in the same time. Currently the WIL placement of the students is totally dependent of the "good will" of industry and as far as the throughput rate goes it is obvious to us that the classic examination based assessment is not working. In South Africa the student's rate of success in tertiary education is directly linked to the quality of high school education. Unfortunately the past political regime neglected many schools attended mainly by black learners. Studies carried out by the authors one in 2005 (Ionescu, 2005) ten years down the line in 2014 (Ionescu, 2014) and the last one in2018 (Ionescu & Mateescu, 2018) showed a worrying trend. The comparison of the three studies revealed that the computer literacy modules offered in high school decreased from 54 % in 2005 to 41 % in 2014 and increased to 52 % in 2018, averaging 49 %. On average 51 % of high school graduates are computer illiterate, consequently the equitable access to engineering education and information is a huge challenge. There is need for a different assessment approach and curriculum content, therefore as from 2020 UNISA will introduce a new set of engineering qualifications and a new approach to students assessment and teaching. In the following chapters the authors will present the current problems and the UNISA new approach to engineering education to overcome / reduce the existing challenges.

2 The development of Distance education (Long – distance learning)

Distance education has a long history, but its popularity and use has grown exponentially as more advanced technology has become available. Between 2000 and 2008, enrolment in distance education courses increased rapidly in almost every country around the globe. Unfortunately, the fraudulent on-line qualifications have also increased posing a real treat to the future of unsuspecting students.

2.1 The development of Distance education (Long – distance learning) in South Africa

The University was established in Cape Town in 1873 as the University of the Cape of Good Hope and changed its name to the University of South Africa in 1916 and moved to Pretoria in 1918. In January 2004, UNISA merged with Technikon Southern Africa (formerly known as Technikon SA) and incorporated the distance education component of Vista University. The combined institution retained the name University of South Africa and became a comprehensive university, offering both vocational and academic programmes. The University of South Africa (UNISA) is the largest university on the African continent and attracts a third of all higher education students in South Africa. The university has over 300,000 student from 130 countries worldwide, making it one of the world's mega universities. Distance education technologies are divided into two modes of delivery: synchronous learning and asynchronous learning:

- In synchronous learning, all participants are "present" at the same time and it requires a timetable to be organized.
- In asynchronous learning, participants access course materials flexibly on their own schedules. Students are not required to be together at the same time.
- The two methods namely distance and campus based education can be combined. This type of teaching has recently come to be called "blended learning" or less often "hybrid learning".

UNISA is a distance learning university but due to laboratory work, project work and summative assessment, all engineering modules are delivered in a blended mode.

3 Assessment methods

3.1 Current methods of assessment within the College of Science, Engineering and Technology

In the present configuration the students are assessed through a minimum two formative assessments loaded on line in the asynchronous mode and a final summative assessment written under examination conditions in the synchronous mode i.e. all the students write the exam in the same day at the same hour in different examination centres, all across South Africa.

The UNISA formative assessments are completed by students without direct supervision as compared with residential universities where tests are written under supervision. For this reason, the weighting of the formative assessments toward the final mark is only about 20 %. The formative assessments consist of two assignments covering the whole syllabus, to prepare the student for the exam but due to low percentage contribution toward the final mark the students tend not to take the assignments seriously. Also due to legal issues, the students cannot be prevented from writing the exam by imposing a minimum mark for the assignments. The massive 80 % contribution of the summative assessment toward the final mark proved to be a bad idea as the students may enter the exam totally unprepared. The current combination of the synchronous and asynchronous assessments proved totally inefficient, resulting in an
8 – 9 % throughput rate.

4 Challenges faced by the future engineering students

4.1 High School challenges

In any research activity, before changing the status-quo the first step is a proper understanding of the existing processes. The authors conducted three studies on a significant sample of University of Technology students, the first one in 2005 over a sample of 390 students (Ionescu, 2005) then ten years down the line in 2014 over a sample of 120 students (Ionescu, 2014) and in 2018 over a sample of 118 students (Mateescu & Ionescu, 2018). Table 1 shows the changes over the last 13th years in high school offerings.

Table 1: Engineering and computer literacy modules offered in South African high schools.

Statistic results from the **2005 survey** (Ionescu, 2005)					
Engineering subjects offered at school			Aces to computer literacy at school		
yes	no	N.A	yes	no	N.A

14%	82%	4%	**54%**	42%	4%
Statistic results from the **2014 survey** (Ionescu, 2014)					
Engineering subjects offered at school			Aces to computer literacy at school		
yes	no	N.A	yes	no	N.A
26%	70%	4%	**41%**	56%	3%
Statistic results from the **2018 survey** (Ionescu & Mateescu, 2018)					
Engineering subjects offered at school			Aces to computer literacy at school		
yes	no	N.A	yes	no	N.A
29%	19%	52%	**52%**	46%	2%

The comparison of the studies revealed that the computer literacy after high school is about 49 %. This trend is extremely worrying as roughly 51 % of the potential students start engineering studies being computer illiterate. The rapid access to information by electronic means and the shear amount of information available may result in the student being side-tracked and a dilution of the absolute necessary information. This “over informing” combined with “computer strugglers” results in poor assessment performance. Also a major handicap proved to be the lack of engineering modules such as technical drawing, mechanics, strength of materials, manufacturing etc. offered at high school level. This total lack of early engineering education is heavily impacting on the student understanding of what engineering is all about. Many engineering students are coming from underprivileged communities with no exposure to any engineering activity, therefore proving theoretical concepts through laboratory experiments are vital. Unfortunately even in the few schools where science laboratories are present, the students are not allowed to do the experiment but just watch the lecturer performing it as shown in table 2 (Mateescu & Ionescu, 2018).

Table 2: Science laboratory experiments at high school level

Do you have a science laboratory at your high school?								
Do you know how to use the laboratory equipment?			Is only the teacher demonstrating the laboratory experiments?			Were you provided with a science kit at the beginning of the term?		
yes	no	N.A	**yes**	no	N.A	yes	no	N.A
65%	30%	5%	**64%**	32%	4%	40%	58%	2%
How do you feel about the teaching at your high school								
Do you have the feeling that you are unable to keep up the pace and you feel left behind			Do you study every day?			Do you have subjects that you just do not understand?		
yes	no	N.A	yes	no	N.A	yes	no	N.A
82%	8%	10%	14%	54%	32%	47%	51%	2%

Because in 64% of the cases only the teacher is allowed to perform the science experiments, the laboratory role is diluted. Becomes something unattainable with students losing interest and not paying attention. Also the defective high school teaching is nowhere more evident than in the 82 % of the students being incapable of keeping up with the pace of teaching. Table 3 shows just how important the laboratory experiments are in high school (Mateescu & Ionescu, 2018).

Table 3: The importance of science laboratory experiments at high school level

The relevance of laboratory experiments in engineering modules								
The laboratory experiment is relevant for all fluid mechanics modules			The laboratory experiment is relevant for all mechanics of machines modules			The laboratory experiment is relevant for all strength of materials modules		
Yes	no	N.A	**yes**	no	N.A	**yes**	no	N.A
86%	2%	12%	**81%**	7%	12%	**86%**	2%	12%
The laboratory experiment is relevant for all thermodynamic modules			The laboratory experiment is relevant for all mechanical engineering manufacturing modules			**The integration of the laboratory experiments into module enhanced the students understanding of the module and their academic performance**		
yes	no	N.A	**yes**	no	N.A	**yes**	**no**	**N.A**
87%	1%	12%	**79%**	9%	12%	**79%**	**9%**	**12%**

4.2 Tertiary education challenges

The current engineering theoretical modules offered by UNISA meet the Engineering Council of South Africa (ECSA) requirements. However, the problem lies with the practical side of the work namely the laboratory experiments. ECSA as a regulatory body of tertiary engineering teaching, requires as compulsory a minimum of three relevant laboratory experiments to be performed by each student for each engineering module, in groups no larger than 5 students (ideal would be one student – one experiment). Before 2015 UNISA did not have any laboratories for the School of Engineering, however the students did their laboratory component of the engineering modules with residential universities, through memorandums of understanding (MoU), depending where in South Africa they were based. Few UNISA students did their laboratory work in the work place once the UNISA lecturer in charge visited and approved the process. This system was not ideal as UNISA did not have a direct control over how the experiments were conducted. The international students did their laboratory work in their own country through MoU's between UNISA and local universities or industry.

5 Proposed solutions for improving the engineering teaching

Within the classification of different levels of learning three main domains namely: Cognitive (knowing / head), Affective (feeling / heart) and Psychomotor (doing / hands) were identified. The modification of the cognitive domain (Anderson &Krathwohl, 2001) as well as Problem-based Learning (PBL) (Savin-Baden, 2000 and 2004), Enquiry-based Learning (EBL) and Action Learning (AL) are examples of good and successful teaching practices. A set of new engineering programmes will be introduced at UNISA as from 2020. The new engineering programmes were designed considering the international compatibility and the generic documents designed by ECSA, ensuring horizontal movement and vertical progression. All new programmes will be assessed on Outcome Based Education (OBE) principles, as the focus of outcomes is to integrate student performance with those needed in the workplace.

Also as PBL involves finding out additional information to solve the problem in real life engineering, the learner has to work out what knowledge is needed to solve the problem and how to apply the findings to the issue. This cognitive theory is the basis of the educational approach known as **constructivism** (Revans, 1980); (McGill and Beaty, 1995);(Atherton, 2013) which emphasises the role of the learner in constructing his own view or model of the material, and what helps with that. Basically, the main cognitive educational approaches and constructivism principles were integrated in the new OBE teaching and assessment methods.

5.1 The application of lean manufacturing (Kaizen) principles in engineering teaching

Kaizen (Continuous Improvement) is a strategy where human beings work together proactively to achieve regular, incremental improvements to a specific activity. Introducing the Kaizen principles in engineering teaching is not that farfetched as the "final product" of engineering education are the very engineers who will apply Kaizen principles in their work place. Kaizen has a dual nature of action plan and work philosophy.

- As an **action plan**, Kaizen is focused on improving specific areas of a particular activity with the emphasis on involving everybody within the particular organisation. The consistent application of Kaizen as an action plan develops Kaizen as a philosophy.
- As a **philosophy**, Kaizen changes the employee's way of thinking about their work and creates long-term value by developing the culture for true continuous improvement.

The Kaizen strategy of continuous improvement can be adequately applied to the process of technical education.

- The **action plan** of any tertiary education institution is the continuous improvement of study material and teaching methodology in order to improve the student throughput, thus eliminating the "waste" – students who repeat subjects.
- The Kaizen **philosophy** develops a culture of true quality education where there is a symbiotic relation student – lecturer – university management, concurring toward the final goal of quality engineering graduates.

5.1.1 Comparison between Kaizen cycle related to lean production and lean education

The basic idea of lean production is to eliminate any type of waste from the production process. This type of cycle is frequently referred to as **Plan, Do, Check**, and **Act** (PDCA). PDCA brings a scientific approach to making improvements, long time overdue, in engineering teaching.
In the production environment there are "Seven Deadly Wastes" that must be eliminated to achieve lean production / teaching as listed in table 4.

Table 4: The "Seven Deadly Wastes"

Lean production (Venkatesh, 2009)	**Lean teaching**
Overproduction: Making something before it is truly needed.	Teaching chapters in the preparatory modules that are not needed at the current instructional level.
Waiting: Time when work-in-process is waiting for the next step in production	Delay in marking the assignments submitted and feed back to the students, resulting in poor exam preparation. Poor laboratory work planning, resulting in students waiting for their turn for the experiment.
Transport: Unnecessary movement of raw materials, work-in-process or finished goods	Poor or late information regarding the laboratory work and exams writing resulting in unnecessary students traveling.

Motion: Unnecessary movement of people (movement that does not add value)	Poor organising of consulting face to face contact classes, resulting in students looking for the venue or campus where the activity takes place.
Over processing: More processing than is needed to produce what the customer requires. This is often one of the more difficult wastes to detect and eliminate	Over teaching i.e. bombarding the students with not needed information resulting in intellectual fatigue and confusion. There is a tendency among some of the lecturers to "show of" with the amount of knowledge that they have in a certain field.
Inventory: Product (raw materials, work-in-process, or finished goods) quantities that go beyond supporting the immediate need.	Teaching chapters that contain information not needed for the progression in knowledge assimilation for the particular module.
Defects: Production that is scrap or requires rework.	Student failure of assessments

5.2 Laboratory work

UNISA invested a massive amount of money in laboratory buildings and modern equipment. As from 2015 the laboratory sessions are conducted in the laboratories at UNISA, Science campus. There is a laboratory timetable whereby once the students travel to UNISA Science campus over one or two full days, the student can perform all the necessary laboratory work for all the engineering modules for which the student is registered. The timing should be done in such a way that the laboratory experiment will take place after completing the theoretical section. The laboratory reports must be swiftly marked and feedback given to the students. In exceptional situations provision should be made for the students to be able to repeat some experiments. All laboratory work should be programmed and done in such a way as to avoid the deadly wastes listed in table 4. This solution is acceptable to ECSA the regulatory body for engineering teaching in South Africa, but unfortunately for the international students there is still a certain amount of unchecked work.

5.3 Assessment of the new engineering programmes

Assessments for the online course need to be authentic (related to the workplace). The OBE assessment will be done by creating assignments that stimulate as much as possible the real-life situations in which students would make use of the knowledge and skills presented in the course. This alignment of education and training is bound to improve the throughput rate as the OBE places the focus on the student's standard and not a universal standard. Also in case of failure (non-competent) the student will be re-examined only for the chapters where the student proved not to be competent. A good OBE assessment must encompass both the "what was known" and "how well it could be applied" as it brings in a cognitive quality aspect to learning.

5.4 Study material for distance learning

An important task of the module lecturer is to reduce the amount of information to a reasonable level without compromising the understanding of the module. In engineering manufacturing / production the Kaizen lean manufacturing principles proved to be extremely successful. The authors found (Ionescu, 2016) that the majority of Kaizen actions are linked perfectly to the Problem-Based Learning (PBL) and Action Learning (AL) which are examples of successful forms of teaching. Considering the distance education students background, the quality of self-study material is extremely important. The study material for each module must contain the following:

- Full information about the module and where it fits into the qualification framework;
- Which are the graduate attributes covered in the specific module. Out of eleven graduate attributes prescribed by ECSA it is recommended two maximums three to be attached to each module
- All basic mathematical and science information relevant to the particular chapter, must be provided;
- The lower level modules must have a "spoon feeding" component as it will facilitate the understanding of the basic principles. For the freshly senior certificate graduates the "spoon feeding" component makes the transition from high school teaching to tertiary education teaching easier;
- The introduction of basic mathematical and science principles in the junior level study material is absolutely compulsory. The student has no access in the work place to such information, except maybe in big companies.
- In the higher level study material, the "spoon feeding" component must be replaced with mathematical and science principles. The self-study component must be encouraged by providing accurate information about the study material accessible to students.
- Because the majority of distance education students are working as well, through a detailed study material the lecturer will facilitate easy access to information.
- It is extremely important to provide the student with enough information to be able to self asses himself / herself.
- The presentation of the laboratory experiments for the particular module must be accurate and clear.

5.5 Achieving sustainable Lean Teaching improvement in tertiary education

One of the greatest challenges in any tertiary education institution is how to achieve sustainable improvement. There are four techniques to be used for achieving sustainable improvement (Ionescu, 2016):

- Engaging students, teaching staff and management;

A powerful technique for engaging everybody is creating a shared vision of the future "improved" state of the institution and clearly outlining how it will benefit everybody. Another powerful technique is recognizing and rewarding desired behaviour. In the context of teaching, this may include providing rotating trophies for the best students or/and lecturers.

- Succeeding Early;

Succeeding early helps to ensure long-term success by building momentum behind the initiative. By way of contrast, if an initiative is perceived as having been tried and failed, it will be much harder to successfully implement that initiative in the future.

- Providing Active Leadership;

Providing active leadership is one of the primary responsibilities of senior management. Active leadership combats the natural tendency of students and lecturers to drift back into old patterns of behaviour and old ways of learning / teaching.

- Evolving the Initiative;

Evolving the initiative applies continuous improvement techniques to ensure that it does not become stale and that the stake holders do not become complacent. The goal is to keep the initiative fresh and interesting. Evolving the initiative also helps to ensure that it thrives over the long-term by constantly adapting it to a changing environment.

6 Conclusions

For a successful Lean Teaching all stakeholders must be involved.
When designing the new modules, avoid repetition and overlapping of information.
Reduce the module content to essential information needed for the student to understand and be able to use the knowledge provided. Any additional information non-essential to the module such as famous design failures, module history etc., which the lecturer would like to give, should be obtained by the student via self-study.
In the study material the lecturer must introduce essential information that will reduce the student study time; i.e. introduce the Greek alphabet used for symbols, basic integrations and derivations formulae, temperature scales, units, conversion tables etc.
Generally, the students resent being "spoon fed" and appreciate contact classes where they are required to contribute, not just passive receivers.
Correlate the programme offered with other tertiary engineering teaching institutions to ensure the mobility of the students.
Use to maximum the modern technologies teaching/learning aids.
Improve the access of students to lecturers and management.

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Essential Competencies of Science and Technology University Students in China

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ABSTRACT

The purpose of this study was to identify a list of the essential competencies that science and technology university students should develop during their early stages of their study in order to prepare for their future professional practice and to diagnose the current status of students' obtaining these competencies from the views of students and instructors and to identify challenges and obstacles to develop students' essential competencies.

With the theories and experiences of higher education, we defined cognitive area, practical area and communicative area as an essential competencies framework, which includes eleven indicators and several specific performances of students. Basing on this framework, we constructed an indicator system with three level indicators and form a questionnaire. Combining with interview and questionnaire survey, we collected the sampling data and compared the strengths and weaknesses of university students' essential competencies in China. It is found that, among the three areas competencies, the best one is at the social area and the worst is at the practical area for university student; It is also found that there is no significant difference in essential competencies of university students in aspects of gender, professions and regions, but in grades. From the whole trend, as the grade increases, the students' essential competencies are improved. At last, we identified challenges and obstacles of development of students' essential competencies in China, including four levels-nation, university, teacher and student.

Key words: Essential Competencies, Chinese Higher Education, Performance of University Students

Type of contribution: research paper

1. Introduction

With the economic development and the specialization of labor division, the social demand of university students' essential competencies is higher and higher. In science and technology higher education, there is a growing prominence for the development of specific professional and personal competencies in addition to mastery of knowledge and skills. Although there is a general agreement on the competencies that students should demonstrate on graduation, there is no consensus on what is important at entry and how these should be incorporated and assessed within the curricula. Substantial literature discusses a wide range of skills and competencies that are necessary for science and technology profession some regarded as hard-core skills and others as soft skills. There is a list of essential skills and competencies addressed in accessible literature including professional ability, creative ability, self-learning ability and teamwork ability. Can we achieve the goals and requirements of improving university students' essential competencies by Chinese higher education?

China's higher education is transforming from exam-oriented to quality-oriented or from knowledge-based to capability-based. By nearly 20 years challenging work, great progress has been made. However, due to the huge inertia formed by history, the task is still extremely arduous and undergoing transformation. So what do essential competencies mean and include? How is the current situation… it is important to research on the current status of how students have developed these competencies.

1.1 Problem formulation

- Although competencies are well-encouraged to obtain, there is a lack of knowledge about the current status, in particular in China;
- Current assessment is focused on information/facts based knowledge instead of skills and competencies that are regarded as essential;
- Internationally although various aspects of knowledge and skills of science and technology university students have been assessed and evaluated, for example, problem solving skills, communication skills, there is a lack of research evaluating these competencies as a whole.
- Little agreement is reached on what should be the essential competencies and how they should be incorporated and assessed within the curricula.

1.2 Aims of the study

- To identify a list of foremost important competencies that science and technology university students should develop during their early stages of their study in order to prepare for their future professional practice.
- To diagnose the current status of students' essential competencies from the views of

students and instructors.

- To identify challenges and obstacles of development of students' essential competencies.

2. Literature review

2.1 Definition of concepts

The term "competence" first appeared in an article authored by R.W. White in 1959 as a concept for performance motivation (White, 1959). In 1970, Craig C. Lundberg defined the concept in "Planning the Executive Development Program" (Lundberg, et al., 1970). The term gained traction when in 1973, David McClelland wrote a seminal paper entitled, Testing for Competence Rather than for "Intelligence" (McClelland, 1973). It has since been popularized by Richard Boyatzis and many others, such as T.F. Gilbert who used the concept in relationship to performance improvement (Gilbert, 1978).

Essential competencies refers to the relatively stable behavioral and psychological characteristics that are formed in the process of problem solving for students to meet the needs of their individual lifelong growth and social development. (Sturing, et al., 2011). Some scholars see "essential competencies" as a combination of practical and theoretical knowledge, cognitive skills, behavior and values used to improve performance; or as the state or quality of being adequately or well qualified, having the ability to perform a specific role. For instance, management competency might include systems thinking and emotional intelligence, and skills in influence and negotiation. Competence is also used as a more general description of the requirements of human beings in organizations and communities.

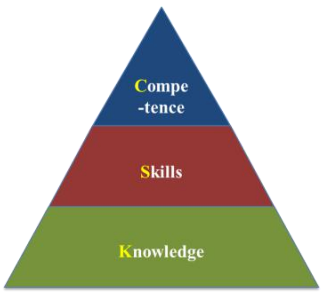

Figure1 Qualification frameworks of learning outcomes

Knowledge–skill–competence (KSCs) was developed by Bloom and his colleagues from 1960s to 1970s (Bloom, 1976; Bloom, et al., 1971; Bloom, et al., 1964). It was generally known as Bloom's taxonomy, based on three domains of educational activities: cognitive, affective, and psychomotor, it was also widely used to describe qualification framework of learning outcomes (Figure1). Based on KSCs and our generalized concept, essential competencies were considered to be classified and embodied. Guo Yuanxiang (Guo, et al., 2017) had divided essential competencies into 3 areas: cognitive area, practical area and social area. This taxonomy was following the different contexts, in which the competence occurs.

In this research, essential competencies is a generalized concept, which includes not only various kinds of abilities formed in learning theoretical knowledge and doing practical activities, but also skills to apply them to solve problems in new situation and context.

2.2 International literature about what competencies are needed?

Competence-based education was world widely spread, and some institutes have established their taxonomy for competences as the guidance for learning and teaching outcomes. For instance, conceive–design–implement–operate (CDIO) model, which started at Massachusetts Institute of Technology (MIT) and other four Sweden universities, set up a series of standards and rubrics to describe what competencies their graduates should have (CDIO, 2010). It was for international engineering education. Simultaneously, some scholars have made standards about competencies in their own field, for instance, Robert Englander extracted a common set of competencies for physicians from existing health professions' competency frameworks (Englander, et al., 2013), which mainly served for students of American medical colleges.

After comparing these two set of standards in details, there were some similarities between them. For instance, they all divide the competencies into several areas or domains such as knowledge, practice, personal, etc.; they all contain detailed and elaborate list of competencies in every domain. Also, there were some differences between them. One of the main points is that they apply to different areas of expertise and specialization, former is for engineering higher education; the latter is for physicians in American medical colleges.

2.3 Chinese literature about what competencies are needed?

To analyze the current situation of Chinese university students' competencies, here we choose several aspects which are more concerned by contemporary China.

- Professional ability

Due to the rapid increase enrollment of university graduates in China and the increasing employment pressure of university graduates, there are more studies on the professional ability of undergraduates in China. Overall, the professional ability of Chinese university students is acceptable, but there are some problems that cannot be ignored. In general, communication and presentation skills, the ability to apply professional knowledge, teamwork skills, interpersonal skills, learning ability and so on are considered as key factors affecting the employment of university students (Guo, et al., 2014). According to the findings of some scholars, the development level of professional ability of Chinese university students is generally good, but the level is not high enough. For example, among the basic professional ability, ability of accessing knowledge independently, ability of analyzing is better, practical ability, learning ability needs to be improved; while job performance and demonstration is relatively weak (Jin, 2012).

- Creative ability

Creative ability is also the basic ability of undergraduates, which is widely concerned in China at present. The lack of ability to innovate is the universal understanding of contemporary university students in Chinese society. From a research perspective, we should have a more comprehensive understanding of this issue. On the one hand, Chinese university students do not lack the awareness of innovation, but they are not good at making use of the conditions of innovation (Huang, et al., 2011). Many university students want to be good at innovation, but they are reluctant to actively participate in the activities of many innovative classes arranged by the school. The second is institutional obstacles. In China, many universities declare innovation is important, while they don't want to reform in the way of assessment. They stick to conventions. Universities still mainly teach knowledge and do not attach importance to the cultivation and development of students' innovative abilities. Third, the lack of an atmosphere of innovation, both in the university and society. Short-sighted behavior that simply pursues immediate economic interests is widespread in China.

- Self-learning ability

Self-learning is based on western humanistic psychology and constructivism learning theory. However, contemporary Chinese university students are uneven in self-regulated learning ability, which are universal problems. The ability of independent study urgently needs to be improved. Mainly as follows: learning objectives and concepts are not clear, learning methods and means are simple, the learning will and management are weak (Sun, et al., 2016), for instance, in this survey it is found that among Chinese university students, learning motivation for finding a good job or parents' expect accounted for nearly 80%, for getting the diploma accounted for 5%, and in another example, only 9.8% of university students in China surveyed have the habit of making a study plan, and most students do not have this habit (Qiu, 2009). These reflect the shortcomings of Chinese university students in self-regulated learning ability.

- Teamwork ability

Team awareness and ability to cooperate are the main goal of modern human resources development and training, but also the core competence of university students. The survey showed that university students in China generally have high awareness of teamwork, agree on the importance of teamwork skills, while on the other hand, they usually think they are not good at teamwork when self-evaluation (Sun, et al., 2016). This fact reflects the impeding effect of the current teaching methods and assessment methods in China in fostering students' teamwork ability (Feng, 2004). For example, in many colleges and universities' graduation design process, teaching norms clearly stipulates that each student should be assigned a topic individually, and complete it independently, although this provision is for preventing plagiarism, but it causes that students often feel they don't need cooperation to complete the graduation project, which is obviously not conducive to cultivating students' ability to teamwork.

Four main abilities about Chinese undergraduates have been discussed briefly. These four major competencies are related to each other, they are very important for university students to quickly adapt to the working environment after graduation. Therefore, university students should attach importance to innovative thinking ability, and teachers should create the teaching mode continually so that students can improve their essential competencies.

2.4 A framework of essential competencies

According to the understanding of literature' comparison, it was necessary to make a new taxonomy for essential competencies. Refer to classification methods from literature mentioned before, and essential competencies have been divided into 3 areas: cognitive area, practical area and social area, following the different contexts, in which the competences occur. Furthermore, every area has 3-4 aspects of ability. For example, ability of thinking critically belongs to cognitive area. The second level indicators are from the literature and summarized from 35 interviewees who are teachers from the science and technology university in China. For each kind of ability, several appreciable and measurable descriptions of the students' specific behavioral performance were listed and selected and then summed up. In other words, more detailed division and definition of each kind of ability has been established, so that each kind of ability can be evaluated and measured by the third level indicators. The full taxonomy of essential competencies was listed in Table1.

Table1 Indicators system of essential competencies (authors)

First-level Indicators	Second-level Indicators	Third-level Indicators
Cognitive area	The ability to collect and process information	Be able to use a variety of tools and methods to collect information skillfully;
		Be able to confirm the information needs quickly and clearly, and to get effective information through multiple channels;
		Be able to summarize, classify, identify, screen, analyze, synthesize and generalize the information obtained.
	The ability to acquire knowledge independently	Be able to use scientific learning methods, develop own learning goals and plans, and organize their own learning activities;
		Be able to think independently;
		Be able to extend knowledge through a variety of learning ways.
	The ability to analyze and solve problems	Be able to discover and articulate meaningful and valuable research questions;

		Be able to apply the existing knowledge and skills to analyze the problems;
		Be able to design and implement solutions to problems by selecting and recalling experiences, knowledge and methods.
	The ability to reflect critically	Be able to put forward your own unique ideas for others' opinions and provide the basis for agreement or disagreement;
		Be able to promptly aware of the problems for their own words and deeds, and promptly adjust their acting direction;
		Be able to effectively interpret, analyze, evaluate, and deduce facts or events.
Practical area	Operating ability	Be able to put theory or project into practice effectively;
		Be able to use various kinds of professional tools.
	Designing ability	Be able to complete research reports and presentations;
		Be able to employ present materials to do creative jobs.
	Creative ability	Be able to participant all kinds of innovation activity in university;
		Be able to win awards in all kinds of undergraduate innovation activities.
Social area	The ability of communicating and expression	Be able to express your views accurately and clearly in verbal or written ways;
		Be able to listen patiently to the opinions of others and accurately obtain the substance of their views;
		Be able to reach a consensus to achieve a win-win situation when your own ideas collide with others' opinions.
	Teamwork ability	Be able to respect and trust team members;
		Be able to maximize personal advantages, and to combined personal effort and team goals;
		Be able to recognize and accept individual differences, and to learn from each other;
		Be able to share opinions and experience with

		others.
	Organizing and managing ability	Be able to manage time and complete task within the deadline;
		Be able to have a comprehensive understanding of team members, and be clear about team development direction and goals;
		Be able to coordinate and arrange all the duties and responsibilities for a team as a team leader;
	Social adaptive ability	Be able to undertake and adapt to the transformation of social roles;
		Be able to carry out social services based on moral and ethical standards;
		Be able to balance their own interests and social benefits;
		Be able to take the initiative to participate in various social activities and be willing to take responsibility.

3. Research methods

3.1 Research questions

The study design was constructed to address the following research questions:

Q1: How are the current status of university students' essential competencies viewed by students and their instructors?

Q2: What are the challenges for university students to develop essential competencies during their university study?

3.2 Research design

The design of this study, which was an empirical research approach, employed a mixed methods design with comprising qualitative and quantitative methods approaches.

3.2.1 Participants

Participants of the quantitative study included university students in science and technology programs from six Chinese universities which were located in three provinces in the middle and western region. This study adopts the technique of convenient sampling. Survey were sent to 600 students, 566 responded and 470 valid. Sample distribution is showed in table 2.

Table2 Sample distribution

Indicator		N	Percentage (%)
Gender	Male	156	33.2
	Female	314	66.8
	total	470	100.0
Grade	Freshman	171	36.3
	Sophomore	73	15.5
	Junior	103	21.9
	Senior	123	26.3
	total	470	100.0
Region	Chongqing	214	45.5
	Shanxi	145	30.9
	Gansu	111	23.6
	Total	470	100.0
Major	Chemistry	141	30.0
	Statistics	202	43.0
	Mathematics	20	4.2
	Pharmaceutical engineering	107	22.8
	Total	470	100.0

Participants of the qualitative study included university teachers from 35 science and engineering fields from 16 universities in the middle and western region of China.

3.2.2 Method and tool of data collection

Table3 Mapping Research Questions

Question	Data type	Data source	Method	Tool
Q1	Qualitative Quantitative	35 college teachers 566 university students	Interview Questionnaire	Interview outline Five-level Likert scale Wen Juan Xing APP
Q2	Qualitative	35 college teachers	Interview	Interview outline

3.2.3 Method and tool of data analysis

Table4 Mapping data type with data analysis methods, tools and content

Data type	Method	Tool	Concrete content
Qualitative	Content analysis	NVIVO	High frequent words Abstract core concept
Quantitative	Statistical	EXCEL	Descriptive statistics: mean, S.E., frequency,

	analysis	SPSS AMOS	percentage Inferential statistics： independent sample test, validity and reliability test

3.2.4 Reliability and validity

In order to reflect the data information, to reflect different contribution degree of different indicator, the first step is to weight the indicators. For the correlation coefficient values of third level indicators are closed (calculated by AMOS), we approximate the weight of third-level indicators to equal weight. For the first and second-level indicators, we choose expert scoring method and analytic hierarchy process (AHP) to weight the indicators. We choose the team member that has pedagogical background to give the judgment matrix. Then calculate the weight as follow table5 (the weight is in the bracket):

Table5 Indicator list table

First-level indicators	Second-level indicators
Cognitive area (0.33)	The ability to collect and process information (0.09)
	The ability to acquire knowledge independently (0.29)
	The ability to analyze and solve problems (0.33)
	The ability to reflect critically (0.29)
Practical area (0.33)	Operating ability（0.11）
	Designing ability（0.26）
	Creative ability（0.63）
Communicative area (0.33)	Ability of communication and expression (0.25)
	Teamwork ability (0.25)
	Organizing and managing ability (0.25)
	Ability to assume social responsibilities（0.25）

We can calculate the score of second-level indicators with weighted arithmetic mean.

Deep discussion and prepare work have done to guarantee the reliability and validity of our research data. Test reliability and validity by Cronbach's Alpha coefficient and KMO and Bartlett's value. Cronbach's Alpha coefficient is 0.95, the KMO and Bartlett's test value is 0.952. Both are nearly to 1. All these show that the scale has good reliability and validity.

4. Results

4.1 Students' view of their essential competencies

4.1.1 Description

- **Overall description**

Table6 Total score description

Indicator	Low （1-2.5）	Middle （2.5-3.5）	High （3.5-5）	Total
N	39	294	137	470
Percentage（%）	8.30	62.55	29.15	100.00

For the 470 undergraduates, table6 shows that the scores focus on the interval (2.5-3.5), nearly 62.55%. The percentage of high interval (3.5-5) is higher than the low interval (1-2.5). It seems the whole distribution is reasonable.

Table7 Each area score description

Indicator	Low （1-2.5）	Middle （2.5-3.5）	High （3.5-5）	Mean	S.E.
Cognitive area	39	264	167	3.31	0.59
Practical area	146	227	97	2.93	0.75
Social area	56	160	254	3.48	0.74

From table7, we can see that the mean score in practical area is the lowest and in social area is the highest. S.E. of practical and social area are higher, this suggests that there are more differences in practical area and social area.

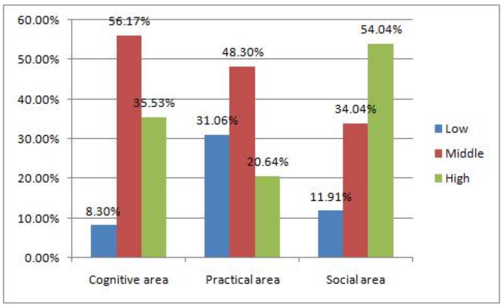

Figure 2 Structure distribution of each area

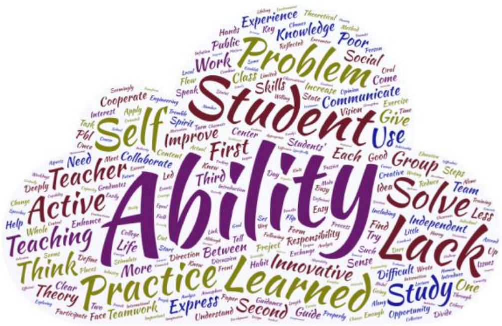

Figure 3 Word cloud of deficient competencies

Figure2 further explain the conclusion above. This result is consistent with the results of our interviews with Chinese teachers. Many teachers think that undergraduates are deficient in practical ability. The results of review are shown in Figure 3.

We decompose the total score into three areas to analyze the problem deeply.

- **Cognitive area**

Table8 Score of cognitive area

Second-level Indicator	**Low （1-2.5）**	**Middle （2.5-3.5）**	**High （3.5-5）**	**Mean**	**S.E.**
Collect and procession information	49	269	152	3.27	0.68
Acquire knowledge independently	49	201	220	3.40	0.71

Analyze and solve problems	64	300	106	3.20	0.62
Reflect critically	52	216	202	3.35	0.71

Table8 shows that Chinese students think that they have relatively good performance in “acquire knowledge independently” and “reflect critically”, but lack in “information collecting” and “problem analyzing and solving”.

- **Practical area**

Table9 Score of practical area

Second-level Indicator	Low （1-2.5）	Middle （2.5-3.5）	High （3.5-5）	Mean	S.E.
Operating ability	130	264	76	3.08	0.66
Designing ability	121	255	94	3.10	0.73
Creative ability	207	180	83	2.84	0.93

Table9 shows that Chinese students have relatively good performance in “designing ability”. But they have some lack in other abilities, especially creative ability.

- **Social area**

Table10 Score of social area

Second-level indicator	Low （1-2.5）	Middle （2.5-3.5）	High （3.5-5）	Mean	S.E.
Ability of communication and expression	54	204	212	3.37	0.72
Teamwork ability	65	118	287	3.59	0.92
Organizing and managing ability	62	184	224	3.47	0.81
Social adaptive ability	56	160	254	3.48	0.75

Table10 shows that Chinese students think they have relative superior performance in social area, especial in teamwork ability and social adaptive ability.

4.1.2 Analysis of differences in gender, grade, major and region

- **Classification tests**

In order to find whether the score is different in different groups, we decompose and test the score distribution further. This can help us to know what the key problem of Chinese students' thinking of their essential competencies.

Table11 shows that the scores of grades are significant different while others are not. This means different grade has different opinions of their essential competencies. So, we will analyze the essential competencies in detail from grade.

Table11 Grade, Region and Major Test

Classification	Statistics	Total	Cognitive area	Practical area	Communicative area
Grade	Chi-Square	22.503	17.232	5.805	17.675
	Asymp. Sig.	0.000*	0.001*	0.121	0.001*
Region	Chi-Square	2.005	3.831	.417	5.700
	Asymp. Sig.	0.367	0.147	0.812	0.058
Major	Chi-Square	1.245	2.584	1.082	2.642
	Asymp. Sig.	0.742	0.460	0.781	0.450

Note: * means significant in 5% significance level.

- **Analysis of grade**

The data in table12 shows some differences are in different grade has different score. The whole trend from freshman to senior is growth. This means from freshman to senior, undergraduates think that their essential competencies grow. The higher education is effective.

Table 12 Score of communicative area

Grade	Low （1-2.5）	Middle （2.5-3.5）	High （3.5-5）	Mean	S.E.
Freshman	13	114	44	3.20	0.51
Sophomore	8	47	18	3.16	0.50
Junior	12	67	24	3.15	0.58
Senior	7	64	52	3.42	0.52

We decompose the total score into different areas. The difference is obviously in table13. The mean scores of whole practical area are lowest and the S.E.s is highest. This means Chinese students think that their practice ability is weak, and their evaluation of their own ability is different significantly.

Table13 Score distributions of grades in areas

area	Grade	Low （1-2.5）	Middle （2.5-3.5）	High （3.5-5）	Mean	S.E.
Cognitive area	Freshman	15	104	52	3.90	0.35
	Sophomore	8	46	19	3.25	0.57
	Junior	11	58	34	3.21	0.65
	Senior	7	55	61	3.48	0.55
Practical area	Freshman	45	97	29	2.91	0.68
	Sophomore	20	41	12	2.83	0.65
	Junior	35	43	25	2.90	0.83
	Senior	31	53	39	3.07	0.83

Social area	Freshman	19	66	86	3.43	0.72
	Sophomore	8	29	36	3.39	0.65
	Junior	20	29	54	3.34	0.85
	Senior	7	29	87	3.70	0.70

In order to find the key problem lies in these scores, we decompose the area score deeply into second-level indicator score. We can test whether there is significant difference of grades.

Table14 Differences test of grades in cognitive area

Second-level indicator	Grade	Mean	S.E.	χ^2	Sig.
Collect and procession information	Freshman	3.20	0.66	10.947	0.012*
	Sophomore	3.26	0.60		
	Junior	3.16	0.77		
	Senior	3.42	0.70		
Acquire knowledge independently	Freshman	3.30	0.67	19.959	0.000*
	Sophomore	3.30	0.71		
	Junior	3.32	0.80		
	Senior	3.63	0.67		
Analyze and solve problems	Freshman	3.13	0.63	9.852	0.020*
	Sophomore	3.15	0.60		
	Junior	3.11	0.66		
	Senior	3.35	0.59		
Reflect critically	Freshman	3.30	0.74	10.874	0.012*
	Sophomore	3.29	0.60		
	Junior	3.22	0.79		
	Senior	3.51	0.69		

Note: * means significant in 5% significance level. The same below.

Table14 shows that from freshman to senior, students' evaluation of their competencies in cognitive area has significant difference. The individual difference is stable. From the scores, we can see a significant improve in students' competence evaluation.

Table15 Differences test of grades in practical area

Second-level indicator	Grade	Mean	S.E.	χ^2	Sig.
Operating ability	Freshman	3.05	0.71	16.938	0.001*
	Sophomore	3.01	0.55		
	Junior	3.01	0.69		
	Senior	3.27	0.65		
Designing ability	Freshman	3.08	0.78	11.097	0.001*
	Sophomore	3.04	0.58		

	Junior	3.04	0.76		
	Senior	3.28	0.75		
Creative ability	Freshman	2.81	0.74	3.129	0.372
	Sophomore	2.71	0.80		
	Junior	2.83	1.43		
	Senior	2.95	1.11		

Table 15 shows that from freshman to senior, students' evaluation of operating and designing ability has significant difference. It improves obviously. But in the creative ability, there is no significant difference from freshman students to senior students. In this ability, the individual differences are bigger than others. This suggests that there is no significant effect on cultivating students' creative ability in Chinese higher education. This result tells us that in higher education, the cultivation of practical competence has "short board".

Table16 Differences test of grades in social area

Second-level indicator	**Grade**	**Mean**	**S.E.**	χ^2	**Sig.**
Ability of communication and expression	Freshman	3.33	0.69	12.319	0.006 *
	Sophomore	3.30	0.64		
	Junior	3.29	0.78		
	Senior	3.52	0.74		
Teamwork ability	Freshman	3.54	0.89	19.728	0.000 *
	Sophomore	3.48	0.81		
	Junior	3.43	1.01		
	Senior	3.88	0.88		
Organizing and managing ability	Freshman	3.44	0.78	12.193	0.004 *
	Sophomore	3.40	0.72		
	Junior	3.31	0.95		
	Senior	3.70	0.73		
Social adaptive ability	Freshman	3.43	0.72	17.509	0.001 *
	Sophomore	3.39	0.65		
	Junior	3.34	0.85		
	Senior	3.70	0.70		

Table16 shows a significant improvement in students' evaluation of competence. From freshman to senior, students' evaluation of competence in social area has significant difference. The individual difference is bigger in "teamwork ability" and "organizing and managing ability". The reason of this phenomenon maybe students are not often able to participate in team activities. There are some chances for students to work with coordination and cooperation, but not all students have the chances or choose the chances.

4.1.3 Summary

Overall, according to the self-evaluation in the three areas, Chinese undergraduates are less capable in practical area compared with cognitive and social areas. Specifically, in the cognitive area, Chinese undergraduates "Acquire knowledge independently" ability and "critical reflection" ability are relatively good, but "information collecting and processing" ability and "problems analyzing and solving" ability have some deficiency. In practical area, the evaluation of Chinese undergraduates' "operation" and "design" ability are relatively higher, while "creative" ability is obviously insufficient. In the social area, Chinese undergraduates think they have relatively good abilities, especially "teamwork" and "social adaptation".

In terms of difference, the essential competencies of Chinese undergraduates have no significant difference in gender, major and region, but only the grade has significant difference. From the whole trend, as the grade increases, the undergraduates think that their essential competencies is improved. Specifically, in the cognitive area, undergraduates of different grades have significant different self-evaluation in various abilities of secondary indicators, especially the ability to independently acquire knowledge. In the practical area, undergraduates of different grades don't have significant different evaluation. But in various abilities of secondary indicators, undergraduates in different grades have significant different evaluation in their ability to design, and there is no significant difference in creative ability. In the social area, undergraduates of different grades have significant different evaluation in the abilities of secondary indicators, especially the difference between teamwork and social adaptability.

4.2 Instructors' view of their essential competencies

We have made some processing and summary of interview data from two aspects. One aspect is teachers generally believe that students should have the ability, another is teachers generally believe that students currently lack the ability (see table17).

Table17 The results of processing of interview data

Area	Should have	Lack of
Cognitive area	The ability to acquire knowledge independently The ability to analyze problems The ability to reflect critically	analyze problems reflect critically
Practical area	The ability to operate The ability to design The ability to solve problem Creative ability	solve problem Creative ability
Social area	The ability of communication and expression The ability of teamwork: collaboration The ability to assume social responsibilities	teamwork adapt society

From the analysis of interview data from teachers, it is found that teachers' evaluation of students' essential competencies is not completely consistent with students' evaluation. For example, in cognitive area, students believe that their "acquire knowledge independently" ability and "critical reflection" ability are relatively good, but teachers think that students are most deficient in these two abilities. In practice area, teachers and students can basically reach consensus. They all believe that the most lacking is creatively ability. In social area, students think they have relatively good abilities, especially "teamwork" and "social adaptation". while teachers believe that students are most deficient in these two aspects.

4.3 Challenges

4.3.1 At the national level

There is no unified demand and regulation on essential competencies training and development of science and technology university students. Although countries have realized competence training and development is the emphasis and difficulty in the current higher education reform, there is not a standard document that state what level of essential competencies should university student achieve upon graduation. Therefore, neither the school level nor the teacher level has reached a certain theoretical consensus, and students' abilities can only be cultivated at different levels based on their personal knowledge and experience. And the investment ratio of the government to education has increased year by year, but most of these financial allocations are used for the cost of education, and the investment in infrastructure construction based on social demand is not high.

4.3.2 At the school level

There is no systematic curriculum implementation and evaluation system based on essential competencies training and development of science and technology university students. As far as we know, different major in training and development students' competence have different emphasis, but teachers will not be able to have pertinence and effectiveness to cultivate and develop students' competence if without a systematic curriculum implementation and evaluation system. And universities have a relatively comprehensive construction of their own advantageous disciplines and facilities, and relatively few other disciplines.

4.3.3 At the teacher level

They have no sufficient curriculum implementation strategies and methods to improve students' competence based on knowledge learning in subject courses. Although many teachers have changed their ideas, they attach importance to the cultivation and development of students' essential competencies. However, at the operational level, there are no scientific teaching methods and strategies on how to cultivate and improve students' essential competencies.

4.3.4 At the student level

They pay insufficient attention to their own competence. Chinese students mainly accept the training of the exam-oriented education in basic education stage. Therefore in the process of higher education stage, they still focus on studying for exams rather than on improving their competence. Most students can not realize that only when their essential competencies is raised to a certain level and meet the requirements of the employers, they can be foothold in the society. Most students are weak in self-control, lack self reflection and self-restraint. They can not find their own shortcomings in time, lack scientific and reasonable exercise, and unconsciously comply with the changes of social development needs.

5. Discussion

This study found that science and technology university students in China are less capable in practical area compared with cognitive and social areas according to their self-evaluation. It is consistent with the results of existing literature. In particular, several studies have shown that science and technology university students' creative ability is very weak. This is well confirmed in this study. And it is found in this study that there is no difference in the creative ability of students of different grades, which indicates that the cultivation of students' creative ability is very insufficient in the current higher education of China. How to cultivate students' practical ability, especially creative ability? The reform of classroom teaching model and method are key factor. Existing studies have shown that student-centered teaching model and method, such as PBL, can effectively improve students' self-learning ability, problem solving ability, creative ability and communication and cooperation ability, etc. Therefore, teachers can try to cultivate students' practical ability by adopting PBL as an innovative teaching method.

This study found that the evaluation results of students essential competencies from students and teachers showed some inconsistencies. In students' self-evaluation, their social area competencies is the strongest, followed by their cognitive area competencies, while their practical area competencies is the weakest. In teachers' opinion, students' practical area competencies is the weakest, followed by their social area competencies. Why is there such inconsistency? On the one hand, this research adopted the mixed research method. For the students, we adopted a large sample questionnaire survey of a quantitative research paradigm, while for the teachers, we adopted interviews of a qualitative research paradigm. So the quantitative research is more general and representative, and qualitative research may only reflect some features. In addition, teachers may not give students more opportunities and platforms to express their abilities in the social area in the process of classroom teaching and learning, so the viewpoint and judgment is somewhat subjective in the survey.

6. Conclusion

In summary, the current status of essential competencies of science and technology university students in China is not optimistic. There are some differences in the performance of students' essential competencies in the areas of cognition, practice and society. The results of students' self-evaluation and teachers' evaluation for performance of students' competencies are inconsistent, but the practical competencies of Chinese university students needs to be improved urgently. It needs to be strengthened and developed from multiple levels and perspectives through the nation, society, school, teacher and student, so that students can further adapt to the requirements of future society and personal development.

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Transformation from Jugaad Mind-set to Engineering Mind-set: A PBL approach

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Abstract

Problem solving is one of the focus areas of engineering education. A generally observed approach to problem solving is working in informal environments and somehow accomplishing goals. This approach is termed as 'Jugaad', it refers to 'easy hack' for a problem rather than having a solution based on rational engineering process. Solutions from such efforts lack quality and reliability. The authors have observed that freshmen tend to have this 'Jugaad' mind-set towards solving a problem, as they are rarely exposed to engineering practices and methods in their schooling. Building engineering mind-set in the freshmen year is desirable as it lays foundation to subsequent training and prepares them for engineering workplace problem solving.

To develop engineering mind-set in freshmen, an attempt has been made in course titled "Engineering Exploration" which focuses on engineering design process, multidisciplinary skills and team work. This course follows PBL pedagogy and the students solve real-world problems to submit a mechatronic prototype as a deliverable. In the first delivery of this course it was observed that the prototypes reflected improper selection of materials and joints between them, inappropriate mechanisms and poor rigidity which in turn affected the quality and reliability of the prototypes. This can be attributed to students being deficient in 'making skills' or prototyping skills and hence followed 'Jugaad' approach, even though they were aware of the engineering design process. To overcome this deficiency, module on Mechanisms was introduced in this course to improve 'making skills'.

The authors observe significant improvement in the quality and reliability of the mechatronic prototypes due to these efforts. This paper describes the need, the process followed and outcomes of the experiment. Continuous improvement in the design and delivery of the module on Mechanisms over the last five deliveries and its impact on students learning are also discussed.

Keywords: prototype, jugaad, PBL, freshman, design

Type of contribution: best practice paper

1 Introduction

The primary objective of education in any discipline is to empower the learners with knowledge, skills and attitudes required to solve problems of the workplace (workplace problems) (Jonassen, Strobel, and Lee, 2006). In engineering education as well, educators have attempted to develop curriculum which equips learners with the cognition and skills of problem solving. Such attempts have received wide acclaim and adoption under the realm of experiential learning which emphasises problem solving over rote learning (Kolb, 2014, Harrisberger, 1976).

Among the several kinds of problems which "practising" engineers work on, design problems lie at the extreme end of high complexity and ill-structuredness, only next to dilemmas, which typically have no clear solution (Jonassen,2004). Design problems lie at the heart of the engineering profession (Stojcevski, 2014).

The engineers design physical artefacts like systems, processes, devices and structures by applying disciplinary and multi-disciplinary knowledge and skills to solve societal problems (Dym, Agogino, Eris, Frey, and Leifer, 2005). The engineers traverse from problem space to the solution space by typically applying the engineering design process and experiential knowledge and skills. The engineering design process begins with formulating a problem statement, gathering information to understand the problem better, generating alternative concepts and embarking upon developing one solution which addresses the problem at hand (Tayal, 2013; Dym, Little, Orwin, and Spjut,2009). Generally, before the manufacturing of final product, the engineers develop a prototype which satisfies the objectives, exhibits the functions and adheres to the constraints imposed upon the solution. A prototype is an operating version of a solution and generally made with materials that are less expensive and easier to work with as against the final version. The prototype serves as a means of communication between the designers and the clients. It is further subjected to refinement and culminates in the final product which meets the clients' needs (Gero, 1990).

From theoretical perspective, the prototype serves as an external manifestation of ideas and is a public entity. It is embodiment of knowledge and can be subjected to discussion, improvisation and critique. A prototype is not a dead object, but a personification of the "culture, history and ideology of the social practices in which the artefacts were construed" which can be experienced through its use and appearance (Fors, V., 2003). As engineering educators, when we view the prototype from this frame of reference, it demonstrates a solution to a design problem and exhibits the disciplinary and multi-disciplinary engineering knowledge and skills required in prototyping it.

Project courses are important part of engineering curriculum. The outcomes of project courses are generally prototypes. Authors have observed that the prototypes developed by students lack quality and reliability. This was mainly because students lacked 'making skills' and resorted to 'Jugaad' approach or putting the prototype together using quick and easy hacks, even though they knew engineering design process. There are several manifestations of this mind-set, the major one being improper selection of materials and joints between them, inappropriate mechanisms and poor rigidity.

In the subsequent sections, the authors have shared their observations, experimentation and experiences in addressing the 'Jugaad' mind-set.

2 Methodology

Project courses are part of engineering curriculum in different years of the studies. Most of the project courses have design as their theme and the outcome is mostly a prototype. Such prototypes are observed to be of poor quality irrespective of which year of the engineering program they are done. Authors believe that an attempt to address the problem at freshman year will have positive impact and scope to improve further. Therefore a study of the problem at freshman year is conducted.

The proposed study follows a qualitative approach with respect to one identified course and attempts to find solutions to the following questions:

1. How does 'Jugaad' mind-set gets manifested in students' projects' prototype?
2. What are the root-causes for 'Jugaad' mind-set?
3. What are the interventions to overcome 'Jugaad' mind-set?

The authors have chosen a course titled "Engineering Exploration" for this experimentation. This course is a freshman engineering course and has the following enduring outcomes: Engineering design, Multi-disciplinary nature of engineering problem solving and team work. The course follows the PBL pedagogy and the students work in teams to solve an identified problem whose solution is a prototype. It is a 3 credits, one semester course. The course has eight modules viz: Introduction to Engineering, Engineering Design, Mechanisms, Platform based development, data acquisition and analysis, project management, ethics, sustainability.

3 Experimentation

This section traces the progressive attempts made by the authors in the above referred course over the past five deliveries in the process of addressing the questions raised in the previous section.

3.1 How 'Jugaad' mind-set does get manifested?

A generally observed approach to problem solving is working in informal environments and somehow accomplishing the goals. This approach is termed as 'Jugaad' and it refers to 'easy hack' for a problem rather than having a solution based on rational engineering process.

It was observed by authors during the second delivery of "Engineering Exploration" course (2015-2016, spring) that the course projects lacked quality and reliability. This warranted an investigation and authors chose two projects which are mechanisms intensive: 1. "Blackboard cleaner" and 2. "Walking robot". The prototype in both these cases were found to be of poor quality. Further, the students were found to be grappling with the complexities associated with the fabrication of links and joints, assembly of mechanisms and interfacing them to actuators during the prototyping phase. Mechanisms were put together using "quick and easy hacks" like two-way tapes, adhesives, nails and the like. Although the student team had conceived "alternate" and "feasible" concepts on paper, they were unable to translate them into mechanically stable and working prototypes. All this was mainly due to usage of improper materials and joints between them, choice of inappropriate mechanisms and poor rigidity.

3.2 Root causes for 'Jugaad' mind-set

The authors have observed that the freshmen tend to have this 'Jugaad' mind-set towards solving a problem, as they are rarely exposed to engineering practices and methods in their schooling. The same thing has been highlighted in (Sheppard, Macatangay, Colby, & Sullivan, 2008) wherein the lack of students' making skills has been one of the challenges in first year design courses. This hampers the design process. Building engineering mind-set and making skills in the freshman year is desirable as it lays foundation for subsequent training and prepares the students for engineering workplace problem solving.

To empower the students with the necessary 'making skills' requires that the faculty formulate appropriate interventions that have been highlighted in the subsequent sections.

3.3 Interventions to overcome 'Jugaad' mind-set

To address the 'Jugaad' mind-set, a module on mechanisms was introduced in the above-mentioned course. The module spans 6 hours with two sessions of three hours each. The learning outcomes of the module are as outlined below:-

At the end of the module, the student should be able to:

1. Explain the need for mechanisms
2. Identify basic components of linkage mechanism
3. Compute the degrees of freedom for a given mechanism

4. Build a Mechanism for a given application

Keeping the above learning outcomes in focus, the module evolved across four semesters spanning from 2016-2017 (spring) to 2017-2018 (spring) and is shown in the table 1.

Table 1 Evolution of Mechanisms module

<table>
<tr><th colspan="5">Across five semesters</th></tr>
<tr><th>Year</th><th>Mechanisms module</th><th>In-class activities</th><th>Simulation</th><th>Out-of-class activities</th></tr>
<tr><td>2016-2017 (fall)</td><td rowspan="4">Refer to sub sections 3.3.1 for concepts</td><td rowspan="4">Refer to sub-section 3.3.2 for description of activities</td><td>Absent</td><td>Absent</td></tr>
<tr><td>2016-2017 (spring)</td><td>Simulation of identified mechanisms (Refer to section 3.3.2)</td><td>Absent</td></tr>
<tr><td>2017-2018 (fall)</td><td rowspan="2">Simulation of mechanisms used in course projects + simulation of identified mechanisms (Refer to section 3.3.2)</td><td>Introduction of mechanisms without context/ (Refer to section 3.3.3)</td></tr>
<tr><td>2017-2018 (spring)</td><td>Systems-thinking: Contextualised learning (refer to section 3.3.3)</td></tr>
</table>

3.3.1 Concepts

The concepts in the mechanisms module focus on enhancing the mechanical prototyping skills of the freshmen. They were selected based on the degree of applicability in the course projects and are as stated below:-

Mechanisms, Degrees of Freedom or Mobility of a Mechanism, Linkage Mechanisms: four bar, Crank Rocker Mechanism, Slider Crank Mechanism

3.3.2 In-session activities

As a part of activity-based learning, the students learn the concepts mentioned in section 3.3.1 through two activities related to linkage mechanisms (four-bar chain: crank rocker mechanism and robotic arm). The students also simulate the mechanisms using the “Linkage” software. The descriptions of the activities are as stated below:-

1. Simulation, assembly and actuation of crank rocker mechanism
2. Simulation, assembly, actuation and control of a robotic arm

The two activities have been conceived with the intention of creating awareness on the complexities involved in fabricating individual components and assembling mechanisms thereof.

Simulation of the aforementioned mechanisms was exciting, but failed to create a context for application on the course projects. Thus, by the fourth delivery (2016-2017, spring) simulation was made mandatory for the mechanisms used in the course project. This brought in the accuracy and precision required to fabricate and assemble mechanisms.

Figure 1: Crank Rocker mechanism and Robotic Arm mechanism

Figure 2: Various mechanisms introduced in the context of systemic thinking

3.3.3 Augmenting classroom learning with out-of-class activities

Until 2017-2018 (fall), the students had attained proficiency in using linkage mechanisms in their course projects. However students also used many other mechanisms which exhibited the 'Jugaad' approach. The students were grappling with the complexities associated with the fabrication of links and joints, assembly of mechanisms and interfacing them to actuators. It was essential to introduce mechanisms in the context of a system.

To address these above mentioned issues, out-of-class activities were designed for some common mechanisms as outlined below and shown in figure 2.

1. Assemble the mechanism (belt drive) to transfer an object weighing 100 gm over a distance of 1 foot in a horizontal direction
2. Assemble the mechanism (gear train) and calculate the change in velocity ratio at the output gear. Also find the torque at the output gear
3. Assemble the screw mechanism to lift a load of 500-1000 gm over a height of 10 cm

4 Data collection and analysis

To study the impact of the mechanisms module and allied activities on the course projects, the videos and photographs of projects across the five semesters (2015-16, spring to 2017-2018, spring) were examined. The criteria 1-3 were identified and criteria 4-6 emerged as the process of examination progressed.

1. Right material selection
2. Proper Joining of materials
3. Appropriate Mechanism selection
4. Structural rigidity
5. Functionality
6. Mechanical Complexity

The criterion 1 to 4 is evaluated by its presence (1) or absence (0). The criterion 5, functionality refers to the prototypes' completely working. However, the criteria 6, mechanical complexity varies across four levels, 1-4, with 1 signifying the least mechanically complex prototype. These levels vary w.r.t number of mechanisms required, power, and torque and speed requirements. These levels are qualitative and set by the authors w.r.t to the prototypes examined. In all subsequent graphs, the numbers 1-4 in the legend refer to mechanical complexity.

The authors refer to the criteria 1-4 as "engineering methods" which are required for successful prototyping. The subsequent section represents the findings w.r.t to the mechanical complexity, functionality and the reflection of engineering methods in the prototypes. The impact study was carried across the five semesters during which the mechanisms module evolved organically to cater to the knowledge and skills required to prototype the solution.

5 Findings and Discussion

This section presents how the mechanisms module impacted the mechanical prototyping skills of freshmen as evidenced through the prototypes. Since the modules' scope widened organically over the past four semesters, the impact on the prototypes varies and the latest version (2017-2018, spring) is the most impactful and mature. The findings are illustrated in graphs 3-7.

Figure 3 illustrates the increase in the number of fully functional projects across different levels of complexity during the five semesters. The data during 2015-2016 (spring) data is considered as baseline data for the study. It is apt to highlight here that the baseline data does not have projects at level 4. However, for all subsequent semesters, a deliberate attempt has been made by the authors to include projects across all four complexity levels.

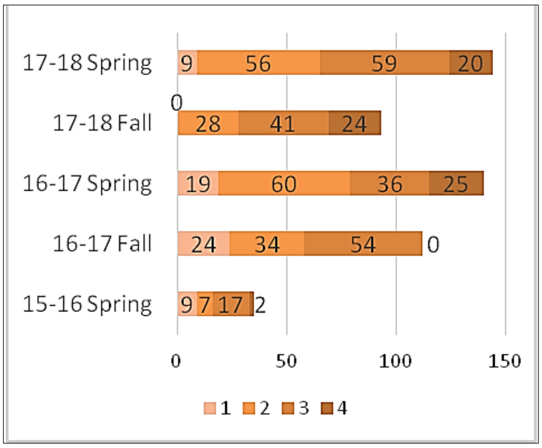

Figure 4: Total projects and complexity levels

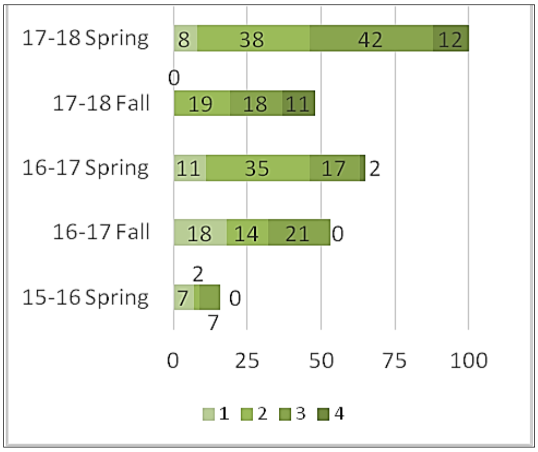

Figure 4: Comparison of fully functional projects w.r.t complexity

During 2017-18, fall, there were no projects falling in mechanical complexity-level 1 (missing blue bar). Otherwise the blue bars across the semesters appear consistent. Examination of the project videos has revealed that projects with mechanical complexity level 1 can be prototyped and made functional using "quick hacks/Jugaad". Such projects can be successfully demonstrated for functionality but lack reliability, rigidity and physical stability which usage of "engineering methods" can bring in. For description of "engineering methods", refer to section 3.

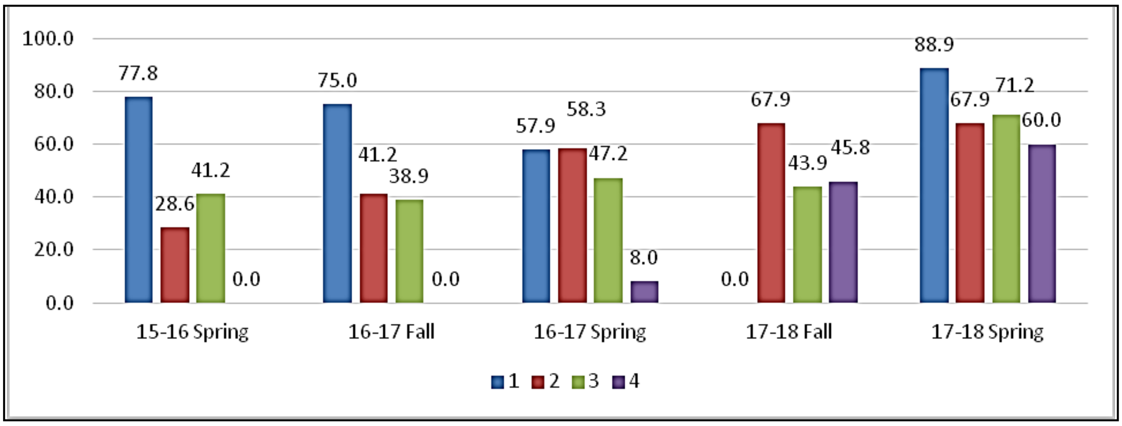

Figure 5: A comparison (%) of functional projects w.r.t complexity over 5 semesters

Figure 4 shows the degree of complexity in projects across the five semesters. The projects of complexity 4 were introduced during 2016-2017, fall semester. As discussed in section 5, the complexity is dependent upon the number of mechanisms and speed along with torque or power requirements for the proposed solution. As the number of mechanisms increases, the systemic complexity increases. This leads to many interfacing and fabrication challenges which the students should address.

Figure 5 depicts the number of functional projects in percentages and their split across complexity levels across the five semesters. The percentage of fully functional projects with complexity level 1, has remained almost same across the semesters. This is due to lower systemic complexity in physically realising them. A gradual increase in the percentage is observed for projects with level 2 complexity. During the first two semesters, there were no projects belonging to complexity level 4. We can notice a steep increase in such projects during the latest two semesters. This steep increase can be ascribed to the systemic initiatives introduced in the form out-of-class activities for mechanisms module as discussed in section 3.3.3. In entirety, from graphs 3, 4 and 5, we can infer that the number of successful projects with higher mechanical complexity is increasing, which is the overall objective of introducing innovations in the mechanisms module.

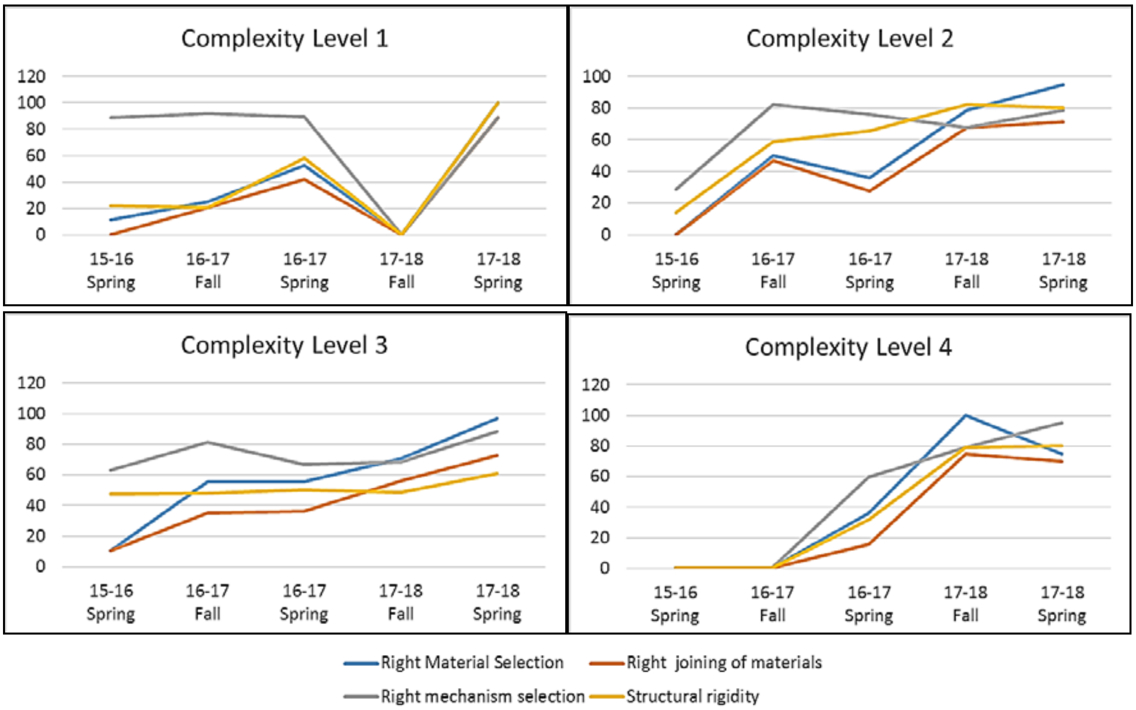

Figure 6: Use of “Engineering methods” in prototypes of varying mechanical complexity levels

Figure 6 shows the number of projects across five semesters which illustrate the presence of ‘Engineering Methods’, for the complexity levels of 1 to 4. During 2017-2018, spring semester, there has been a progressive rise in the number of solutions which have been prototyped using engineering methods as compared to ‘Jugaad’.

Comparing the figures 4 and 5 (increase in number of functional projects) with figure 6, the authors can infer that there is improvement in quality of project in terms quality and reliability which can be attributed to “engineering methods” viz. material selection, joining of materials, mechanism selection and structural rigidity which was progressively introduced in the module on mechanisms.

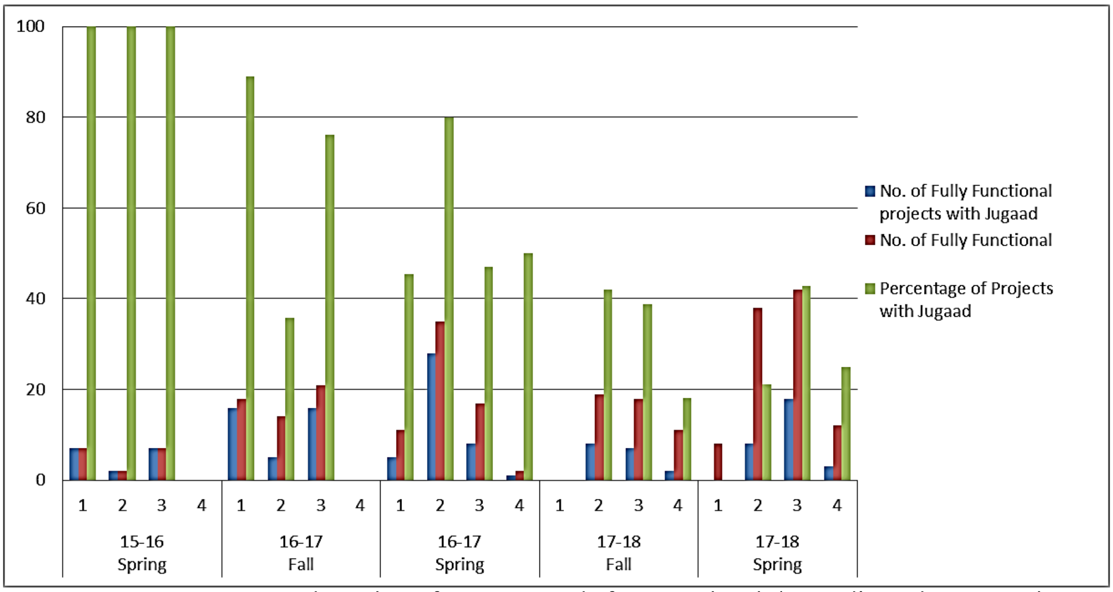

Figure 7: Percentage and number of projects made functional with 'Jugaad' mind-set over the semesters.

It can also be observed from figure 7 that over the past five semesters the percentage of projects with 'Jugaad' mind-set is reducing for all levels of complexity.

6 Conclusion

This paper focuses on developing making skills among freshmen through introduction of a module on mechanisms. Authors observe a fair degree of success in their efforts. The continuous innovations in the curriculum of mechanisms module has resulted in better quality projects. The percentage of projects with 'Jugaad' mind-set is reducing as engineering methods are prominently visible in the students' projects over the semesters.

The study in this article is restricted to mechanical aspects only. However, it is to be noted that electronics subsystems also play important role and required skills are to be acquired as any complex mechatronics systems does have complex electronics sub system as well. The effect of introducing engineering methods in electronics aspects of the projects has also played a role in making students' project successful, which is a part of another study.

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Active methodology like Problem Based Learning (PBL) and cases solutions. ¿Do the students develop metacognitive skills?

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Abstract

The purpose of this research is to determining to what extent the application of active methodologies, specially selected and design for the first years of engineering careers, help increasing student´s metacognitive abilities students. With this in mind, we selected two universities from Lima; they both use active teaching methodologies, but with different approaches. One of the universities uses the Problems Based Learning (PBL) based methodology; while the other university uses as a basis, the online Case-Solving. In both cases, the situations are contextualized and designed in order to develop abilities in the students.

This study used a mixed approach. A Likert scale test was used to measure the metacognitive skills before and after applying the methodology, in order to analyse its evolution. Additionally, individual interviews were conducted with students involved in the process, in order to identify which factors might be relevant to the development of the sought skills.

The results of the research proved that both are appropriate methodologies to develop metacognitive skills in the short time, and that one of them can provide better results than the other. In addition, the importance of context of the group where the methodology was applied has been fundamentally emphasized, as well as the modes and forms in which it is applied, highlighting the leading role of both student and teacher.

Keywords: metacognitive skills, learning and active methodologies, metacognition and learning

Type of contribution: research paper

1 Introduction

Now, it is more and more evident how we need to prepare our Engineering students to face their professional future. It is necessary to prepare them, not only in their profession, but also in developing competences like critical thinking, assertive communication, teamwork, solving problems skills and especially self-assessment; of their own competences and reflecting about that. That is one of the reasons why there are many criteria to assess the quality of Engineering program. One of them is based on United States Accreditation of Engineering Technology (ABET 2016). The focus in I+D+I (investigation, development and innovation) requires for Engineers to have the capacity to solve problematic situations with social responsibility and etic engagement.

Basic sciences are a part of curriculum in the Engineering career. In our university, the students must study Physic, Mathematic and Chemistry courses in the firsts two years. Chemistry is an obligatory course of the Engineering curriculum. However, the students consider it is a difficult matter, unnecessary and boring. That was reflected in the large number of students who failed to pass this matter. In the words of students; they find Chemistry hard to understand and weren´t able to find a real application or relevance for their profession.

For a long time, the number of failing students was high. The situation was more or less the same in many universities of Lima, Perú. Some universities decided to change this situation in order to achieve, the necessary competences for the Engineering carrier. In 2006, university A began to teach Chemistry with a hybrid methodology based on Problem Based Learning (PBL) and university B decided to teach Chemistry based on line Cases-solving.

In both universities, the methodology is completely different in classes. At university A, students worked in teams of four at all times, they solved mini-problems. The teacher previously designed the activities. There were different types of activities: concept forming, applied concept and concept assessment. The teacher guides the teamwork and explains, a few times for clarifying and answering questions. At university B the teacher first explains and then the students solve contextualized problems applying the concepts they just learned. They can work alone, in pairs or in teams.

In both cases, the design contemplates training them to make decisions and explain these them. Table 1 compares the two methodologies.

Table 1: Comparing methodologies. (Semester 2017-I)

University A (Based ABP)	**University B** (Based online Case-Solving)
- Hybrid methodology based on PBL	- Hybrid methodology based on Case-Solving.
- The sample was integrated by 46 students of the first year of the programme who had basic knowledge acquired in high school.	- The sample was integrated by 26 students of the first year of the programme who had basic knowledge acquired in high school.
- The PBL problem is presented to the students in the first class. In that moment they recognize that they know and how much they Know about the situation. The problem is usually about some kind of industrial problem and it means the 20% of the final grade of the course. The students must suggest possible solutions to the problem situation and analyse these throughout along the four units of the course. There is an integrating stage where students must made their final proposals and defend them publicly. Rubrics are usually used in this process.	- The case is presented to the student in the virtual platform. They know when they find it. The situations are presented depending on the unit. There are five different Case-Solving. The five cases have a weight of 24% of the final grade. Each case consists of three parts: a question related to the subject which the students must answer individually and discussing it with their classmates in a forum. After, they do a quiz and finally they work on the case. There is a rubric for evaluation
- For the PBL problem, the students work in groups of four and they must do their independent research outside the classroom. They receive permanent feedback, evaluation rubrics, and do co-evaluation and self-evaluation of their group work.	- For the Case-Solving, the students work in groups of three, four or five. They work on the cases presented in the virtual platform outside the classroom. They can receive online teacher feedback.
- Four weekly hours of class in the classroom where students acquire the knowledge by working on the activities the teacher designs to learn, apply and evaluate concepts. Activities take into account students' previous knowledge or well-known situations of daily life. It is students' responsibility to find the activity in intranet, print it and bring it to class. Students work in the same group outside and inside the classroom.	- Four weekly hours of class in the classroom where students acquire the knowledge by working on pre-elaborated worksheets. First the teacher explains the concepts, then, the students apply them. The teacher gives students the worksheet. They can work individually or in groups. Students can choose their groups outside for the session class and inside the classroom for the Case-solving.
- In the classroom, the teacher's role is of a facilitator and counsellor, he answers questions and helps with doubts. Occasionally he draws to conclusions at the end of class or interrupts students' work when it is necessary to clarify ideas.	- In the classroom, the teacher's role is explains the concepts. Then, his role is of a facilitator when students work in the worksheet, answers questions and helps with problems.
- The students have access to power point presentations of content (on the intranet) which they can use during the sessions by using their electronic devices. Sometimes	- The students have all the content of class in their virtual classroom. They can use it in the face to face session on their electronic devices. Sometimes at

before the session, they have to read or do a concept map. - Along the semester, there are five laboratory sessions, where the experimental part is developed.	beginning of the session they solve tests to verify previous knowledge (Kahoot) - Additionally, there are six laboratory sessions, where experimental part is developed.

In recent years, research has been done to seek for the best methodologies for the teaching-learning process. In addition, curricular changes have been introduced to develop more skills and competences and not only the teaching of content. Also, formative assessment has become very important. In consequence, there is a search for some key-competences in engineering carriers, like critical thinking. (Guerra, 2016, Kolmos 2016).

At the same time, the assessment process plays a fundamental role (Lopez Pastor, 2012). Some methodologies such as Problem Based Learning (PBL), Project Based Learning and Case-Solving meet the requirements of coherence between the process and its evaluation.

Both methodologies, PBL and Case-Solving are based on teamwork or social interaction and they require some conditions:

- Their structure has to depend on each individual input. It implies their design is the key.
- The interaction has to be direct and permanent. It can be face to face or through multiple internet options.
- Students must take individual responsibility of their work and guarantee their commitment.
- The group needs to assess the process of their own work and reflect about it in order to improve their performance.

However in this research we did't measure the critical thinking, our aim was measure the influence of methodology in develop of metacognitive skills.

1.1 Metacognitive skills

Motivation and metacognition are two complex concepts, but closely related. Motivation drives us to want to do something. In the case of students, when they feel motivated, it means that they actually want to learn. Metacognition means becoming aware during the learning process about their weaknesses and their strengths when solving a problem. (Mc Cluskey et al, 2013)

The term metacognition is not recent; Flavell, (1979) named it like metamemory and, later, defined it as cognition about cognition. When we face a task, some strategies are required, then, we: select the contents, look for relations among them, organize them, give them structure to understand their meaning and transfer them to a new situation. Learning to use these strategies makes the student self-regulated.

The metacognitive skills plan and supervise the action of the strategies and have a double dimension: knowledge and control (Torreblanca & Rojas Drummon, 2010).

Metacognitive skills refer to the fact that students know, use and select cognitive strategies which they think are appropriate to solve a problem. Not only that, but the student also reflects and evaluates the results that come from the use of those strategies. (Torreblanca & Rojas Drummon, 2010).

Since the curricula asks for graduate engineers to have fully developed the competences asked from them, it is only logical to assume that students are developing metacognitive skills in order to achieve this goal. Then, we decided to measure to what extend active methodologies help students develop metacognitive skills. We also wanted to know which factor students considered important when developing metacognitive skills.

To measure the metacognitive skills, we applied the test of Cooper, M. Sandi-Ureña, S (2009). We applied pre and post-test, at the beginning and the end of the academic cycle. To find out what the students considered important factors to develop metacognitive skills we conducted in depths structured interviews.

There are many examples of research when we told about metacognitive skills. The same authors who elaborated the test we have applied in his research analyses them. They measured metacognitive skills when students faced chemical problem. They had to identify a series of substances and choose which sample correspond with each substance. They used a software that allows to follow how they had thought and because they had decided to select one or another prove.

Other authors have measured the metacognitive skills in PBL environments but not in the learning of chemistry. Althought it was qualitative research, students' metacognitive skills were increased (Ley Fuentes, 2014). In relation to critical thinking in chemistry learning environments have also been investigated with encouraging results especially when students work in basis on PBL. (Rivas, S. et al 2014).

For several years we have been collecting both qualitative and quantitative information and so we have evidence of some achievements such as: more students pass the course, they improve their communication skills, teamwork improve, the attitude of the student change, students increase their research interest, etc.

However, motivation, critical thinking and metacognitive skills are very complex to measure since many factors must be taken into account. The instruments to measure these are insufficient and reality surpasses it.

The information which has been collected during these years and the conversations with students lead us to ask ourselves:

What is the degree of influence of active methodology based on PBL and online Case-Solving methodology in the development of metacognitive skills in the first year of their career in two private universities when students solve industrial chemical problems?

We also needed to answer these two questions:

-Do any of these methodologies develop to a greater degree students' metacognitive skills?

-What aspects influence significantly in the development of metacognitive skills?

My proposal was: Both methodologies have a similar influence in the development of metacognitive skills. That is true when they are well designed and there are several factors that facilitate their development.

2 Methodology

The nature of this research was descriptive and explanatory. It was designed to analyse the change of each group in relation to their metacognitive abilities and the reasons for this. Therefore the information was collected as follows:

- Quantitative phase: we applied a test at the beginning and at the end of the semester to measure the increase of metacognitive skills. The data was analysed statistically.
- Qualitative phase: an interview guide was designed for the explanatory part to look for expected and emerging categories

Table 2: Techniques and instruments of recollecting data.

Technique	Instrument	Sample
Test	Test metacognitive skills (quantitative)	Students of two universities pre and post-test with their own active methodology
Individual Interview	Semi-structure Interview (qualitative)	Ex-students of the Chemistry course

2.1 The test

The instrument was taken from the inventory of metacognitive activities (MCAI) by Cooper, M. & Sandi Ureña, S. 2009. It was designed to measure metacognitive skills when students solve chemical problems.

The instrument uses a Likert scale from 1 to 5 where 1 means strongly disagree and 5 means strongly agree. It has 27 items which 13 of them correspond to the dimension of knowledge and 14 belong to the dimension of regulation. It has validation of construct by cross method with an internal reliability, Cronbach's alpha of 0.85 and a Pearson correlation of 0.64.

2.2 Individual Interview

The interviews lasted approximately one hour and all of them were recorded in audio. The preliminary content of the interview was validated by experts. The interview included open questions in search of the expected and emerging categories. The interview was conducted to find: effort made, feedback offered, impact on the evaluation, strategies they used, classroom climate and other aspects that students considered may influence their metacognitive skills.

2.3 Population and sample

In university A there were 46 students enrolled in the general chemistry course and in university B there were 26. All of them were included in the study. Both universities have a similar infrastructure in classrooms and laboratories. The groups were homogeneous in relation to their ages and gender. Table 3 compares the study groups.

Table 3: Characteristic of the study groups

Characteristics	University A	University B
Methodology	On basis PBL	On basis cases solving
Class organization	Group of 4	Individual or in pairs
Laboratory Organization	The same groups	Groups of 3
Students	46	26
Age	17 to 21	17 to 21
Gender	70% male, 30% female approximately	70% male, 30% female approximately

2.4 The process

- We made sure the methodology was being used in each university.

- At the beginning of the semester, a pre-test was taken for evaluation of metacognitive skills. At the end of the semester a post-test was taken to measure the new metacognitive skills. The test was given to volunteers and it was anonymous. The way to call for volunteers for the interview was this: when the teacher gave the test to students they were told "if you want to be interviewed, it is necessary you write your name in the test". In the post-test, we reminded them to write their name again. There were 5 volunteers in university A. One of them was not interviewed because he was a minor. He was 17 years old. In university B four students were selected in the same way. Four interviews were conducted in each university.

- The quantitative and qualitative data was processed.

3 Results

The research had a mixed approach and with two independent phases and the information was analysed with the aim to answer the research questions.

3.1 The quantitative results

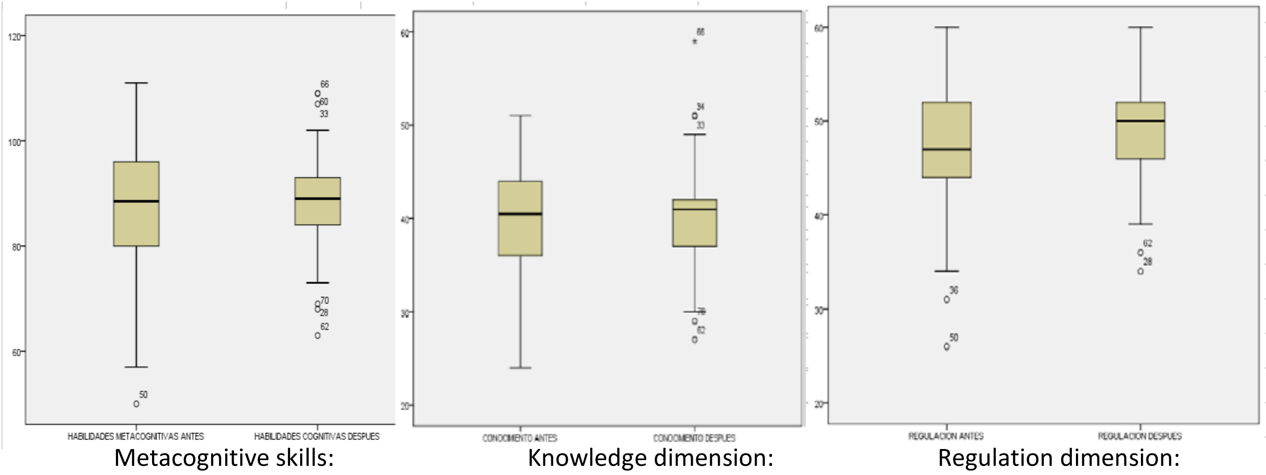
The quantitative data was analysed statistically with SPSS software version number 24 and Wilcoxon's T was used because the samples are related. The population decreased during the semester in one student at university A and two at university B. It was considered those students who studied the whole semester. The results can be seen in the following tables and figures.

In the figures and tables shown, we can appreciate the changes in the score of the test. We see, that although only in university B, these changes are significant statistically ($p < 0.05$).

It must be taken into account that there are also small changes in university A.

Table 4: University A, change in metacognitive skills

Variable	Measure	n	Half	Standard deviation	z	P
Metacognitive skills	Before After	46	87.3 88.8	13 9.8	-0,73	0.47
Knowledge dimension	Before After	46	39.9 40	6.1 6.1	-0,33	0,75
Regulation dimension	Before After	46	47.4 48.9	7.5 5.3	-1,24	0.22

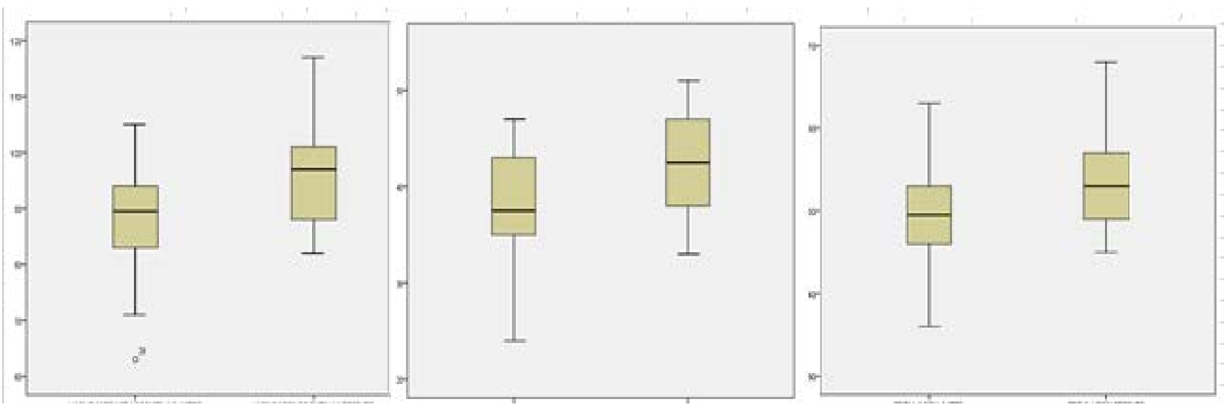


Metacognitive skills: Before After
Knowledge dimension: Before After
Regulation dimension: Before After

Figure 1: University A, applying Wilcoxon T

Table 5: University B, change in metacognitive skills

Variable	Measure	n	Half	Standard deviation	z	P
Metacognitive skills	Before After	26	88 95.5	9 9.4	-2.96	0.003
Knowledge dimension	Before After	26	37.9 42.3	5.5 5	-2.88	0.004
Regulation dimension	Before After	26	50 53.5	6 5.5	-1.88	0.06



Metacognitive skills: Before After
Knowledge dimension: Before After
Regulation dimension: Before After

Figure 2: University B, applying Wilcoxon´ T

3.2 The qualitative results

The information provided by the qualitative data shows the relevance of the context of the sample. We thought that the samples were similar due to the similarities regarding sex, age and infrastructure in each university. But the interviews offer a different perspective.

The purpose of the interview was to know how much a student knows about his own cognitive process when solving an industrial chemical problem. The questions were open, the students expanded their opinions and were open about their feelings. It was expected that some categories would emerge, however in university A, students' comments were especially relevant.

In the semester 2017-I there were many problems with teamwork. There were some factors that influenced in the results. For example, we usually have between five and ten percent of students with scholarships, however this term we had thirty percent of them granted by the government. It is important to mention these students usually work really hard because they want to pass their courses. However, even when they are good at applying algorithms, they find it difficult when they must analyse, decide and argue.

At the beginning of the semester, groups of four were formed with one or two scholarship students. The intention was to keep diversity. Often, these students work individually because they are concerned about their grades. This problem could be solved but one semester is very short. Another fact that influenced the results was it was only in the chemistry course where students worked in heterogeneous groups while in the other courses it was different.

In addition, the curriculum was also modified. A course that belonged to the third semester was moved to the second one. That was another reason why students were very concerned and said they had a lot of work to do.

Most of opinions favoured the methodology and achievements. Comments like "it made us know more"... ..."it helped us to find an answer on our own"...." Making connections with real facts allowed us to have a broader vision of the topic and to consider the aspects that influenced it"... "It allowed a better development of skills to defend our position"...." Making a mistake was not bad, it helped us to see where we were wrong"... etc.

It was also relevant for the student.

- A good relationship with teachers and classmates as it resulted in motivation towards learning.
- A varied and timely feedback because it allowed them to recognize errors and reformulate their proposal.
- Working on their solutions allowed them to acquire organizational capacity and responsibility.

However, regarding the difficulties, it was the transfer of knowledge from one reality to another and in teamwork, the difficulty arose when they faced different points of view to solve the problem.

The table 6 tries to categorize the information about these difficulties.

Table 6: the student´ relevant aspects to develop metacognitive skills

Expected category	Emerging category	Comments
Transferring knowledge from one reality to another	Difficulty interpretation	"When solving a problem, it is easier to find a numerical answer than to give a scientific interpretation to this result…"
	Applying the Knowledge	"Frequently, when I solve a problem It is difficult to think why or how I would apply it to another problem" " It is difficult to decide what kind of information you can apply in another situation"
Rating teamwork	Self-knowledge	"..It was hard for the group to walk in an organised way..." "...It can be exhausting if only one knows…" "The team work is great if you work with people who take responsibility of their work, if not, it is frustrating"
	interactions	"I learned how to deal with the ones who don't collaborate...." "We helped each other and learned to share ideas" "….. discuss the issues and do our self-evaluation" helped our teamwork" "It is difficult to work with others but finally the teamwork helped us to respect others' opinions."
	Acquire skills	"Discussing anything we didn't understand was good because later we could identify our own skills in order to contribute the team work " "We found difficult to learn to delegate work and trust the others…"
Having to face a variety of solutions		"We are used to the fact that a problem has one solution, so looking for alternatives was really demanding" " … we doubted when we had the solution, we didn't want to look for another one"

3.3 Discussing the results

Solely on the basis of quantitative results, we should say that the best methodology to increase metacognitive skills is the online Case-Solving. However, qualitative data provide a different point of view.

Quantitative and qualitative results seem contradictory but it is not really like that. The University A students felt motivated but also felt very pressure, this is the reason for the 2017-I results.

The main problem was to make students work in a team. They worked with others but they didn't compromise on the work. It was seen in the term 2017-II when we applied the test again and the result was very different. The figure 3 shows the data 2017-II and the different reality.

Figure 3: Comparing metacognitive skills growth between semester 2017-I and semester 2017-II at university A

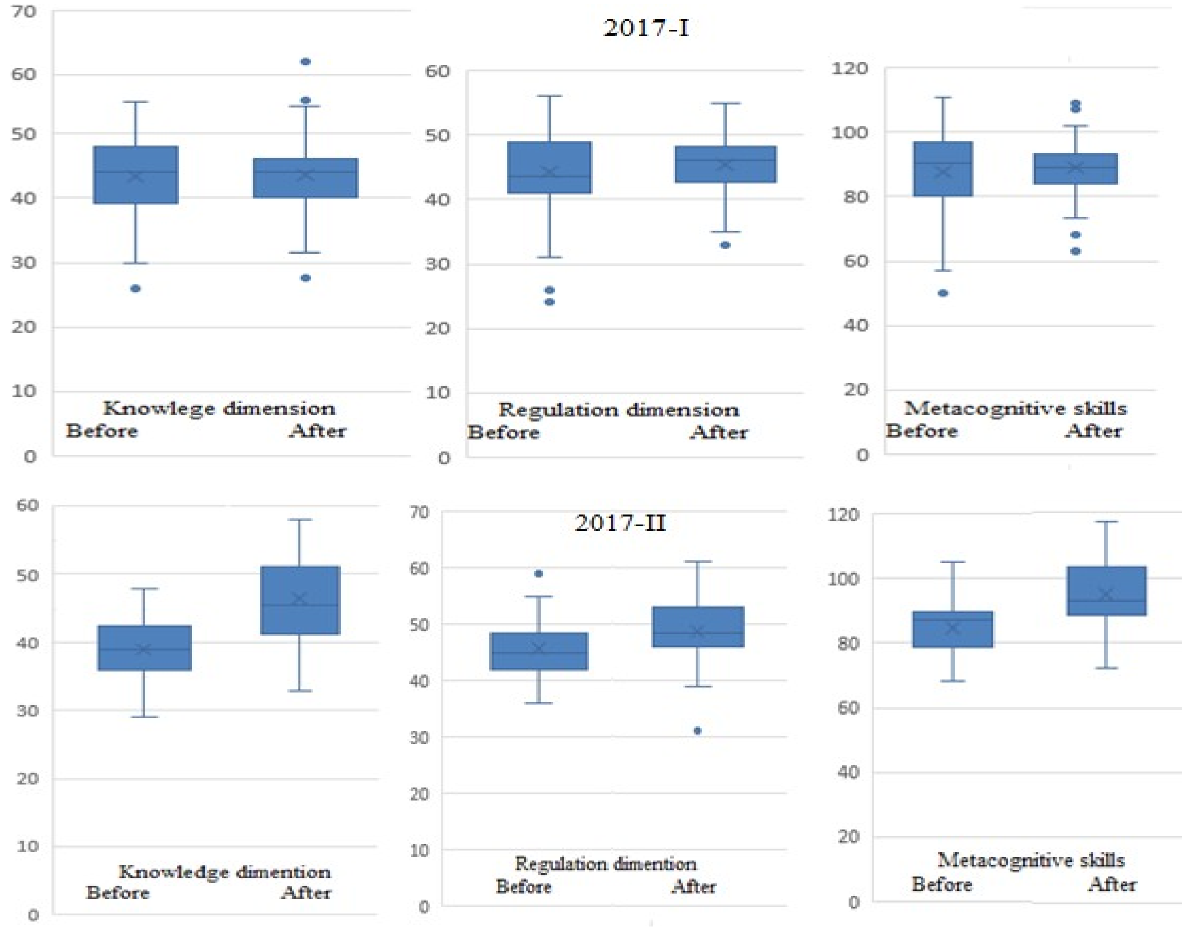


Table 7: Comparing University A change in metacognitive skills

Variable	Measure	2017-I (n=46)		2017-II (n=41)	
		Half	Standard deviation	Half	Standard deviation
Metacognitive skills	Before After	86,88 88.27	12,88 9,79	84,6 94,4	8,61 11,86
Knowledge dimension	Before After	42,88 42,92	6,48 6,53	39 45,97	4,78 6,44
Regulation dimension	Before After	43,53 45,2	7,02 4,65	45,45 48,2	5,14 6,51

An important detail to mention is that when we review the test negative questions score´ at the University A. They decreases their score substantially in the post test. That happened in five of the six the negative questions 20, 22, 24, 25, 26 and 27. Perhaps, the most notable change was in the question 22: Once I know how to solve a problem, I did not spend time to understand the involved concepts.

Results confirmed the strong influence of students' context. The conversations registered in 2017-I had already given several reasons for the unexpected results, but the new measurement allowed to confirm the role of the context.

Both methodology and the type of assessment were the same, but the group was different. In that case, there was the same methodology basis on PBL. But, there were fewer government scholarship students, groups of four were randomly formed and they were taught according to the new curriculum to which they were more adapted.

4 Conclusions, recommendations and reflections

The research was intended to identify which of those two methodologies can develop more easily metacognitive skills in the engineering student´.

4. 1 Conclusions

We can offer some conclusions about both methodologies when we analyse qualitative and quantitative information.

- The quantitative data indicates that Case-Solving is better than PBL when it is aimed to develop metacognitive skills. This is a really incomplete conclusion. When we analysed the qualitative data we realized that it happened because in that moment each group had a different context and their needs and requirements were different. We can see it in the results of 2017-II.
- By measuring the increase of metacognitive skills in first-year engineering students, we were able to see the influence of the methodology. The increase in university A was not statistically relevant but it is not totally true because when we reviewed the score in the questions expressed negatively, they showed a decreased score.
- Metacognitive skills are a complex concept. The results show the relevance of measuring metacognition from several points of view.
- In one semester, the increase of metacognitive skills was seen in a significant percentage, although it is usually a slow process.
- In agreement with the answers given by the students, there are many factors which affect the student' motivation:
    - A good design of the problem or case increases the interest of the student and makes it possible to connect it with the reality, its application and besides it keeps the interest throughout the process.
    - A good relationship with tutors and peers increases motivation and facilitates teamwork
    - Appropriate feedback is highly relevant. Students need guidance and ongoing training when they want to learn a special skill. If we seek to develop metacognitive skills, we need to coach them.
    - They need to do real teamwork. It is the most difficult to achieve but the work of each of them in the group is the strength to build lifelong learning.

4.2 Recommendations

The results of the test and the interviews allow us to measure and analyse relevant aspects to develop metacognitive skills, then based on these findings we recommend:

- *We must achieve that the student is aware of his own learning process.* They are not used to take control of their learning and continue expecting the teacher gives them all the information. It is difficult for them to think critically and analyse their work. Therefore, they need training and internalize their process and must recognize their own objective. It is our task to help them to achieve it, especially in their first year of study.

- *The participation of the teacher is decisive.* The teacher is who designs the activities, the problems, the cases, the rubrics, and decide how to evaluate these, how to approach to these, how why and when to give feedback. Then, the teacher needs to be aware his decisions influence in their students. Therefore the teacher must be very careful in every detail when addressing students.
- *The interactions teacher-student-student.* Interactions occur all the time, in the classroom and outside of it. We require a permanent dialogue whether face to face or virtual. When we show affection, enthusiasm and solidarity to the students, we transmit motivation towards learning. They respond directly or indirectly by valuing and recognizing their own cognitive and metacognitive skills. Indeed, the human factor and relationships can help the inclusion and democratization of learning. (Castro-Carlin, y Lavado Padilla, P. 2016).
- *Adequate feedback.* We have to give students the opportunity to get feedback. But this feedback must be timely, when they need it. It is necessary to consider enough spaces for it. That feedback should include the justification of each change that they decide to make. By closely monitoring the process, you help them internalize the concepts and better manage their skills. Well-targeted feedback should increase critical comprehension (Guerra & Holgaard 2016) and help to recognize and avoid potential mistakes, abilities that an engineer requires.
- *The work context.* When the teacher presents a problem or case, he must know the specific context. The research places it as relevant. If we want to achieve good results, we should adapt the problem or case to the real context.

4.3 Reflection

This research was conducted based on what we have been doing during these last years. We expected PBL methodology was better to develop metacognitive skills but the quantitative result surprised us. The qualitative data helped us to understand the reason in that time. Then, we looked back and learned not to take for granted that results will not change through the time.

Previously, information on metacognitive skills was compiled with other instrument. The author of this research designed an instrument and it was used to measure metacognitive skills with good results (Cañas, 2015). However, although this instrument has good validity and reliability, it still needs to be validated in other contexts. In this research we used the test of Cooper and Sandy-Ureña, because this instrument was validated in the United States, Spain and Peru and was applied in the solution of chemical problems where teamwork was also considered.

After the result of this research, I decided to apply both instruments in the 2017-II semester and compared results, we were obtained very similar results. This research shows the corresponding results to the Cooper and Sandi- Ureña test, in order to be able to compare the results of the two semesters by using the same test.

My conclusion is that it does not matter which of the two methodologies are used. When the requirements are fulfilled, which have been expressed in this research, it is expected to obtain an optimal result with any of them when developing metacognitive skills.

In my opinion, an important advantage in problem-based learning is that it allows the student to work with the same team for a longer time. It values more the teamwork and thereby facilitates the formation of other skills

Through the results, we know that in order to improve our performance as teachers, it is necessary that in the future we have a special interest to design materials and situations which deliberately stimulate students' metacognitive skills. We observe that our students are constantly changing and we must adapt to their needs.

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Measuring student perceptions of tutor effectiveness in problem-based learning

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Abstract

Although numerous studies on tutor effectiveness in problem-based learning can be found in the literature, there is a paucity of studies that employ psychometric-tested survey instruments. This study aimed to validate a survey instrument to evaluate tutor skills in problem-based learning. A sample of 1162 polytechnic students undertaking the Cognitive Processes and Problem Solving course participated in the study by filling out an online survey to evaluate their tutors. The sample was randomly split into 2 sub-samples to conduct the scale validation. Exploratory factor analysis (EFA) was conducted on Sample A (N=571) to select the items and determine the number of factors. Confirmatory factor analysis (CFA) was conducted on Sample B (N = 591) to cross-validate and confirm the factor structure of the scale determined in the EFA. Both EFA and CFA provided empirical support for a three-factor model solution and showed a good model fit. Each subscale demonstrated good internal consistency reliability and predictive validity. The three subscales were (a) developing disciplinary skills and knowledge (5 items); (b) managing peer learning (3 items); and (c) facilitating learning process (3 items). The potential use of the survey instrument, along with directions for future research are discussed in the paper.

Keywords: validation, instrument, evaluation, tutor, problem-based learning

Type of contribution: research paper

1 Introduction

The underlying principle of problem-based learning (PBL) is social constructivism, which seeks to create an environment where students learn in the context of solving meaningful problems, constructing mental models, co-creating knowledge through collaborating with peers in a team and engaging in self-directed learning (Hmelo-Silver, 2004; Norman & Schmidt, 1992; Schmidt & Moust, 2000). Compared to traditional classroom learning, in problem-based learning, students take on the role of knowledge collaborators instead of knowledge recipients, and teachers assume the role of facilitators of learning as opposed to knowledge transmitters (Goh, 2014). Numerous studies have shown that PBL teachers (tutors hereafter) played important roles in impacting students' outcomes, including quality of students' learning experiences, their motivation to learn (Chung & Chow, 2004; Rotgans & Schmidt, 2011), group functioning (Van Berkel & Dolmans, 2006), and academic achievements (Schmidt & Moust, 1995; De Grave, Dolmans, & Van Der Vleuten, 1999).

In PBL, the tutors are expected to scaffold students' learning and help them to construct knowledge, probing the students to think deeply and modelling for them the kind of questions that they should be asking themselves during problem solving (Chng, Yew, & Schmidt, 2011). The tutors are also expected to follow the discussion generated by the students closely, and consider when and how they may intervene and contribute to the learning process (Wetzel, 1996).

Many studies have been conducted to better understand the roles of the tutors in PBL by identifying attributes and behaviours of effective tutors. Mayo, Donnelly, Nash, and Schwartz (1993) identified two important characteristics of effective tutors as helping students to identify important issues and providing feedback to students along with encouraging feedback from the group. In another qualitative study, Goh (2014) identified three attributes of effective tutors in a PBL classroom: (a) repertoire of questioning techniques when responding to learning issues; (b) timeliness of interventions when students are facing learning obstacles; and (3) awareness of the individual student's learning goals and situations.

Several studies on the influence of tutors' subject-matter expertise on students' achievements remain inconclusive. For instance, Davis *et al*. (1992) found that students facilitated by expert tutors showed higher academic achievement compared to students facilitated by non-expert tutors, whereas Dolmans, Wolfhagen and Schmidt (1996) found that tutor expertise did not influence student achievement. A study by Silver and Wilkerson (1991) on the facilitation process by expert versus non-expert tutors suggested that tutors with subject matter expertise tend to play a more directive role in facilitation by providing answers to questions posed by the students and suggesting more ideas for discussion.

In a study to profile effective PBL tutors using the Tutor Intervention Profile (TIP) instrument, De Grave *et al*. (1999) found differences in facilitation styles, where one group of tutors relied more on the use of expert knowledge, whereas another group of tutors relied more on their abilities to stimulate the learning process in the group. What was noteworthy in the findings of the study was that tutors who emphasised on the learning process in the group were perceived to be more effective than tutors who emphasised content, although the differences were not statistically significantly.

1.1 Measuring PBL Tutor Effectiveness

Several studies on using instruments to evaluate PBL tutors have been found in the literature. For instance, De Grave, Dolman, and Van der Vleuten (1998) developed a 33-item instrument to evaluate behaviours of the tutor in the group when students analyse the case, generate learning issues and report to the group about their findings during self-study. The four factors are (a) elaboration, (b) directing the learning process, (c) integration of knowledge, and (d) stimulating interaction and individual accountability.

Using the constructivist approach to learning in PBL and intrapersonal behaviours of the tutors, Dolmans, Wolfhagen, Scherpbier and Van der Vleuten (2003) developed a 22-item questionnaire to evaluate the effectiveness of PBL tutors based on five theoretical dimensions: (a) constructive/active learning, (b) self-directed learning, (c) contextual learning, (d) collaborative learning, and (e) interpersonal behaviour of tutors. Recognising students' fatigue when filling out a long questionnaire, Dolmans and Ginns (2005) developed and validated a short questionnaire consisting of 11 items using the similar five factors as Dolmans *et al*. (2003).

Dolmans, Wolfhagen, Schmidt and Van der Vleuten (1994) developed and validated a 13-item instrument to evaluate tutors' behaviours in responding to a set of tasks based on three factors: (a) guiding students through the learning process, (b) content knowledge inputs and (c) commitment to the group's performance.

The survey instruments to evaluate PBL tutors in the above-mentioned studies were developed predominantly in the context of medical schools in universities. To date, few instruments have been developed to evaluate PBL tutors in the post-secondary institutions. Hence, this study is an attempt to fill the gaps in the literature by developing and validating an instrument to evaluate the effectiveness of PBL tutors in a polytechnic.

2 Research Questions

The primary purpose of the study was to develop and validate a PBL Tutor Effectiveness Questionnaire (PTEQ) that evaluates the behaviours of PBL tutors. The following research questions were formulated to guide the data analysis:

a) What is the factorial structure of the PTEQ scale?
b) What is the validity and reliability of the PTEQ scale?

3 Method

3.1 Participants

A total of 1162 first-year diploma students undertaking Cognitive Processes and Problem Solving module participated in the study by filling out an online questionnaire that evaluates their tutors' effectiveness in facilitation. The majority of participants were male (55.1%) and their average age was 18.01 years (SD = 1.39). A total of 46 PBL tutors, consisting of 19 full-time and 27 part-time tutors, were evaluated by the students. The data from 571 randomly selected participants were used for exploratory factor analysis (EFA), and the data from the other 591 participants were used for confirmatory factor analysis (CFA). In total, data from all the participants (N=1162) were used for structural equation modelling.

3.2 Educational Context

This study was conducted in a polytechnic in Singapore which delivers more than 260 modules each semester from a wide range of diplomas in various fields. Majority of the modules are conducted using the PBL approach, where a problem scenario is presented to a class of 25 students who work in small teams of five with a class tutor, once a week over a 13-week semester. Each PBL lesson consists of three learning phases and interspersed by two periods of self-study (O'Grady, Yew, Goh, & Schmidt, 2012). The module chosen for this study is a compulsory first-year general module, Cognitive Processes and Problem Solving.

3.3 Procedures

During week 10 of the 13-week semester, an email with an online questionnaire link was posted in the course announcement of the Learning Management System for students to participate in the study. The duration of the online questionnaire was 10 minutes, and students were given a 2-week period to complete the questionnaire. The study was approved by the Polytechnic Institutional Review Board (IRB) and was conducted accordingly.

3.4 Measures

The item pool was mainly drawn from items selected from the existing measures of PBL tutor behaviours and characteristics (De Grave *et al*., 1998; Dolmans *et al.*, 1994, 2003; Dolmans & Ginns, 2005) as well as newly crafted items based on the principles of effective teaching and learning in the institution where the study was conducted. The number of proposed items for each factor are: 6 items for 'Developing Disciplinary Knowledge and Skills', 4 items for 'Managing Peer Learning' and 3 items for 'Facilitating Learning Process'. A sample item was "The lecturer explained complex concepts in simple terms". A 5-point Likert rating scale where 1 indicating 'strongly disagree' and 5 indicating 'strongly agree' was used for all the PTEQ items.

To ensure content validity, the items were reviewed by three experienced full-time PBL tutors with at least 10 years of teaching experience. A 3-item measure of Perceived Value of Learning (PVL) was included in the study as an outcome variable to test for predictive validity, and this was adapted from the individual interest scale by Rotgans and Schmidt (2014). The three PVL items were "I learned many useful things in the module", "I find the module relevant to the job I may undertake in future" and "I am clear about the learning outcomes of this module". The Cronbach's alpha coefficient for the PVL measure in the current study was .93.

4 Results

4.1 Descriptive Statistics

The descriptive statistical analyses show that the mean ratings of all the items ranged from 4.24 to 4.41. The standard deviations ranged from .67 to .85, and the skewness and kurtosis indices ranged from -.1.31 to -.88 and .69 to 2.50. Based on Kline's (2005) recommendations of skewness and kurtosis (|3| and |10| respectively), the data in the study were considered to be univariate normal (Table 1).

Table 1: Descriptive statistics of the 13 items proposed for the PTEQ, N = 1162

Item	Mean	SD	Skewness	Kurtosis
KS1_The tutor explained the topics using examples and illustrations.	4.41	.67	- .97	.96
KS2_The tutor explained complex concepts in simple terms.	4.35	.74	-1.17	1.77
KS3_The tutor addressed the difficulties I faced with the lesson.	4.34	.74	-1.16	1.82
KS4_The tutor presented the subject matter in an interesting way.	4.24	.85	-1.12	1.18
KS5_The tutor helped me achieve the lesson outcomes.	4.34	.73	-1.08	1.57
KS6_The tutor asked questions relating to what I had learnt before.	4.31	.73	- .88	.69
PL7_The tutor encouraged us to give feedback to one another.	4.35	.72	-1.07	1.44
PL8_The tutor regularly checked my team's learning progress.	4.41	.72	-1.31	2.50

PL9_The tutor encouraged me to share ideas with my classmates when we work in our team.	4.40	.69	-1.10	1.75
PL10_The tutor guided my team members in working together.	4.37	.74	-1.25	2.16
FC11_The tutor gave constructive feedback on how I am learning.	4.35	.75	-1.25	2.13
FC12_The tutor helped me reflect on how I could improve my learning.	4.31	.78	-1.19	1.81
FC13_The tutor provided opportunities for me to share what I have learnt about the topic.	4.34	.73	-1.19	2.28

4.2 EFA using Sample 1 (N=571)

Exploratory factor analysis (EFA) was conducted with the data from 571 participants to determine the factors evaluating tutor effectiveness in PBL. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for the initial EFA was .96, indicating that the factors are distinct and reliable. KMO values close to 1 and above .90 are considered excellent (Field, 2013). In addition, Bartlett's test of sphericity showed that Chi-square, $\chi^2(55) = 6922.52$, $p<.001$, indicating that certain relationships exist among variables. The results of both KMO and Bartlett's test of sphericity indicated that EFA can proceed.

The first EFA was conducted, following which, 2 items (i.e. KS6_The lecturer asked questions relating to what I had learnt before, and PL10_The lecturer guided my team members in working together) were omitted because they were loaded on 2 factors with factor loadings greater than .30. Before removing these two items, we checked the content and wordings to determine if these items could be interpreted in multiple ways by the respondents. As a result, 11 items were included in the second EFA. The scree plot suggested three factors, along with conceptual interpretation, explaining a total of 84.83% of the variance. The subscale of Developing Disciplinary Skills and Knowledge accounted for the highest proportion of variance with 76.18% This was followed by, to a lesser degree, Managing Peer Learning and Facilitating Learning Process subscales which explained an additional 5.18% and 3.47% respectively. The principal component analysis (PCA) extraction method with oblique (promax) rotation was applied to the data when conducting EFA. We chose an oblique rotation because the subscales of the PTEQ were conceived to correlate with each other. Table 2 presents the factor loadings of the final 11 items, ranged between .60 and .93. Following the recommendations by Hair, Black, Babin and Anderson (2010), items with loadings greater than .50 are retained for practical significance.

Table 2: Exploratory factor analyses results for three-factor oblique solution, N=571

	Factor Loadings				
Items	1	2	3	*M*	*SD*
KS2_The tutor explained complex concepts in simple terms.	.93			4.35	.71
KS4_The tutor presented the subject matter in an interesting way.	.78			4.25	.82
KS1_The tutor explained the topics using examples and illustrations.	.76			4.39	.67
KS3_The tutor addressed the difficulties I faced with the lesson.	.64			4.33	.73

KS5_The tutor helped me achieve the lesson outcomes.	.60			4.31	.74
PL9_The tutor encouraged me to share ideas with my classmates when we work in our team.		.86		4.42	.68
PL7_The tutor encouraged us to give feedback to one another.		.84		4.35	.72
PL8_The tutor regularly checked my team's learning progress.		.83		4.42	.72
FC12_The tutor helped me reflect on how I could improve my learning.			.84	4.31	.78
FC11_The tutor gave constructive feedback on how I am learning.			.76	4.37	.73
FC13_The tutor provided opportunities for me to share what I have learnt about the topic.			.70	4.34	.73
% Variance	76.18	5.18	3.47		

Factor loadings smaller than .50 have been omitted.

4.3 CFA using Sample 2 (N=591)

A confirmatory factor analysis (CFA) was conducted to check the stability of the three-factor structure with the data from 591 participants. SPSS AMOS version 22 was used for the CFA. Multiple fit indices were used to examine the goodness of model fit as different indices reflect different aspects of the model fit (Hair, Black, Babin, & Anderson, 2010; Hu & Bentler, 1999). Hu and Bentler's (1999) recommendations are: chi square to df ratio or χ^2/df < .30, comparative fit index (CFI) >.90, Tucker Lewis Index (TLI) >.90, root mean square error of approximation (RMSEA) <.08, and standardised root mean square residual (SRMR) <.80. The three-factor model fit the data well (χ^2/df = 2.71, CFI = .99, TLI=.99, RMSEA = .054, SRMR = .014).

In addition, we tested the reliabilities of the three subscales of the PTEQ with both the EFA and CFA samples. The reliability coefficient is an important psychometric property of the scale as it indicates the proportion of variance in the scale scores, attributable to true scores (DeVellis, 2011). The results in Table 3 showed consistently high reliability coefficients for the 3 PTEQ subscales for both EFA and CFA samples, ranged between .91 and .94, demonstrating that these subscales are reliable and valid.

Table 3: Internal consistency reliabilities of the three PTEQ subscales for EFA and CFA samples

Subscale	Internal consistency reliability (α)	
	EFA sample (N=571)	CFA sample (N=591)
1. Developing disciplinary knowledge and skills	.94	.94
2. Managing peer learning	.92	.91
3. Facilitating learning process	.93	.93

4.4 Mean, Standard Deviation, Internal Consistency Reliabilities and Interfactor Correlations based on Total Sample (N=1162)

Sample 1 (N=571) and Sample 2 (591) were combined into a total sample (N=1162) to calculate the mean, standard deviation, internal consistency reliability and interfactor correlations (see Table 4). The internal consistency reliabilities of the three subscales of the total sample ranged between .92 and .94, which were above Nunnally's (1967) recommended level of .70. The interfactor correlations of the three PTEQ subscales based on the total sample were positive and significant, ranged between .84 and .87 ($p<.001$). All the three PTEQ subscales were positively and significantly correlated with the perceived value of learning, ranged between .56 and .62 ($p<.001$), providing evidence on predictive validity of the PTEQ.

Table 4: Mean, standard deviations, internal consistency reliabilities and interfactor correlations, and perceived value of learning based in total sample, N = 1162

Factor/Subscale	Internal Consistency Reliability (α)	M	SD	Bivariate Correlations			
				1	2	3	4
1. Developing disciplinary knowledge and skills	.94	4.34	.67	1			
2. Managing peer learning	.92	4.39	.66	.84**	1		
3. Facilitating learning process	.93	4.33	.71	.87**	.86**	1	
4. Perceived value of learning	.93	4.15	.84	.62**	.56**	.59**	1

** denotes $p<.001$.

5 Discussion

The purpose of the study was to report on the reliability and validity of an instrument to evaluate tutor effectiveness in PBL. The result of the confirmatory factor analyses showed that a three-factor model comprising 11 items had a good fit with the data. However, all the three factors were highly correlated with each other, suggesting that the factor scores provide limited unique information across the three factors.

All the items of the PTEQ scale combined accounted for 84.83% of the total variability in student's PTEQ scores. With 15.17% of the variability unaccounted for, 84.83% explained variability is considered sufficient variance explanation in social science studies (Tabachnick & Fidell, 2007).

The PTEQ scale could be used in multiple ways. It provides specific evaluation feedback to tutors, both on the item level as well as on a subscale level, helping tutors to be aware of and reflect on their facilitation strategies in PBL. The PTEQ can also be used as a benchmarking tool for institutional quality assurance where tutors can compare their mean PTEQ item and subscale scores with the mean scores of all the tutors in the faculty.

During the PBL foundational training for beginner tutors, the PTEQ could be used as guidelines for institutional expectations of good facilitation in PBL lessons. Peer coaches or expert tutors could also use the PTEQ as an observation checklist to support the professional development of beginner tutors, as well as to use it as an continuing improvement tool. Finally, evaluation studies conducted on the tutors with the PTEQ may assist with priorisiting staff development activities.

6 Limitations of Study

Although the PTEQ demonstrates good reliability and validity, several limitations need to be acknowledged, suggesting future research direction to address these. First, this study only used students in a particular polytechnic in Singapore, which may not be representative of the population of students in other higher educational institutions in Singapore. As a result, the generalisation of results of this study need to be interpreted with caution. Multiple samples of students across different polytechnics and higher educational institutions should be considered for further validation of the PTEQ. Second, students' perceptions of tutors in PBL may differ depending on the subjects taught. Comparing the results of PTEQ and learning outcomes will enhance our understanding of students' perceptions of tutor effectiveness in different subjects conducted using PBL. Third, this study adopts a cross-sectional design, and therefore did not consider multiple time intervals in the data collection. Longitudinal studies can be conducted in future using repeated measures of PTEQ over several semesters to determine the extent of possible change and development over time in tutor effectiveness.

7 Conclusion

The current study provides clear evidence that the newly developed PTEQ scale that measures students' perceptions of tutor effectiveness is reliable and valid. The new scale helps researchers conduct studies in various contexts, for instance, identifying trends in students' perceptions of tutor effectiveness, examining relationships between tutor effectiveness and learning outcomes, academic achievements and other contextual factors such as group functioning and students' situational interests. It is hoped that the new PTEQ scale will invite future studies that will provide further insights on how tutors can be more effective in facilitating PBL lessons.

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Project-based Learning in Tertiary Education in Vietnam – Its Suitability and Roles of the Main Agents

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Abstract

Within the context of modern education nowadays, enhancing student-centered learning is likely to be what troubles teachers and educators in tertiary education the most, all over the world. Among a plethora of pedagogical tools replacing the "chalk and talk" passive teaching approach to which students no longer respond, Project-based Learning (PBL) stands out as a model generating a higher level of students' involvement and shifting their roles towards the main agents in the learning process. Surely enough, changes in the positions of learners entail adjustments in the parts of instructors, and the very questions confronting many PBL practitioners then are *How does this innovative approach suit their particular educational contexts?* and *What should teachers and students do to amply fulfill their roles in PBL classrooms?* The purpose of this study is to seek answers for such queries, regarding the higher education context in Vietnam. Accordingly, the paper begins by critically reviewing the literature, providing some insights on PBL and comparing this innovative model with its forerunner- Problem-based Learning before making judgment on the selection of the approach for university classrooms in Vietnam. It then presents a critical discussion on the positions of learners in PBL in order to pave the way for some indications to maximize their roles and enhance learning outcomes before proposing a detailed description and analysis of the teachers' roles in PBL. Hopefully ,this clearer understanding of PBL will form the basis for fruitful suggestions for the promotion of PBL in tertiary education institutes in Vietnam and many other Asian countries.

Keywords: student-centered, Project-based Learning (PBL), Problem-based Learning, students' roles, teachers' roles

Type of contribution: conceptual paper

1 Introduction

"Learning is something students do, NOT something done to students."

Alfie Kohn

Seemingly, it has become a cliché to discuss the significance of student-centered learning in educational contexts these days since its pivotal roles has already been acknowledged by most teachers, curriculum developers and scholars around the world (Overby, 2011; Wright, 2011; Asoodeh *et al*, 2012; Glowa & Goodell, 2016). In preference, educators now devote more efforts and thoughts in devising effective approaches to maximizing learners' engagement and building more student-centered classrooms. Relentless attempts of these enthusiastic community members have resulted in plenty of fabulous tactics and methods for teaching, among which Project-based Learning (PBL) has yielded impressive results in Western countries and riveted more and more international attention.

In the tertiary education context in Vietnam, particularly, research clearly points to a linkage between traditional “teacher-led classrooms” and “little motivation” or “[limitations] in helping students achieve the learning outcomes” (Nguyen, 2009, p.5; Hoang, 2014, p.218). Over the past decade, Vietnamese education administrators and policy makers strongly “urged the educators to apply new educational strategies in their education” in order to enable students to “develop their creativity and working skills” (Nguyen, 2009, p.5). Being considered as the key to unlocking students’ critical thinking capability and providing them with authentic real-life lessons, PBL is presumably a workable solution for those central problems of higher education. So far, however, as Felipe et al indicated “little work has been done to introduce PBL outside of the western countries” especially in Asia (2016, p.321). At the same time, there are two approaches having the same acronym of PBL in the literature (Project-based Learning and Problem-based Learning), which might cause slight confusion among PBL practitioners. In the growing body of research literature in Vietnam, specially, there has been a serious dearth of documented activities or strategies for teachers to apply PBL in teaching and learning, especially in term of in-class techniques. Finally, there are not many references on the roles of students and teachers in PBL classes have been discovered through publication.

For the purposes of improving personal practice and somehow contributing insights to the relevant literature, this paper aimed squarely at answering the two questions *How does PBL suit the specific educational context of Vietnam? and What should teachers do to amply fulfill their roles in PBL classrooms?* Accordingly, it should start out by providing some understanding of Project-based learning as well as analyzing the similarity and differences between this strategy and its forerunner- Problem-based Learning, which are followed by an argument over the selection of Project-based Learning for Vietnamese university classrooms and other similar Asian contexts. In the next section, backed up with what has been identified from various literature on the responsibilities of leaners in PBL classrooms, an analysis of students’ key roles will be presented. Finally and most importantly, descriptions of the teachers’ roles are given to pave the way for some indications to optimize their roles.

2 What is Project-based Learning?

2.1 Project-based Learning definitions

There is a consensus among many Project-based learning advocates that it is an interactive educational intervention which has its root from the idea “learning by doing” of John Dewey dating back to the end of the nineteenth century (Harmer & Stokes, 2014; Ngo, 2014; Tascı, 2015; Ulrich, 2016). From then onwards, with the advances of neuroscience and psychology as well as the development in learning theory, more and more researchers have supported Dewey’s idea that students should no longer be *exclusive listeners* but *active doers* in their classes, and it is necessary that they have chances to learn through experiencing, particularly by doing projects (Ngo, 2014; Tascı, 2014; Ulrich, 2016) . Undoubtedly, this school of thought not only challenged the teacher-directed approach dominating higher education classrooms around the world for a long time, but it also marked a radical shift in learning and teaching, from teacher- centered to learner- centered approach and a move from receptive mode of learning to a perceptive one.

Froyd and Simpson (2010. p.2) claimed that PBL is one of many effective strategies in a broad range of various student-centered learning approaches , namely

> Active Learning (Bonwell & Eison, 1991) • Collaborative Learning (Bruffee, 1984) • Inquiry-based Learning • Cooperative Learning (Johnson, Johnson, & Smith, 1991) • Problem-based Learning • Peer Led Team Learning (Tien, Roth, & Kampmeier, 2001) • Team-based Learning (Michaelson, Knight, & Fink, 2004) • Peer Instruction

(Mazur, 1997) • Inquiry Guided Learning • Just-in-Time Teaching • Small Group Learning • Project-based Learning • Question-directed Instruction

In a more recent study, Felipe and his co-writers defined PBL as "a student-centered learning approach in which students work collaboratively in groups that involves interaction and cooperation among learners. In this setting, students learn through hands-on activities focused by a project" (2016, p.320). This definition is close to that of Holm (2011) who described this method as "a student-centered instruction that occurs over an extended time period, during which students select, plan, investigate and produce a product, presentation or performance that answers a real-world question or responds to an authentic challenge." Practically, PBL learners may find themselves involving in the nine steps delineated by Stix and Hrbek (2006, chapter 11)

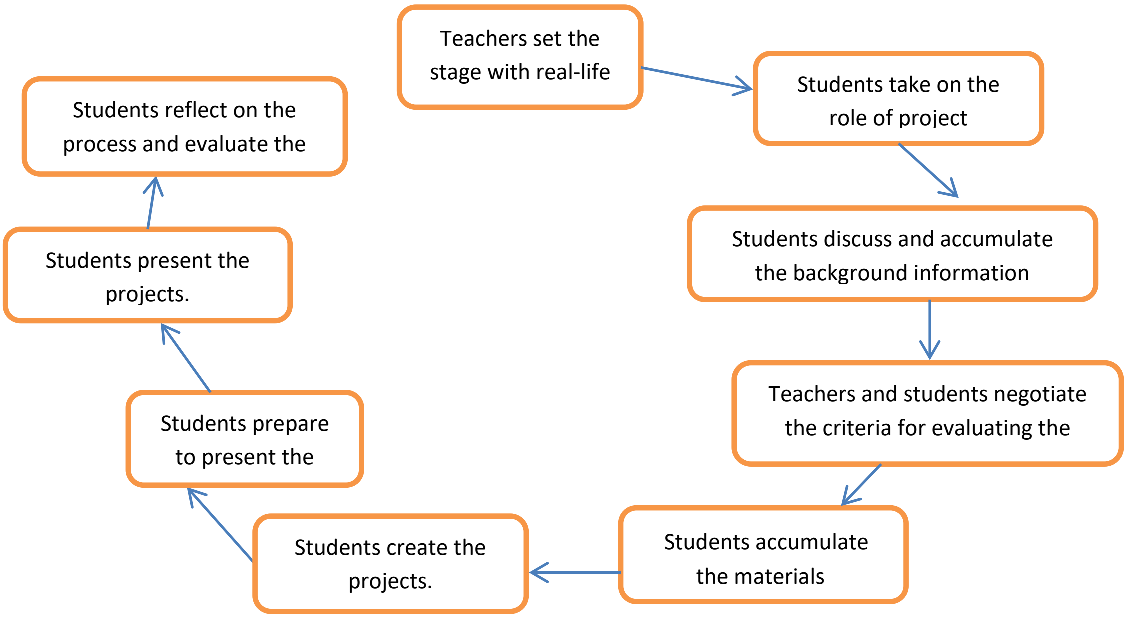

Figure 1: Nine steps of Project-based Learning approach

All in considered, PBL lays its foundation on the two big stones *student-centered learning* and *projects.* Accordingly, in PBL classrooms students are the main agents and projects are the main educational materials. Engaging themselves in such an interesting approach, students are given the chances to be pioneers in their own journeys exploring new realms of knowledge; that is to say, they take greater responsibilities towards their learning, joining in reasoned discussions, devising plan, making efforts to achieve shared goals or final products and gaining practical skills through working on real-world projects. The project in PBL in particular must be an authentic challenge, an inspiring educational inquiry as well as a meaningful means which fulfils the course requirement. To put it in more concrete terms, a project in Project Based Learning can be designated as "a multi-faceted and often extended sequence of tasks culminating in a final work product" (Barge, 2010, p.9).

2.2 PBL- *Project*-based Learning or *Problem*- based Learning?

In the relevant literature, the term PBL are generally co-used for two student-centered instructional approaches, namely Problem-based learning and Project-based learning. It is asserted by John Larmer that they "are really two sides of the same coin", or that is to say, these strategies are very closely related despite some slight distinct flavour in application (2015, para. 10). As their names suggested, both the PBLs are in the spectrum of X-based Learning and can be also classified as inquiry-based learning. In these two

PBL classrooms, students are given opened- ended and often multifaceted questions or tasks to tackle over a longer period of time than in conventional lessons. Additionally, it is emphasized by Larmer that in framing a project, instructors could encourage students to work in groups and solve an authentic problem, and in this way he considered "problem-based learning a subset of project-based learning" (2015, para.6). Most noticeably, both these innovative pedagogies are believed to help boosting motivation and promoting necessary 21st century skills among their practitioners (Campbell, 2014; John Larmer, 2015; Savery, 2016).

Inevitably, Project-based Learning bears some distinction from its forerunner in the application process. To begin with, problem-based learning is about finding solution for a real-life problem; meanwhile project-based learning centres round the achievement of shared goals or creation of final products. Importantly, as Larmer indicated, Problem-based learning tends to be single-subject and may be conducted within a single lesson while project based learning is more likely to be multidisciplinary and lengthier (2015, para.9). And thus, it is hardly too much to infer that Project-based Learning involve a more complicated process and often more challenging than its foregoer. Finally, if Project-based learning can be broken down into nine general steps of designing and implementing, Problem-based follows nine specific stages as shown in the diagram below,

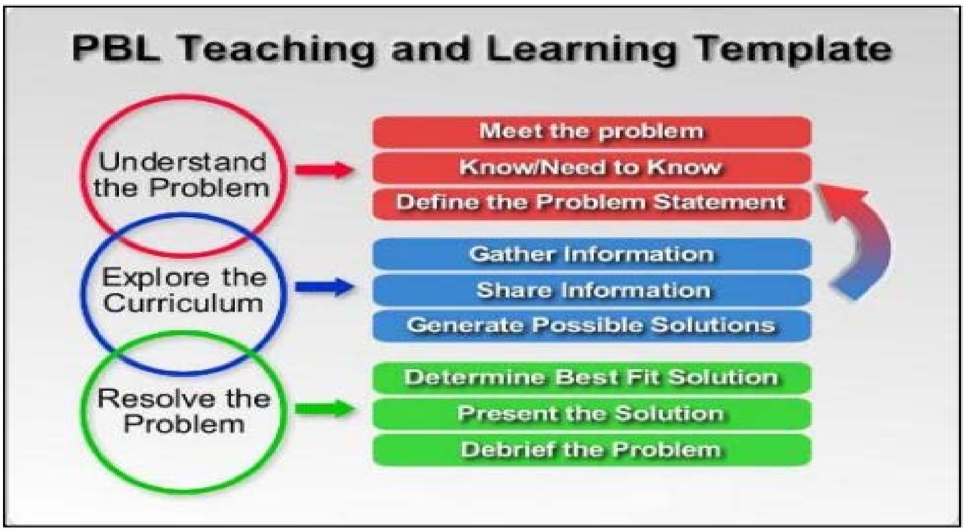

Figure 2: Nine steps of Problem-based Learning approach (Center for Teaching, The University of Iowa)

Despite the inevitable differences between the two PBLs, as concluded by many researchers, it is the active learning model and student-centered approach that are worthy not how we name the tasks. Evidently, these twain innovative methods will occupy prominent places in the 21st century classrooms (Campbell, 2014; John Larmer, 2015; Savery, 2016).

3 Why is Project-based Learning?

3.1 Outstanding features of Project-based Learning

In an article reviewing the relevant literature, Kokotsaki et al claimed that Project-based learning can exert powerful effects on different educational settings and on different levels of schooling, from elementary to tertiary education (2015, p.1). Owning similar features to other student-driven approaches, PBL has been widely acknowledged as an efficient way to engage learners in learning, support learner autonomy, guarantee the high achievement in learning outcomes as well as provide them with practical skills to fit in the current knowledge-based and highly technological era.

PBL to generate motivation

The first and most important feature that PBL advocates always boast about is the high level of student motivation in PBL classrooms. Over the last decade, a large body of research on PBL, either summative or formative evaluation, demonstrates its power in fostering students' motivation in learning. Concerning PBL advantages in education, Kavlu stressed that learners who involve in PBL "show increased motivation and engagement in their studies"(2015, p. 211). Likewise, in a critical review of research on Project-based Learning, Thomas provided convincing evidence of motivation in PBL classrooms at various schools where attendances increased to over 95 percent (2000, p.10). Similarly, using the qualitative research method of interview to examine the awareness of teachers and students' reactions towards PBL, Beneke and Ostrosky reported that "most felt that their students were successful, noting improved interest and motivation" (as cited in Holm, 2011, p.5).

It was indicated by *Carl Wieman Science Education Initiative* that the factors contributing to motivation among learners include "personal relevance, some control of the learning process, and a sense that one can master—and is mastering—the material" (2013, p.1). This idea is in line with that of Ferlazzo who delineated four core elements that generate intrinsic impulses in learning, namely *autonomy, competence, relatedness and relevance* (2015, para.1). Careful analyses into its definition and characteristics show that PBL involves all these four elements of motivation. Firstly, by definition, it is nothing but the authentic materials and real-world projects; that is to say, PBL rewards learners the opportunities to interact with all kinds of materials available within their reach or tasks which bear immediate relevance to their learning. Relatedly, in PBL classrooms, students have chances to work on projects that are significant to themselves and their communities, and subsequently are intrinsically motivated. A closer look at this method reveals that besides relevance and relatedness, there also exists a strong and mutual link between PBL and learner autonomy. When defined an autonomous learner, Leni Damn clarified that he or she was a person who owned "the readiness to take charge of one's own learning in the service of one's needs and purposes" (1995, p.1). In their descriptive qualitative research, Yuliani and Lengkanawati pointed out that PBL "has promoted learner autonomy, which covers the criteria of self-instruction, self-direction, self-access learning and individualized instruction in each stage of Project-based activity" (2017, p.285). It was further explained by Blumenfeld et al that within the fabric of PBL, weighty responsibilities rests with students for they have to seek solutions for "nontrivial problems" by questioning, debating and examining the ideas, planning the framework, analyzing the data, as well as reaching conclusions and creating products, all done by themselves (1991, p.371). Obviously, in an framework that students evidently take heavy charge in their learning like PBL, it is inevitable that they are autonomous learners in their learning process.

PBL to promote learning outcomes and 21st century skills

Project-based Learning, which has the power to boost learner autonomy and student motivation, should accordingly have great impact on learning outcomes which can be dissected into various elements, namely *academic results, conceptual achievements and various skills needed for student's future.* The linear relationship between autonomy, motivation and academic achievements has been widely recognized by a vast array of literature (Dailey, 2009; Ilter, 2014; Bullock, 2017; Yuliani & Lengkanawati, 2017). Regarding academic performance, a body of evidence emerged suggesting that there is a noticeable change in students' test scores before and after involving in PBL. Findings from quantitative analyses conducted by Barak and Dory indicated that many PBL students in the Department of Chemistry in Israel Institute of

Technology achieved the highest grade on their post-test and final exam than the students of traditional method did (2004, p.117). Also, supported by qualitative data from interviews and observations, these two researchers concluded that the freshmen in the experimental group gained proper conceptual understanding of required chemical knowledge (2004, p.117). Likewise, juxtaposing academic achievements for learners instructed by PBL approach and conventional teaching strategies, Vanessa Vega remarked that “PBL increases long-term retention of content, helps students perform as well as or better than traditional learners in high-stakes tests, improves problem-solving and collaboration skills, and improves students' attitudes towards learning” (2012, para.5). In the same vein, similar dramatic gains in cognitive achievements were identified in an experimental study investigating conceptual gains of PBL and non- PBL groups of students; its author, Ilhan Ilter found out that PBL increased their understanding towards social studies notion, or that is to say, this innovative approach was able to improve students conceptual achievement (2014, p.487).

It is also worth noting that PBL significantly own the ability of promoting a repertoire essential real-life skills, the so-called 21st century skills for future career readiness among its practitioners. These competencies, as mentioned by Helen Soule, composed of the 4 Cs - *critical thinking, collaboration, communication* and *creativity*” (2014, para.2). A number of studies have found that PBL can be usefully employed as a means of aiding students in promoting these 4 essential skills. This effect has been asserted by Stephanie Bell when the researcher claimed that the integration of PBL in classes probably facilitate “[students’] collaborative, negotiating, planning, and organizational skills” (2010, p.43). It can be further explained by Tretten and Zachariou (1995) that experiencing PBL, learners have opportunities to both work on their own and in groups, being self-driven to employ critical thinking skill to elucidate problems and offer solutions for such problems in carrying out real-world projects. Throughout this productive process, learners “learn and/or strengthen their work habits, their critical thinking skills, and their productivity... new knowledge, skills and positive attitudes." (p.8)

3.2 PBL suitability in the context of Vietnam

So far, studies examining the educational powers of PBL has provided clearer insights on how able this innovative approach is in satisfying both cognitive and affective needs, fostering engagement and interaction, and assuring positive learning outcomes as well as 21st century skills among leaners in a variety educational institutions around the world. The question confronting many Vietnamese PBL practitioners now is how far this strategy will work in their very educational contexts of higher education. Generally, Vietnamese students share most of the characteristics of students elsewhere in the world, and hence PBL is likely meet their needs and able to engage them in learning. Particularly, born with the rooted “saving face culture”, Vietnamese students even the youngest ones are often shy and afraid of being laughed at when making mistakes, which is likely make them reluctant to stand up individually speaking out their own ideas (Vo, 2014, p.68). Like China, Japan and some other Asian collective cultures, Vietnamese students’ learning style shows considerable Confucian influence; in other words, the learners in Vietnam “tend to be group-oriented” , obedient and “value harmony” (Truong, 2017, p.86-87). In such cases, the capacity of bringing learners together in group works and encouraging collaboration skills of PBL would be desirable characteristics for Vietnamese educators dealing with the problems of students’ shyness.

According to a report by Vietnam’s Ministry of Labour, Invalids and Social Affairs, in order to make Vietnam an industrialized and a modernized country by the year 2020, one of the crucial things Vietnamese have to do is to improve the quality of the labour force since the current education “[fails] to meet the industrial sector’s needs for skilled human resources and capacity development in both hard and soft skills” (2015, p.1). It is stressed by Vietnamese governors that this ambitious goal cannot be achieved unless it is "supported by the preparation of skilled labour force and quality improvement in teaching and learning"(as cited in Ho, 2016, p.1). Moreover, according to the report *Skilling up Vietnam: Preparing the workforce for a modern market economy* of the written by Christian Bodewig et al (2014), Vietnamese future workforce also needs to be equipped with the essential 21st century skills, namely *technical skills*, *cognitive skills* (problem-solving and critical thinking), and *behavioural skills* (team work and communication) (p.6). Taken all these requirements and the aforementioned valuable theoretical evidences on PBL into consideration, it is hardly too much to say that that PBL is a desirable solution to resolve the ill state of learning and teaching reported by many educators, providing more professional labourers to match the international job market needs and assuring the success of the industrialization and modernisation process in Vietnam.

Over and above what have been so far discussed, there also exist some favourable features attracting more considerations from PBL practitioners in Vietnam. As previously discussed, many other university students from Confucian cultures, Vietnamese are notoriously shy, obedient and have passive learning style. These Asian students, however, have recently dispelled this popular belief and shown the desire to step out of their comfort zones. When comparing attitudes of two groups of students (one from eight different Asian countries including Vietnam and the other from three European countries) towards learning styles, Littlewood concluded that these two groups have similar ideas on their preferred styles, and that Asian students no longer want to sit obediently and take the passive roles in class (as cited in Tran, 2013, p.73). Similarly, in a research examining the status of tertiary education reform in Vietnam, Jessica Thompson draw a conclusion that if teachers keep acting as the fountain of wisdom, sitting on the chair and conveying their knowledge, students will remain passive, listening obediently and struggling to grasp their teachers' ideas (as cited in Tran, 2013, p.73). In contrast, if teachers structure the lessons in a more interactive ways and encourage students to raise their voices, they will be more open-minded and actively participate in learning (as cited in Tran, 2013, p.73). Positively, though tested on a small scale, preliminary results from a study by Filepe et al suggested that "PBL approach is well adaptable to CHC [Confucian Heritage Culture] students and Vietnamese student were able to integrate its principles effectively". In brief, it can be inferred from those above research that Vietnamese students are willing and eager to adopt a more active learning style like PBL approach.

4 The roles of teachers and learners during PBL intervention

Now that PBL has proved itself reasonably practical within Vietnamese higher education context, there is still one more important area that needs further discussions- the roles of its participants. It is obvious that within the frameworks of any teaching approaches, teachers and learners are the two main agents and have a joint responsibility in assuring desirable learning outcomes, and this is also true in PBL classrooms. The questions, then, for many PBL practitioners to ask themselves are *What key roles should students assume to enhance their learning outcomes? and What should teachers do to amply fulfill their roles in PBL classrooms?* which will be in turn analyzed in the following sections

4.1 What key roles should students assume to enhance their learning outcomes?

Like many other student-centred approaches, Project-based Learning requires each individual to take charge of their own learning as much as possible; accordingly, all PBL learners including Vietnamese ones have to assume active roles in all nine steps of PBL intervention (figure 1) mentioned in the definition part. The responsibilities of learners in PBL, then, can be specified into four fundamental roles: *eager learners, academic thinkers, self- mentors and leaders.*

Involving in PBL, it is a must for students to assume the role of *eager learners*. They should always bear in mind that they are an inseparable part of their group, and that regular attendance at class is important since the learning outcomes rely heavily on their presence and performance in every stage of group work. In the first, fourth and last steps of PBL, namely *Setting the Stage with Real-Life Examples*, *Negotiate the criteria for evaluating the projects* and *evaluate the projects* (figure 1), where teachers seem to take the whole charge, there are still rooms for students to shoulder the responsibility. Theoretically, it is indicated by Johnston that the primary role of a student in PBL is a “ready learner” and that learners must and should have “the opportunity to self-select, or be selected, to participate in a real world project based on their aptitudes and preferences” (2005, p.59-60); and that is to say in the very first step of PBL, students’ active roles can be assured only if they have chances to choose the projects or at least the challenge features involving the tasks they are going to undertake. Practically, before students actually roll up their sleeves and carry out the projects, they should be provided with some options to choose from; then, they need to show their willingness in putting forward their ideas as well as selecting the topic with realistic expectations and personal preferences. In the same vein, it is important that students actively assume their cooperative roles in setting achievable project objectives and criteria for the evaluation processes since they themselves are the project doers.

Following each steps in PBL process, students simultaneously take the roles of *leaders, academic thinkers and self- mentors.* Obviously when students assume more responsibilities in learning and arrive at many important decisions in their own projects, they need to think critically and make judgments on why they do what they do. Taking roles of project designers and data collectors in the second and fifth stages of PBL, learners need to develop their search techniques, reflect on the information they get and decide on the approach they need to create the projects. While going through various project works, students get opportunity to work on in-depth study, question and test the ideas and then are self-taught from “real world experiences” (Johnston, 2005, p.62). Finally, in order to avoid the problem of “free-riding” and establish a community of “reflective learners” in project-based class, project leaders are prerequisite for each group. Like leaders in other fields, a learner taking the role of a project leader needs to inspire his fellows, delegate tasks to his members, promote shared view among team members as well as engage them in achieving their shared goals. Additionally, as it is indicated by Ayas and Zeniuk (2001), PBL students should perform the tasks of “coaches and facilitators serving others” in project-based learning. The leadership model in PBL, as they argued, is quite unlike that of management, and the leaders of projects “lead by learning” and only “evolve where and when necessary” (p. 72).

4.2 What should teachers do to amply fulfil their roles in PBL classrooms?

In PBL classrooms, together with the transitions in the positions of learners and changes in the characteristics of class activities, new expectations towards teachers’ roles arouse. As PBL students’ needs are quite distinctive from those of conventional ones, teachers need to make themselves accordingly adapt and radically differentiate their instructional performance.

Giving power away and receiving more!

In her book *Learner-Centered Teaching: Five Key Changes to Practice,* Maryellen Weimer asserted one of the key changes in a student-centered learning classroom is to create *the balance of power*; and she also added that power sharing greatly benefitted not only the students and their learning but aslo the teachers themselves (2008, p.23-45). Likewise, as John McCarthy stressed, teachers can promote student-centered learning by *giving up need for control*, *allowing students to share in decision making* and *believing in their capacity to lead* (2015, para.5). Obviously, students will be more engaged when they can do what they want to do, and the simplest way is to allow them decide what they want to explore. Starting with a brainstorm of students' favourite topics can be a worthwhile idea for PBL teachers, and then dialoguing together to match their interests with course requirements is another inspirational one. In addition, people in general and students in particular would be willing to do stuff or eager to study when they owned the sense of pride, said Melissa Dahl (2016, para.1); thus, if students are shouldered with the leading roles in the learning process as well as given the position of leaders in their groups, they will make efforts to fulfil their roles of *eager learners* and *leaders ,* which are discussed in the previous section.

Taking roles of critical resource providers, designers, facilitators and assessors

Sharing power with students does not mean teachers in a student centric context like PBL will have more freetime. This, on the contrary, requires these teachers to take more time and responsibility; and in order that students fulfil their parts as *academic thinkers* and *self- mentors*, it is advisable that teachers take four decisive roles including *critical resource providers, designers, facilitators* and *assessors*. Apparently, that PBL teachers cleverly design learning activities for their students to eagerly join in is of vital importance. Also, rather than just preparing lectures before classes, teacher would need to extensively update their knowledge in the related fields since they might receive a ton of questions from their powerful students in all three stages –Pre, While and Post PBL.

In the first phase of PBL where teachers set the stage for students to study a particular topic in the coursework, it is necessary that they lay some ground work as structuring the problems or tasks to direct the projects towards content-based requirements and providing some basic knowledge in the related fields. In this stage, the instructors may find it useful giving students chances to put forward their choice and voice by offering them a variety of options to choose from. A safe approach is to provide students three options, two of which designed by teachers based on what most students probably want to work with, and the third is a "blank check"- a room for students to propose their own ideas of interest (McCarthy, 2015, para.8). Also in this very first stage, as Stix and Hrbek indicated (figure 1), teachers may want to design the criteria for evaluating the products with some negotiation with students-the most crucial stakeholders of the projects. As Andrew Miller (2016) pointed out "with good assessment practices, PBL can create a culture of excellence for all students and ensure deeper learning for all" (para. 1); it is then the challenging task of PBL teachers to adopt, adapt, tailor, design and re-design suitable assessment strategies for each particular project. Moving on to the while stage of PBL, teacher is more of facilitators and scaffolders helping students sketch their plans, intervening when their learners' direction is not practical and proposing suggestions for other hard-to-solved problems. In the last stage of PBL, teacher will assume the role of assessors and appraisers sharing their reflection, collecting and analysing feedbacks from other students as well as offering some suggestions for improvement.

5 Conclusion

To sum up, this conceptual paper was conducted by a practitioner- researcher for the purpose of investigating the effectiveness and suitability of PBL in a particular Asian educational context as well as proposing suggestions on optimizing roles of learners and teachers. The discussion and analysis of the paper clearly pointed out that PBL was indeed a workable strategy for some particular problems in Vietnamese higher education context. Despite being a small-scale research conducted in a short period of time which may not be generalized in dissimilar contexts, the paper still substantially contributed fresh insights about PBL to the relevant literature, raising the interest in the educational power of PBL in tertiary education in Vietnam. Witnessing the multi effects of PBL in teaching and learning, this study hope to get the attention of latter researchers on studying the effects of this innovative approach in other contexts with students at different ages and levels as well as the in-class techniques for the implementation of PBL in teaching and learning.

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Mixing facilitator roles to enhance PBL: Lessons learned from teaching accounting at Duy Tan University

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Abstract

Problem-based learning (PBL) approach has been applied since the 1970s and brought about remarkable results in higher education. This teaching method promotes students' self-awareness and stimulates their creativity through open-ended problems while the teachers play facilitating role guiding students to achieve courses' objectives. It can be said that the success of PBL adoption is greatly dependent on teachers' facilitation. At Duy Tan University, PBL teaching method has been implemented in accounting discipline since 2013 and completely transformed students' perceptions and learning attitude, enabling them to have advantages over competitors in their job search in recent years. The benefits of PBL to students have inspired the paper authors to study the facilitation roles of the teachers in PBL classes. After analysing the survey results on 8 teachers and 125 students from Accounting Faculty, we find that good teachers should have competence to constantly adjust their facilitation roles to match the dynamics of PBL environment. They should be very flexible in choosing suitable types of facilitation depending on specific situation of accounting project, thus, within the same project, they are required to apply a mix of different facilitator roles to provide timely consultancy and stimulate students' progress. This paper is expected to be helpful to universities where PBL is adopted for students of diversified background.

Key words: PBL, self-directed learning, facilitator roles, accounting discipline, mix of facilitation types

1. Introduction

PBL is an active learning approach in which ill-structured problems are used as a stimulus for students to learn (Barrows, 2000). The ill-structured problems are usually open-ended and do not necessarily have a single correct answer so that students have to consider alternatives and provide a reasonable and logical argumentation to support their solution. Research evidenced students who have learned from PBL program can apply their knowledge to new issues, improve active learning (Graaff & Cowdroy, 1997), develop criticality (Savin-Baden, 2003) and improve self-directed learning capability better than students from the traditional program (Evensen & Hmelo, 2000). From this perspective, instructional activities in PBL environment play a different role than traditional teacher-centred environment. Instructors no longer play a didactic, transmission-oriented role but an interaction-oriented role of facilitators who are not only masters in the subject field but also able to organize students' learning process, create conditions to direct students' own learning and development, work as a "process guide" to assist students to achieve studying purpose (Gregory, 2002).

In real life, the involvement in the student's learning process and group process, however, may vary depending on group, project and instructor's PBL teaching experience. Based on levels of involvement and the degree of participation in students' problem, Holten-Andersen et al. as cited in (Kolmos, Du, Holgaard, & Jensen, 2008) classified three typical facilitator roles (1) the facilitator acts like a group member (2) dialogue based facilitation and (3) the facilitator acts as a consultant. A dialogue based facilitator as described by Andersen is willing to gives space for students to take initiative and try their own idea while s/he provides guidance. Acting as a group member, facilitator has strong impact on the project work but at the same time, s/he deprived the responsibility of students' own learning. As a consultant, facilitation role is only active when groups ask for facilitation. Different facilitation roles may result in different progression in learning process and group process. In PBL class where instructors take the role of a dialogue based facilitator or a consultant, the students are the "project owner". On the contrary, if the instructors participate as group member, they tend to be a strong member and as the result, they are project owner instead of students (Kolmos, Du, Holgaard, & Jensen, 2008).

Depending on problem status and stage, students might have different expectations to facilitators. The interplay of facilitation roles is necessary to promote students' learning progress. It is possible to mix elements of group member and consultant in different phases of the course. *"There is no ideal role to suit facilitation as it will depend on the group and the course of the project. As a facilitator you do not decide yourself which role you take on and it might be necessary to practise all three roles within the same project course*". (Kolmos, Du, Holgaard, & Jensen, 2008)

In Vietnam as in other Asian countries, students and instructors have been accustomed to teacher – oriented method. Moving from the traditional teaching style to PBL format poses great challenges to instructors. They are sometimes unsure about their role or what facilitation type they might apply to facilitate students' self-directed learning because students are not usually confident to seek answer themselves and instructors have been familiar with lecture delivering. Therefore, finding out the suitable facilitation role that instructors should play seems to be a crucial component of successful curriculum change.

2. PBL at Duy Tan University

From 2013, Duy Tan has shifted from the traditional teaching method to PBL. Although PBL has led to many difficulties in adopting the methodology, it has brought in some encouraging results. Particularly, the students are more active in their learning, more confident in teamwork and they gain more communication and presentation skills when compared with students from other institutions. Recruiters highly appraised graduates from Duy Tan University as responsible and dynamic candidates who possess deep knowledge content, critical thinking and creativity. These good qualities have enabled Duy Tan graduates to have advantages over competitors in their job search in recent years. 94% of Duy Tan students have the right jobs after six months of graduation (Nguyen, 2018). Such employment rate is among the highest in the country, equivalent to those of leading national universities and surpasses regional universities (Nhu, 2008). The results imply that PBL adoption has been a success at Duy Tan University. The benefits of PBL to students have inspired the paper authors to study about the approaches that the instructors have applied in PBL environment so as to identify an exemplary theme in PBL facilitation for the future.

In November 2017, we conducted a survey on 8 accounting instructors to identify the facilitation actions that these instructors have applied in PBL class and found that most of these instructors have primarily lecture-based experience and they have been accustomed to delivering their knowledge to students by lecturing. The reason why we conducted the survey in the Accounting faculty is because accounting students have more PBL courses than students of other majors; the accounting instructors, thus, have experienced more PBL activities than their colleagues. At Duy Tan, accounting subjects taught by PBL method include financial accounting, managerial accounting, intermediate accounting, advanced accounting, tax accounting, basic auditing, financial auditing, financial statement analysis, etc. Each specialized subjects has 3 credit hours and usually lasts for a semester. Every semester, students, on average, work on two to three PBL projects in the major subjects and one or two small projects in the complementary subjects. Students accept such workload because they have got accustomed to PBL since their first year and the complexity and difficulty of project increases gradually in accordance with their accumulated knowledge. Most importantly, they realize that after graduation they will need to know how to organize their work effectively to complete many projects at the same time. This workload is a preparation for them when they go to work for the business.

The interviewed instructors shared with us that when the university implemented PBL, confronting with new teaching method, they felt quite uncomfortable but they had made great effort to conduct PBL session. In an accounting PBL class, instructors follow 6 phases of facilitation (1) contact phase – (2) contract phase – (3) preparation phase – (4) implementation phase – (5) evaluation phase (6) end phase. At the beginning of the course, instructor divides class into small groups of 5-7 students. Each group carries out a project related to the subject and the instructor provides supporting activities to assist the students including forming groups, setting up course policy and regulations, helping groups to make working plan and goal for the whole period and for each specific week, assigning tasks and targets for every group member, recommending necessary learning materials for the course, supervising the implementation process, evaluating performance results and progression of groups and group members on a regular basis, closely working with the group for troubleshooting and anticipating the final products, and at the end of PBL session, instructors summarize what have been learnt from the project and what could be done for the next time. In most circumstances, instructors are helpful and actively involved in all aspects of students' learning process and group process. They usually provide timely guidance to keep groups on the right track. Not only do they act as project reviewer but they also work as project director or even project editor if necessary. According to the interviewed instructors, they believe that such control facilitation can assure that all students in class could reach course learning objectives.

Thus, the aim of this study is to determine whether such facilitation framework is effective and find out students' perceptions of good facilitation role that the accounting instructors should play to help students in their self-directed learning.

3. Method

One month after the survey on 8 accounting instructors, in December, 2017, we conducted another survey on 125 senior Accounting students who have just finished course ACC-PBL 496. There are two reasons why we choose these students to study. (1) They have been exposed to PBL method for three and a half years through a number of courses with some PBL instructors. (2) The course ACC-PBL 496 is the final course designed for senior students before they prepare themselves for their internship in Spring. The problems presented in the class PBL 496 are open-ended with no right or wrong solutions and they are created by instructors to simulate problems in the real world. In this course, students have to formulate their own integrated solution(s), using not only skills and knowledge in Accounting but also in other related fields like Finance, Marketing, Human Resource, Information Systems, etc. For these reasons, we hope these fourth-year students are mature and have enough experience to answer the survey questions and provide thoughtful feedback on PBL teaching method to contribute ideas about the effective role of PBL facilitators.

To find out students' evaluation on the role of instructors in PBL learning sessions, we collected data through 2 ways: through a written questionnaire completed anonymously by individual students and through focus group interview. The interview questions are based on the previous study by Alice Ling and Loy Kiah Jee (Ling & Loy, 2007)

Written questionnaire includes 3 questions:

1. What do you think of learning via PBL after 4 years at DTU?
2. Please share the specific ways that your instructors have helped you in your learning?

3. What would you like your instructors do differently to help you learn?

The purpose of the first question is to help the students reflect on their learning experience under PBL method during 4 years at DTU. The second question assists the students to reflect on the specific areas that instructors have done well to facilitate students in PBL environment. The intention of the last question is to have the students reflect on the instructors' shortcomings and the students could propose ways for betterment. Question No. 2 and 3 would generate response to help us identify the actions that instructors should do and the specific facilitation role that instructors should play in PBL classes to help students with their self-directed learning.

Focus Group Interview

Focus group interview took place right after the students completed the written questionnaire. At the beginning of the interview, all groups were assured that their responses would be kept anonymous so that they could answer the questions straightforwardly. After that, we asked the groups 3 above-mentioned questions again. By interviewing the focus groups, we could allow the students to elaborate on what they could not express in their written responses. Moreover, through focus group interview, we could have deeper understanding about the role of instructors in PBL session. To get more data about how instructors have equipped students to take control of their own learning and group process, we use the following prompt list to ask the groups.

1. What kinds of questions did your instructors usually ask? Did these questions help you to think?
2. When you asked your instructors about a difficult issue, did your instructors give the answers? How did you feel when they did or didn't? What would you have preferred?
3. Did the facilitators help to link knowledge acquired in previous PBL sessions? How do you see that taking place?
4. Did the facilitators help you with your reflection? How did you feel when they did or didn't? What would you have preferred?
5. Did the facilitators get involved in your group? What did they do in your group? How do you feel when they did or didn't? What would you have preferred?

4. Result

Based on the written responses of individual students and focus group interview for three key questions, we got the following results.

4.1. Students' appreciation of PBL benefits

All response showed that the students appreciated the application of the PBL method in teaching accounting. Since their first year, accounting students have been exposed to PBL and this teaching method has transformed their learning attitude and equipped them with professional skills. They shared with us the idea that PBL was a new educational method that they had never been taught at high school. In their first year, when they studied the courses via PBL method, they felt challenged because they must shift from the traditional teaching method to a student-centered pedagogy, from surface learning to deep learning.

The students admitted that as they got familiar with PBL, this teaching approach has positively impacted their personal autonomy. In all accounting courses, they are required to work in small teams to explore the presented problem situations. They must identify the issues related to the problem, list what they know, list what they need to know to solve the problem as well as actions to be taken within timeline, write report with the solution to problem with supporting documents, present and defend their work, review and reflect on their individual and team's performance… Through all these activities, they could learn how to become partners, develop collaboration, presentation and communication skills and at the same time, accept responsibility. They shared that they have the motivation for professional identity in their group as well as in the class and know that they must carefully plan their self-study activities in order to be optimally prepared for the next group meeting.

Many students shared with us that they have become confident when making presentation and speaking in front of large audience. PBL help them develop their interpersonal skills, they could learn how to persuade others but at the same time, they learn to listen and accept the difference. All the positive feedback implies that Duy Tan University has selected the right teaching method when deciding to implement PBL.

4.2. Students' appreciation of teachers' activities in PBL classes

The students appreciated the instructors' encouragement in their learning process. When they made mistake, the instructors helped them identify the errors and guided the learning back to the right track. In addition, the instructors help them to link knowledge acquired in previous courses with the current subject, for example, making connection between advanced accounting and intermediate accounting, financial auditing and financial accounting, financial accounting and tax accounting by using clear examples and illustrations. When students asked the instructors about a difficult problem or a confusing project situation, the instructors usually summarized what the students had said and asked if this was what they meant and gave continuous feedback. Besides, the instructors also taught them how to make presentation and prepare supporting documents and spread-sheet in the most efficient way that helped the audience could understand and participate in their presentation. Generally speaking, the students noted and appreciated instructors' effort in organizing activities in PBL class.

4.3. Opposite views on facilitation preference

For question 3 about what students would like the instructors to do differently to help them learn, we received two opposite views on this issue which reflected different preference about facilitation type among students. While a number of students felt pleased with the current facilitation in PBL courses, others would prefer the instructors make some adjustments to the current PBL framework to stimulate their self-directed learning. The latter thought that instructors tended to act as a group leader and that stemmed from the fact that instructors were too concerned about the students and they wanted to make sure that students never went the wrong way and got optimum result. These students, however, would expect to have higher levels of independence.

Response to the questions from the prompt list affirmed the difference among students. For the question "When you asked your instructors about a difficult issue, did the instructors give the answers? How did you feel when they did or didn't? What would you have preferred?", all the interviewed students replied that when they encountered difficult questions or situation, the instructors usually provided them with clear answers and detailed explanation until they could understand the issue thoroughly. While a number of students expressed that they felt happy and reassured when receiving the answer, the other students, however, prefer to be encouraged to explore the depth of the subject themselves. They like to be challenged to recognize the issue or at least they prefer the instructors to guide them finding the answer by posing probing question instead of giving the answer.

Similarly, for the question "Did the facilitators get involved in your group? What did they do in your group? How do you feel when they did or didn't? What would you have preferred?" The answer echoed what the instructors had responded in November survey. The students admitted that the instructors helped them to make plan for necessary activities, assigned tasks to group members, recommended necessary reference textbooks, helped them forecast the final product and instructors usually checked the group progress and provide guidance to keep the groups on right track. The dependant students expressed that they preferred close guidance and control to ensure that they were doing everything in the right way. They expressed that they would appreciate it if instructors provided further assistance when they needed. However, things went differently with the self-confident students with professional strength. They shared with us that when they were in their first year at university, they had limited experience with PBL work, they needed to receive a thorough facilitation, but from the second and third year when they became more experienced, they preferred some levels of independence. They would prefer the instructors to keep a distance to their group, give them space to explore the problem, research on information and try their own idea. They thought that, in the fourth year, the students were mature enough to be responsible for the project, they preferred consultancy from the instructors and that the instructors should only provide facilitation when students asked them for advice. In addition, they prefer to be empowered to decide the tasks and roles of each member in their group instead of being assigned by the instructors because they thought that assigning tasks to group member is the job of group leader, not of an instructor and they are confident that they could arrange this issue themselves. They emphasized that in the current facilitation framework, the instructors helped them to choose the theory and method to apply in their project as well as directed and edited their project report implied that the instructors were playing a dominant role in students' learning process and group process. The self – confident and experienced students shared with us that instead of telling them what students should read and learn, instructors should help students determine on their own what they need to know and how to learn. For example, instead of directly saying that "you should review the definition of "intangible fixed asset", the instructors should guide them to reflect on the problem with probing question such as "Are there any other issues that we should think about?"

5. Discussion

The interview with 8 accounting instructors in November and a survey on 125 accounting students in December showed that shifting from the traditional teaching method to PBL approach, the academic staff had made great effort to introduce and establish new culture of active learning and develop practical professional skills for the students. When deploying PBL session, they tend to rigidly act as an important group member to ensure that all students have flawless projects. This philosophy, however, could affect the active role of students in their self-directed learning. Many students, even though appreciating the effectiveness of PBL, still prefer control facilitation. Meanwhile, a number of students have really "grown up" from PBL teaching method, they are aware of their responsibility in PBL and believe that they could learn from their mistakes. To match the dynamics of learning context, the instructors should consider some suggestions.

Redefining PBL facilitation role depending on the learning context

During PBL session, instructors should be situation – dependent by referring to the variety in professional level and personality traits of students to "read" and "decode" them and stimulate their learning. Therefore, within the same PBL class, instructors should practise all roles (group member, dialogue based facilitator and consultant) depending on the student progression and apply suitable facilitation strategies for different students based on their professional levels. For example, the inexperienced students should have more control and receive a detailed response; the experienced and self-confident ones, on the contrary, should have more independence and stress on process facilitation. According to Kolmos et al., the mixing of facilitation types can also be used in different course stages. At the beginning of the course, if the students have difficulty with the projects, the level of involvement should be high, and later, when students become stronger and more experienced, instructors should redefine their facilitation role as dialogue based facilitators or even consultants (Kolmos, Du, Holgaard, & Jensen, 2008). To choose the appropriate facilitation type, at the contact phase of the course, instructors should evaluate students' experience about the project by asking questions relating to the course and projects. If the students have limited experience with the project work, the instructors can execute a more thorough facilitation. Facilitation types should be adjusted continuously as the students make progress during the project.

Paying attention to questioning and responding strategy

Results from the survey suggest that the instructors should pay more attention to questioning and responding strategy because effective questioning and responding is an important precondition to promote self-directed learning and stimulate students to seek possible solution by themselves. In all circumstances, instructors should ask questions that require students to use reflecting skills, encourage them to think more deeply and critically. Within a single class period, the instructors should vary the level of questions. However, they should ask higher-level question firsts. If they receive inadequate or incorrect response, they might ask lower-questions to check whether students know and understand. They should also use probing questioning techniques to get students more involved in critical analysis of their own and other students' ideas. As for responding techniques, when students ask about a difficult issue that they encounter, instructors should not necessarily rush to provide information or answer the question but they might redirect the question to the whole class to encourage active learning and student-to-student interaction or they might help the student to seek the answer by asking open-ended questions which allow students to see the big picture as well as some fine details. Suitable questioning and responding strategy will inspire self-confident and experienced students because they are challenged to develop their strengths, and at the same time, encourage weak students to find ways to the answer themselves.

Avoiding distinctive professional difference between groups

A very important issue that we noted from the survey is that instructors should not allow students to form the groups themselves because students normally tend to select their friends to work. This could lead to the situation that some groups are so brilliant but the other groups are so weak because students often play with people of the same "level". Consequently, the weak groups will end up with little content acquisition and inefficient group process and will be overwhelmed by the strong groups during the PBL course. This method of group forming will pose a lot of difficulties for instructors to deploy successful class facilitation. Thus, we suggest that instructors should assign students to groups based on their ability, skills and background knowledge and ensure that students of different qualities are disposed in the same group. The strong and experienced students will act as the leaders responsible for encouraging their group members to participate and contribute while the weak and inexperienced students will follow. To evaluate the quality of students, on the first day of the course, instructors should generate a pre-test including a list of questions relating to the background knowledge, skills and experience necessary for the project and ask the students to do. The result will help the instructors to form groups reasonably. For example, if the project is about organizing accounting activities for a virtual corporation, the group needs someone with strong background about general accounting to work as a Chief Accountant, but also needs someone with knowledge in Accounts Payable, Accounts Receivable, someone with Inventory Accounting experience and someone meticulous responsible for book-keeping… Working together during PBL session, they could foster group experience and peer teaching.

Motivation and encouragement for all students especially for the quiet and dependent students

Even though the instructors have already organized groups reasonably well, they should always spend more time with quiet and dependent students by asking, listening and encouraging them to contribute their ideas to projects. Such encouragement and motivation should start right from the very early stage of the project. Instructors should arrange meeting with the timid students to find out the reasons for their lack of contribution. If there are any reasons that obstruct their contribution, instructors should provide timely support. The regular help and meeting should be organized until the students become confident. In all cases, instructors should have positive expectations to all students because positive attitude empowers students and yields positive results.

6. Conclusion

This study aims to research the facilitation actions of PBL instructors by interviewing a group of 8 accounting instructors and to investigate whether such facilitation framework is effective by interviewing 125 senior accounting students. Through the survey with the students, we found out that all students appreciated the benefits of PBL and the activities that instructors had done to help them in their learning. However, there are two opposite views on effective facilitation role that the accounting instructors should play to help students more in their self-directed learning. Analysis of student feedback reveals that PBL instructors should ensure flexibility and contextualization of facilitation in PBL class. A competent PBL instructor, thus, should master several facilitation types and have the ability to select the suitable facilitation role. They should develop their questioning and responding techniques, avoid distinctive professional between groups, provide motivation and encouragement to students to enhance group collaboration. Through these activities, instructors might decode students and help them to be reflective about their learning and thus, instructors might adjust facilitation accordingly.

This study hopes to create a deeper understanding of what exemplary PBL instructors should do so that in the future more effective staff development programmes can be designed to develop the professional competency of PBL instructors. The follow-up study is to evaluate students' self-directed learning development and satisfaction after the instructors having redefined facilitation type at Accounting Faculty. Students' self-directed learning development and satisfaction is of great importance since students are the subjects of learning and the first consideration of teaching.

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Problem-Based Learning: Barriers to Effective Facilitation in a Social Constructivist Classroom

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Abstract

This study is conducted in an institution that adopts a social constructivist approach in its teaching and learning environment where the predominant instructional approach is Problem-Based Learning (PBL). Students are given opportunities to share, debate, make sense of, and build on their learning collaboratively. To this end, it is essential that lecturers are equipped with the knowledge and skills to create and facilitate these learning opportunities successfully. The aim of this study was to identify the barriers to effective facilitation in a PBL classroom. Data from the Certification in Facilitation were analysed to identify the common pedagogical shortcomings demonstrated by lecturers in the PBL classroom. The sample consisted of 67 lecturers (candidates) who attempted but did not attain the in-house Certificate in Facilitation between 2015 and 2017. Candidates were evaluated by the certification panel based on seven dimensions of effective teaching and learning: (i) learning environment; (ii) prior knowledge & knowledge and skills acquisition; (iii) facilitation and scaffolding; (iv) collaborative learning; (v) self-directed learning; (vi) reflection; and (vii) assessment. Analysis of the performance scores and qualitative developmental feedback provided by the certification panel was conducted. The results indicated that the lowest-scoring dimension was "facilitation and scaffolding". The common observed shortcoming of candidates that hindered effective facilitation was that they were inept in asking effective questions and tended to be leading instead of guiding students in their learning. Data analysis of the candidates' training records indicated that they completed very few or no optional training programmes related to teaching and learning prior to their Certification in Facilitation attempts. The study findings suggest that support for lecturers in the teaching and learning dimension on "Facilitation and Scaffolding" can be improved. The support could be in the form of, but not limited to, developing relevant training and professional development programmes for lecturers.

Keywords: facilitation, problem-based learning, social constructivist, classroom learning

Type of contribution: Research paper

1. Introduction

According to social constructivist educational theory, a classroom is a learned community. Within this context of social constructivism, meaningful learning occurs when there are authentic tasks and collaboration between peers and teachers (experts) (Azzarito & Ennis, 2003). PBL is a constructivist educational approach that organises curriculum and instruction around "ill-structured" problem and build on students' prior knowledge (Barrows, 1988). In a PBL classroom, teachers act as facilitators to help learners develop critical thinking, problem solving, and collaborative skills as the learners work together to explore and derive the optimal solution for the "ill-structured problem". The attainment of learning outcomes in a PBL lesson is dependent on both the "ill-structuredness" of the problem and good facilitators (Kapur & Kinzer, 2007). To strengthen the interactions between teachers and students in a PBL classroom, one needs to study the factors influencing teachers' facilitation skills and what constitutes effective facilitation.

Literature on constructivist teacher education point out that teacher-training in social constructivist learning environments may enhance teachers' critical thinking and help teachers' metacognitive awareness levels (Kroll & Laboskey, 1996). A growing body of research studies highlight the importance of "constructivist teacher education" in educating teachers (Lunenberg & Korthagen, 2003; Tynjälä, 1999). In the context of polytechnic education, effective questioning techniques of facilitators and timeliness of facilitator feedback have been commonly identified as characteristics of good PBL facilitation (Goh, 2014; Ling & Loy, 2007). While there is growing evidence that social constructivist approach helps to train teachers effectively as well as studies on attributes of good facilitators, there are limited studies that examine the factors that hinder effective facilitation in a PBL classroom. In this regard, Leow, Koh and Chua (2017) sought to complement the findings on what constitutes good PBL facilitation with their study on barriers to effective facilitation. The present study aims to build upon the preliminary findings by Leow, Koh and Chua (2017) and seeks to find out the common pedagogical shortcomings demonstrated by lecturers in the PBL classroom from the perspectives of panellist in the in-house Certification in Facilitation programme.

2. Methods

2.1 Education Context

This study is conducted in a polytechnic in Singapore that adopts a social constructivist approach in its teaching and learning environment where the predominant instructional approach is PBL. The institution has an in-house Certification in Facilitation programme that was developed in 2003 to define and develop the competencies required of lecturers to facilitate within a PBL classroom. The panellists in the programme are faculty members in the institution and are themselves certified in facilitation and have been identified by the institution to be peer reviewers based on their experience and expertise. All panellists are required to attend yearly benchmarking sessions, led by the institution's Educational Development Department that helmed the Certification in Facilitation programme, to align their standards of evaluating the candidates who are PBL facilitators.

Candidates attempting the Certification in Facilitation typically have been employed by the institution for more than a year. They are required to:

a) attend a recommended set of compulsory training programmes before attempting the Certification in Facilitation programme;

b) submit a teaching portfolio and a video-recording of a lesson; and
c) attend an interview with a panel of three interviewers.

The video-recording captures the interactions of the candidate with the students for the whole PBL lesson, which typically lasts for at least four hours. All three panellists are given access to the video-recording prior to the interview. During the interview, the panellists use segments of the video-recording and portfolio to initiate discussions with the candidate.

The certification is based on the institution's faculty training framework that focuses on seven dimensions of effective teaching and learning. These dimensions focus on (i) the creation of a conducive learning environment; (ii) the activation of prior knowledge and the acquisition of new knowledge and skills; (iii) effective facilitation and scaffolding of learning; (iv) the infusion of collaborative learning; (v) the use of self-directed learning to internalise learning and foster meta-cognition; (vi) promoting self-reflection; and, (vii) assessing meaningfully and authentically. Together, they form a framework known as the Principles of Effective Teaching and Learning. Based on candidates' performance at the interview, evidence from their facilitation of the lesson in the video, as well as the quality of their portfolio, candidates are assessed and given a score for each dimension as shown in Table 1. The higher the score, the better the candidate's performance in the dimension.

Table 1: Performance indicators for respective scores

Score	Performance Indicators
1	Emerging - Able to anticipate students' learning needs but may not be able to intervene or strategise ways to support them appropriately. Intentions may not correlate with actions, or actions may not help students achieve certain learning behaviours.
2	Competent - Able to anticipate students' learning needs and is able to intervene or strategise ways to support them appropriately. May not always be cognizant of the impact of an action on learning.
3	Proficient - Able to anticipate and diagnose, as well as strategically respond to students' learning needs using appropriate interventions or strategies that support students in achieving certain learning behaviours.

The certification panel decides on the outcome and provides developmental feedback, together with the score, for each teaching and learning dimension in an outcome letter for each candidate.

Prior to the certification exercise, candidates would have completed at least 84 hours of training encompassing the seven dimensions of effective teaching and learning, as well as other domains such as pastoral care and career guidance. Beyond these recommended training programmes, candidates also attend other optional in-house training programmes.

2.2 Participants

This study analysed the Certification in Facilitation outcome letters and the training records of 67 unique candidates who attempted but did not attain the certification between 2015 and 2017. The candidates were from faculties across the institution: applied science, engineering, hospitality, infocommunication, management and communication, sports health and leisure, and technology for the arts.

2.3 Procedure

The study was approved by the institution's Institutional Review Board. Data were collected from two key sources: (i) Certification in Facilitation outcome letters and (ii) training records of the candidates. The data were de-identified before analysis was conducted.

The performance scores in the outcome letters were analysed to compare candidates' performance in the respective teaching and learning dimensions and to identify their lowest-scoring dimension.

Thematic analysis, a method of identifying, analysing and reporting patterns within data (Braun & Clark, 2006), was used to further examine the developmental feedback in the outcome letters. This was conducted to identify common themes in facilitation barriers observed, specifically in the lowest-scoring teaching and learning dimension. Comments in each sample qualitative feedback in the outcome letters were identified and categorised into themes, and the frequencies of their occurrences across the samples compared.

The types of training that the candidates had completed before they attended the Certification in Facilitation interview were also analysed to inform the training profile of the candidates.

3. Results

The performance scores in the Certification in Facilitation outcome letters of the 67 candidates were analysed. Table 2 shows a summary of the scores, ranked in descending order of the dimension with the most number of candidates scoring a performance score of 1.

The dimension on "Facilitation and Scaffolding" had the most number of candidates with 58 (86.6%) scoring a performance score of 1. This number of candidates scoring 1 is significantly more than that of the next two dimensions on "Reflection" and "Prior Knowledge & Knowledge and Skills Acquisition", with 45 (67.2%) and 44 (65.7%) respectively. Dimension "Facilitation and Scaffolding" had the lowest mean score (1.13) and standard deviation (0.34). The results suggest that "Facilitation and Scaffolding" was the predominant dimension that panellists identified majority of the candidates to be weak in.

On the other hand, dimension "Learning Environment" had the least number of candidates with a performance score of 1 and most number of candidates scoring 3.

Table 2: Performance scores of 67 candidates in the seven teaching and learning dimensions

Dimension	No. of candidates scoring … 1 (%)	2 (%)	3 (%)	Mean (SD)
1. Facilitation and Scaffolding	58 (86.6)	9 (13.4)	0 (0.0)	1.13 (0.34)
2. Reflection	45 (67.2)	21 (31.3)	1 (1.5)	1.34 (0.51)
3. Prior Knowledge & Knowledge and Skills Acquisition	44 (65.7)	23 (34.3)	0 (0.0)	1.34 (0.48)
4. Collaborative Learning	42 (62.7)	24 (35.8)	1 (1.5)	1.39 (0.52)
5. Self-directed Learning	40 (59.7)	26 (38.8)	1 (1.5)	1.42 (0.53)
6. Assessment	37 (55.2)	30 (44.8)	0 (0.0)	1.45 (0.50)
7. Learning Environment	21 (31.3)	43 (64.2)	3 (4.5)	1.73 (0.54)

The developmental feedback in the Certification in Facilitation outcome letters for the 58 candidates who attained a performance score of 1 for "Facilitation and Scaffolding" were further examined to identify the common pedagogical shortcomings demonstrated by these candidates. From the qualitative feedbacks, the two most common obstacles to effective "Facilitation and Scaffolding" observed and highlighted by the panel was that lecturers were inept in asking effective questions and lecturers tended to be leading instead of guiding students in their learning. Table 3 shows examples of feedback from the panel that relate to the two obstacles.

Table 3: Common obstacles to effective "Facilitation and Scaffolding"

Common obstacle	% of sample with obstacle	Examples of feedback relating to obstacle
Inept in asking effective questions	52%	– *"intention of lecturer's question was unclear"* – *"questions posed by lecturer were not derived from the learning issues and seemed irrelevant"*
Leading students' learning	45%	– *"lecturer's scaffolding was focused on leading students towards arriving at correct answers than on helping them evaluate or form their own approaches"* – *"lecturer tend to correct students and share answers too quickly and in a leading way"*

The optional training programmes taken by the 67 candidates before they attended the Certification in Facilitation interview were analysed. Out of the seven teaching and learning dimensions, four of them, namely "Prior Knowledge & Skills Acquisition", "Collaborative Learning", "Self-directed Learning" and "Reflection" were not reflected in the scope of optional training programmes attended by the candidates. Overall, more than one third of the group, 23 candidates, did not attend any optional training programmes related to the seven teaching and learning dimensions.

4. Discussion

PBL is a student-centred instructional model in which students need to self-direct their learning to determine what they know and do not know about the problem (Jonassen & Hung, 2008). One of the essential roles of the PBL instructor is facilitation of the learning process via asking students effective questions (Jones et al., 1993). The findings from the analysis of the Certification in Facilitation outcome letters revealed that the candidates scored particularly low in the "Facilitation and Scaffolding" dimension and further suggested that many of the candidates who did not attain the certificate demonstrated inability to ask effective questions and tended to lead instead of guide students' learning. It is unsurprising that such traits hinder the effective facilitation of the candidates in a student-centred lesson environment. The findings reinforce the need to strengthen lecturers' questioning skills, which can include expanding their repertoire of questioning techniques and heightening their awareness of the timeliness of their questions and responses (Goh, 2014; Ling & Loy 2007). Lecturers should also be reminded to give students the autonomy to chart and evaluate their own learning, and to find a balance between supporting students' learning and letting students learn to embrace self-directed learning (Conway & Little, 2000).

The findings from the training records indicated that candidates completed very few or no optional training programmes related to the seven teaching and learning dimensions prior to their Certification in Facilitation attempt. The lack of additional training beyond the recommended training programmes may have affected candidates' level of competence in facilitation and correspondingly their preparedness for the certification.

5. Limitations of Study

PBL involves a dynamic interaction of the teacher's beliefs, goals, and knowledge (Hmelo-Silver & Barrows, 2006). The present study focuses on the actions demonstrated by candidates in the PBL classroom. The candidates' previous teaching or learning experiences and their beliefs and understanding of the social constructivism approach to learning may affect the way they conduct their PBL lessons. Further studies in these aspects would provide more insights on the barriers to effective facilitation and the types of support to provide to lecturers.

Another limitation of the study is that the analysis of the training record does not provide insights on candidates' perceptions of the effectiveness of the available training programmes in preparing them for effective facilitation or for the certification. However, the findings help to identify relevant training programmes in facilitation that can be developed for lecturers conducting PBL lessons.

The study was conducted on a sample size of 67 and the coding for analysis was conducted by a single researcher. Having a bigger sample size and three researchers to code the data would improve the inter-rater reliability of the data by multiple researchers, and hence would increase the robustness of the study.

6. Conclusion

This study indicated "Facilitation and Scaffolding" as the teaching and learning dimension which most candidates did not perform well in. Being inept in asking effective questions and having the tendency to lead instead of guide students in their learning were identified as the common obstacles to effective facilitation. These findings suggest that support for lecturers in these areas can be improved, which can be in the form of, but not limited to, developing relevant training programmes for lecturers. Besides analysing the feedback from experienced peer reviewers, in this case the panellists, viewpoints on definitions of effective facilitation can also be sought from lecturers (candidates) themselves as well as students to broaden our understanding of the barriers to effective facilitation.

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Employing learning analytics for monitoring student learning pathways during Problem-Based Learning group work: a novel approach

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Abstract

Learning Analytics (LA) aims to improve the learning process by analysing learning data, and communicating the results of this analysis to both educators and learners. LA has been employed in a few cases for improving PBL group work but the literature has yet to discuss in detail the incorporation and potential of LA in this context. In this paper, we describe our approach that aims at developing a platform employing LA for monitoring students' learning pathways during Problem-Based Learning (PBL) group work. The platform is developed in Moodle, and it provides a communication and information channel between project supervisors and students, and between students belonging in the same group. Moreover, the platform provides ways for student groups to better manage their projects, and at the same time enables project supervisors to follow groups' progress during the semester. The platform is also used as a place, where students hand-in assignments that are related to their project work and report their status in the project. In this platform, we employ various LA tools offered by Moodle in order to monitor both group and individual student activity. Such tools provide learning data on individual student engagement and activity within the platform, generic statistics on the use of the platform, and insights into the exchange of information in the platform. In this paper, we present the functionality of the various modules that build up this platform, and discuss the type of learning data generated and the methods to analyse this data. We conclude this paper with a discussion on the benefits and the limitations of this approach.

Keywords: PBL group work, learning analytics, Moodle, educational data

Type of contribution: best practice paper

1 Introduction

In the last decades, the introduction of digital technologies (such as online learning environments, learning management systems, social media etc.) in education has led to the generation of a variety of multimodal learning data (Siemens & d Baker, 2012). This data is generated while educators and learners interact with such technologies and can provide valuable insight into the learning process. However, there was limited use and analysis of such data up to 2010, when Learning Analytics (LA) gained momentum as a research field (Siemens & Long, 2011). LA aims at providing ways to gather and make sense of educational data in order to improve the learning experience for learners and teachers, and better adapt courses' design. According to the Society for Learning Analytics Research (SoLAR), learning analytics is defined as follows:

"Learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs." (Ferguson, 2012)

In this paper, we describe our approach that aims at developing a platform employing LA for monitoring students' learning pathways during Problem-Based Learning (PBL) group work, we present the functionality of the various modules that build up this platform, and discuss the type of learning data generated and the methods to analyse this data. The paper is organized as follows: section two refers to other approaches that used LA for better supporting group work, section three describes the proposed platform, while section four discusses the methods employed in a trial where this platform was employed. Section five presents the categories of the educational data gathered on the platform, and section six discusses our plans for the analysis of the educational data gathered, and the evaluation of the trial. We conclude this paper with a discussion on the benefits and the limitations of this approach.

2 Background

Although group work is assumed to have positive effects on student learning, experiences from educational practice indicate that it can also introduce problems for both students and teachers. Examples of such challenges include students who only maintain an appearance of being actively involved, or students who let others do the work, also called free-riders (Salomon & Globerson, 1989). Therefore, research has paid much attention to the problem of differentiation of individual contributions in group projects (Earl, 1986; Goldfinch & Raeside, 1990; Kommula, Oladiran, & Uziak, 2009). Later on, researchers attempted to mitigate free-rider problems and improve students' perceptions about group work (Brooks & Ammons, 2003; Elliott & Higgins, 2005). All these approaches were based on student assessments of the performance and contribution of their group members and in some cases student self-assessments. With the rise of LA as a research field, educational researchers attempted to address the challenges in group work by employing LA methods.

Tempelaar et al. (2014) proposed a LA infrastructure that combines learning dispositions data with Learning Management System (LMS) student engagement/activity data, and data extracted from computer assisted formative assessments. Their study ran in an introductory mathematics and statistics module combining face-to-face PBL sessions with e-tutorials, and investigated the predictive power of learning dispositions, outcomes of continuous formative assessments, and other LMS generated data in modelling student performance and their potential to generate informative feedback. The results of this study showed that computer assisted formative assessments were the best predictor for detecting underperforming students and academic performance, while basic LMS data did not substantially predict learning.

Conde et al. (2017) developed a LA tool that enables teachers to perform teamwork competence assessment of a group of students taking into account how the individuals acquire the essential components of such competence. This tool uses the Comprehensive Training Model of the Teamwork Competence in Engineering Domain (CTMTC) method to gather competence evidences, and it was used in two Bachelor courses on Computer Science. In this comparison case study, the tool was incorporated in Moodle, where the teachers of the two courses posed an activity that should be completed in teams applying the CTMTC methodology. The Moodle forum was the main space for interaction, and the Moodle wiki was used by students to display the outcomes of the activities. The work done in the wiki had to incorporate the phases described in CTMTC. The results of this study showed that there was a significant correlation between posts/views and individual final grades in both courses and this can be taken into account when analysing group members' use of educational resources and interaction that takes place in the web of data. Moreover, it was found that the perception of teamwork competence acquisition among students has changed after the application of CTMTC, and that teachers perceived this tool as applicable in different contexts, flexible and portable.

Spikol et al. (2017) employed multimodal LA (MMLA) in order to understand what happens when students are engaged in collaborative, project-based learning activities. They developed a MMLA platform, where various streams of data are collected, and multimodal interactions are processed and extracted with the aim to identify which features of MMLA are good predictors of collaborative problem-solving in open-ended tasks in project-based learning. Moreover, manual entered scores of collaborative problem-solving were regressed using machine-learning methods. In this research study, the authors found that where the students are looking, the distance between them, the motion of their hands are key features for identifying collaboration in small groups of engineering students. Therefore, they proved that the physical aspects of collaboration is an important part of this type of learning and that MMLA provides new methods for providing evidence about the impact of such learning approaches.

In this paper, we present a platform that supports PBL group work by using LA to exploit the data generated during this kind of learning. The aim of this approach is to gain insight into student progress, group cooperation, and supervisor-group collaboration while students engage in this kind of group work. Moreover, the platform seeks to provide student groups with methods to manage their work (meet milestones, organize their time, etc.) and share information within the group and with their supervisor. In the next session, we describe the various components of this platform.

3 The Proposed Platform

The proposed LA platform is implemented in the Moodle LMS, which keeps track of user activity and provides other LA tools for monitoring student progress. Since the platform targets group work, the students are divided in groups. It is assumed that group forming takes place outside the platform, and that each group is guided by a teacher, called supervisor. Each group in Moodle contains the group members and their supervisor. The platform is separated in sections, which support different purposes and contain activities to serve these purposes. The activities that take place within the group (or between the group and their supervisor) are set in "Separate groups" mode in Moodle, meaning that each group sees their own version of this activity.

The first section is a placeholder for general information regarding the group work. This section contains two forums: one is dedicated to announcements by teachers, and the other is devoted to an open discussion about group work. In the first forum, students do not have posting rights. This section contains also resources (files), which teachers consider relevant to the process or the content of group work. Lastly, this section contains an assignment activity, in order for groups to send their initial problem statement to their supervisor, according to the PBL approach. This activity is set to "Separate groups", so this information is only exchanged between groups and their supervisor.

The second section contains activities that support group communication and management. There is a forum activity and a chat activity for internal communication regarding the group work. Moreover, there is a checklist activity, which serves as a simple Gantt chart, and contains the main tasks of the group work based on the PBL approach. The tasks are defined by the teachers, which encourage students to add additional tasks, if needed. The groups can mark as done all completed tasks, thus facilitating project management, and at the same time informing their supervisor on their process.

The third section in the platform serves as a communication and document-sharing channel between groups and supervisors. This section includes assignment activities, which represent milestones of PBL group work. These assignments require specific deliverables and they are due on specific dates, facilitating project management for the groups. The section contains a forum activity that supports communication between the group and their supervisor. This activity is meant to replace all other online communication channels, (e.g. emails, sms, Facebook, etc.) between these two parties. Lastly, there is a wiki activity, which is used by the group as a progress report and an agenda before each physical meeting with the supervisor. Since the wiki activity keeps its previous versions, the groups and the supervisors get an overview of the progress of the work at the end of the semester.

The fourth section is dedicated to feedback activities. There are feedback activities for students, where each student can provide feedback on the group forming, collaboration, and progress anonymously. These feedback activities provide teachers with information on issues within the groups. There is also a feedback activity, where supervisors are required to evaluate their groups twice: once at midterm and once at the end of the semester.

4 Methods

The platform described in the previous section has been applied to gather, process, analyse, and interpret educational data during the second semester project at the Medialogy bachelor program of Aalborg University Copenhagen. Medialogy is an education that focuses on research and development, which combines technology and creativity and looks at the technology behind areas such as advanced computer graphics, games, electronic music, animations, and interactive art, to name a few. According to the PBL – Aalborg Model, which is applied in all programs at Aalborg University, the Medialogy program curriculum is mapped onto semesters, where students spend approximately 50% of their time on course work (3 courses) and the other 50% on a semester project, where students collaborate in groups. The semester courses support project work, which follows the PBL approach. Each semester is governed by a fixed theme, which is selected to serve as the context, where the courses and the semester project address the learning objectives. Each group of students is assigned a supervisor, who guides the students during the project, and makes sure they are progressing according to the goals of the semester.

The theme of the second semester at Medialogy is “Human-Computer Interaction”, so during the semester project the students should foster key competences in designing, developing and evaluating an artefact, such as a desktop or a mobile application, using a user-centred approach. While pursuing this aim, they are able to apply knowledge and skills in mathematics, programming and interaction design. The platform was used for the semester project module during the spring semester 2018, where 94 Medialogy students were divided in 14 groups. In this semester, six teachers acted as supervisors for the semester projects (some teachers supervised more than one group). The structure of the platform adjusted to this case is shown in Figure 1. In the next section, we present the educational data gathered during this semester project module.

5 Educational Data Gathered

The various components of the platform allow for the collection and analysis of different type of educational data. In the following, we present the different categories of data.

5.1 Student engagement and interaction with the LMS

Student engagement and interaction with Moodle data is gathered and analysed using the standard functionality of Moodle (reports), and three plugins for Moodle (GISMO, Statistics, and Heatmap). This type of data is gathered as students use the platform in order to shape an understanding of their overall engagement with the LMS.

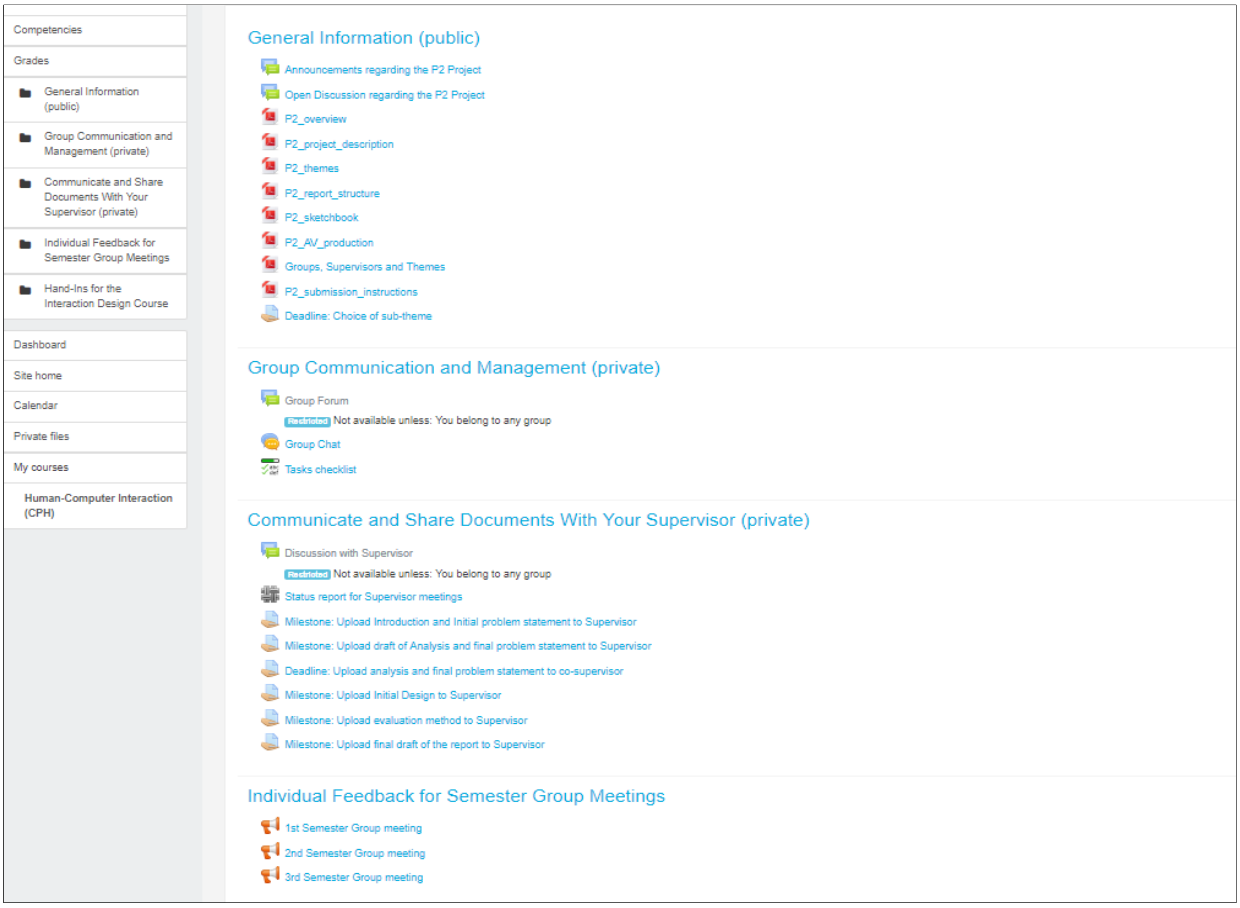

Figure 1: The platform adjusted for the semester project module in the second semester of Medialogy (Student view).

By employing the logs for the specific Moodle page, we are able to extract student action reports. Moodle distinguishes between the following actions on the various activities: create, view, update, and delete. The activity report provides the total number of views by number of users, and the date of the last access on each activity. Moreover, through the course participation reports, Moodle provides information on views and posts per activity. An overview of the views and posts for the wiki and the four forum activities per student of a random group are shown in Table 1 (we use the name “group A” to ensure anonymity). This information provides an overview of each group member engagement with all activities (numbers on the other activities not show here to save space). By adding the total number of views and posts for all group members, we can create a metric for the group engagement with the different activities (last column in Table 1). If we divide this metric by the number of students in each group, we get a “normalized” metric for each group engagement with each activity, and in this way we are able compare the engagement of different groups. Table 2 shows the total and mean value of views and posts on the wiki, forum, and file (resources) activities for group A.

In order to better visualize and combine the data provided by the Moodle reports, we installed the LA plugin GISMO on the platform. GISMO is a graphical interactive monitoring tool that provides visualization of students' activities in Moodle. With GISMO, we are able to visualize various aspects of student engagement, such as reading of materials, submission of assignments, engagement with forums etc. Figure 2 shows four graphs on student engagement for group A created in GISMO. The value of the GISMO graphs are that they are interactive and can be easily adjusted in time, or for individual students.

Table 1: Number of views and posts per wiki and forum activity for the seven students of a random group (group A, s1= student 1, s2=student 2,etc.)

Activity (Action)/Student	s1	s2	s3	s4	s5	s6	s7	Total
Wiki (View)	0	9	4	3	0	17	12	45
Wiki (Post)	0	0	0	0	0	3	1	4
Wiki (Total)	0	9	4	3	0	20	13	49
Discussion with Supervisor Forum (View)	3	87	75	67	0	32	27	291
Discussion with Supervisor Forum (Post)	1	2	11	0	0	6	2	22
Discussion with Supervisor Forum (Total)	4	89	86	67	0	38	29	313
Announcements Forum (View)	1	0	0	1	0	1	1	4
Open Discussions Forum (View)	1	3	0	0	0	0	0	4
Open Discussions Forum (Post)	1	0	0	0	0	0	0	1
Open Discussions Forum (Total)	2	3	0	0	0	0	0	5
Group Forum(View)	0	2	3	0	1	0	1	7
Group Forum(Post)	1	0	0	0	0	0	1	2
Group Forum(Total)	1	2	3	0	1	0	2	9

The Heatmap plugin is another tool that was added in the platform. This tool overlays a heatmap onto a course to highlight activities with more or less activity in order to help teachers gain insight into the use of the various elements of their courses. The Heatmap paints each activity with a colour from pale orange to vivid red depending on the number of user views on this activity (pale orange being the less used, and vivid red being the most used activity). Under each activity, the tool provides specific numbers of user views and the number of users, who viewed the activity. Moreover, it adds a small block with a summary on total views and distinct user views for the whole module (Figure 3). This information is only visible to users with a Teacher role.

Table 2: Total and mean value of views and posts on wiki, forum, and file activities for group A.

Engagement summary	Total	Mean
Accesses on wiki	49	7.00
Accesses on forums	331	47.29
Accesses on files	54	7.71

The Statistics plugin for Moodle was installed on the platform in order to have a quick overview of accesses to the platform per day. This plugin adds a graph in the Moodle page, where total connections per day are shown for the last 30 days (Figure 3). When a teacher clicks on the “More details” link, the names of the users connected on the current day are shown.

5.2 Forum discussions content

The content of forum posts on the platform provides insight into the discussions taking place among group members, and between groups and their supervisors. In order to identify the issues raised during these discussions, we apply an inductive approach for qualitative analysis on discussion data (Miles & Huberman, 1994). During this data analysis, consensus on findings is sought among three researchers in order to ensure a deep reflexive analysis, and to strengthen the validity of the findings. One of these researchers is actively involved in the second semester of Medialogy (not as a supervisor), which greatly assists in interpreting students' and supervisors' posts. The goal of this analysis is to create a list of the various topics raised and their frequency during the semester for each group (internally, and during communication with the supervisor), and then correlate the data in the list with the other type of data gathered on the platform.

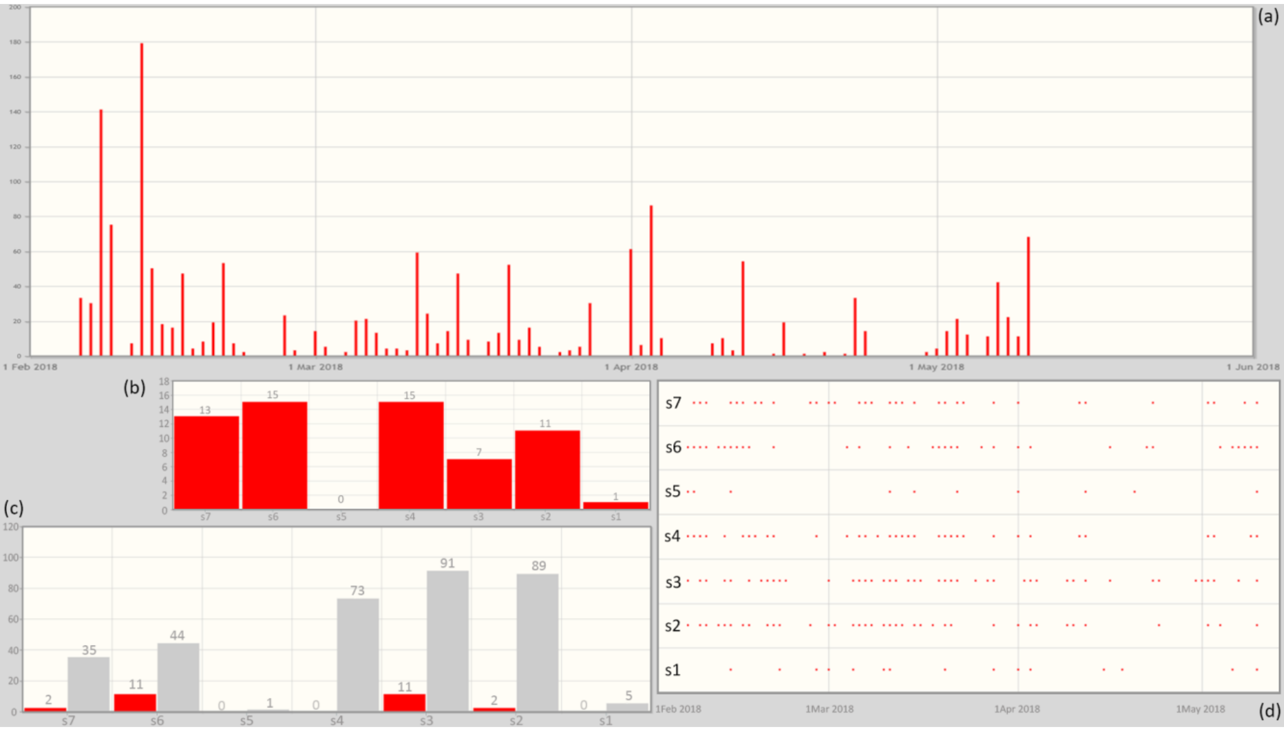

Figure 2: (a) Total accesses to the platform per day, (b) Total accesses to the files (resources) on the platform per student of group A, (c) Forum posts/views per student of group A (red=posts, gray=views) 4. Student accesses to the platform over the semester (dots represent days they).

5.3 Assessment data

The last type of data gathered is group and individual assessment data. Group assessment data is gathered through a feedback activity, where supervisors are asked to evaluate their groups in four aspects: group internal collaboration, group collaboration with their supervisor, project management, and overall performance. Supervisors fill out this feedback two times: once at midterm, and once at the end of the semester. At midterm, supervisors are also asked to provide an estimation of the group's final grade (referring mainly to the final product of the project, since students get individual grades during examination). Group assessment data are also gathered from the student side. Students evaluate their group's formation, internal collaboration, collaboration with the supervisor three times during the semester by using the feedback activities before each semester group meeting.

Individual assessment data is available after the final examination on the semester project module. The final examination is group-based, i.e. all members of the group present parts of their project and then answer questions posed by two examiners (the supervisor and a censor). However, at the end of the examination, the group members get individual grades depending on their performance during the presentation, and the Q&A round.

Figure 3: The Moodle platform with the Heatmap and Statistics plugins enabled.

5.4 Further data analysis

The aforementioned data was used once in the semester in order to identify groups that were at risk (low engagement data, late/lack of submissions of assignments, few/no wiki updates) and inform the respective supervisors. It was left to the supervisors to decide if they had to take some action. Moreover, student feedback was accessible by supervisors, so they could adjust their collaboration with the groups during the semester. At the end of the semester, we aim at applying statistical correlation and regression tests on the various sets of data in order to identify if and which pairs of data are related, and if some data can be used to predict the outcome of other sets of data. The qualitative analysis of the forum discussions will also provide insights into the learning and collaboration process of each group, and into the collaboration between groups and supervisors. By analysing posts, where feedback was given on specific parts of the project by the supervisors, the status reports, and each group's submitted assignments, we also aim to extract qualitative group assessment data.

6 Discussion and Conclusion

This paper presents a platform for applying LA methods to PBL group work. This platform was developed in the Moodle LMS, and provides teachers with different type educational data. By employing Moodle plugins, and quantitative and qualitative analysis on this educational data, we aim at getting insight on both the progress and the process of the PBL group work. Moreover, we are able to get data on the engagement and progress of individual students. In order to pilot the overall LA approach, and the functionality of the platform, we introduced it to the semester project module of the second semester of the Medialogy program. During this semester project module that follows the PBL pedagogy, the collaboration, interactions, and progress were taking place offline until now. It was therefore only the supervisor of each group, who had an overview of the group collaboration, and progress during the semester. However, in cases where the groups did not communicate with their supervisor, there was no way even for the supervisor to have such an overview. Moreover, it was challenging even for the supervisor of a group to get insight into the individual contributions to the project among the members of the group, at least before the final examination. Finally, it was difficult for supervisors to evaluate intermediate phases of the project, if the groups did not inform the supervisor about them, or they did not refer to such phases in their final report.

Our approach provides an overall view on student engagement and actions in the LMS supporting their semester project. Such an overview can be used to address groups or students at risk during the semester. Although student engagement in LMS is not always predictive for learning, we believe that low engagement is indicative of underperforming students. This assumption can be also mitigated on a group level, i.e. groups with lower engagement metrics were less productive during the semester. A few cases of students who dropped out during this semester agree with this assumption, which still has to be proved by the analysis on the collected data. The assignment activities that were introduced for groups to submit intermediate milestones to their supervisor, and the analysis of the forum discussions, and the wiki posts can be used in order to better evaluate the progress and the intermediate phases of the project.

The analysis of the forum discussions will also provide insights into the supervisor-group communication, and collaboration, which so far were taking place via emails and physical meetings. Such insights can be used to identify different patterns of communication and collaboration, and investigate if and how the group's and the supervisor's approach to them affect the group's performance or other aspects of the semester project.

While this platform provides information on different aspects of PBL group work, it requires also extra effort from groups and supervisors, since both of them had to get used to a new way of collaboration. Moreover, the strength of this approach on providing rich educational data depends entirely on the dedication by both teachers and students to use it. For instance, the forum and the chat activities meant to support communication among the members of a group have not provided any valuable data, since students usually select other platforms to perform these tasks (mainly Facebook and Skype), and therefore hardly used them.

Apart from analysing the educational data, we aim also at gathering student and teacher perceptions on the use of LA methods in these PBL semester projects. In order to evaluate the overall approach and the functionality of the platform, we will distribute questionnaires to the students and the supervisors involved in this trial. The supervisors will be asked also to fill out a guided self-reflection report based on the LA data available at the end of the semester. For the self-reflection analysis, we employ Gibbs reflective cycle (Gibbs, 1988). The aim of this analysis is to make sense of what happened, and plan future actions. The results of this evaluation will be used to adjust the platform and design the next iterations of its employment in PBL project work.

7 Acknowledgements

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The necessity of improving students' learning motivation with large student groups in Chinese higher education

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Abstract

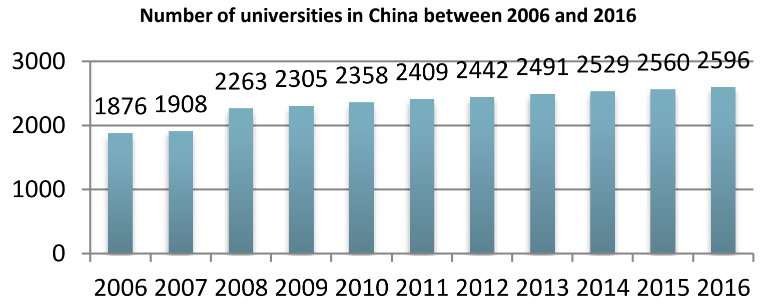
Large student groups are the practical situation of Chinese higher education. With the scaling up of the higher education, how to deepen the inner quality development while enlarging the outside quantity development is the main problem which may affect the whole system of Chinese education in the future. In this article the learning situations in the universities and the necessity of improving students' learning motivation with large student groups in Chinese higher education is analysed. We hope to find the effective way of improving the higher education with large student groups and give some contributive suggestions to the higher education reform.

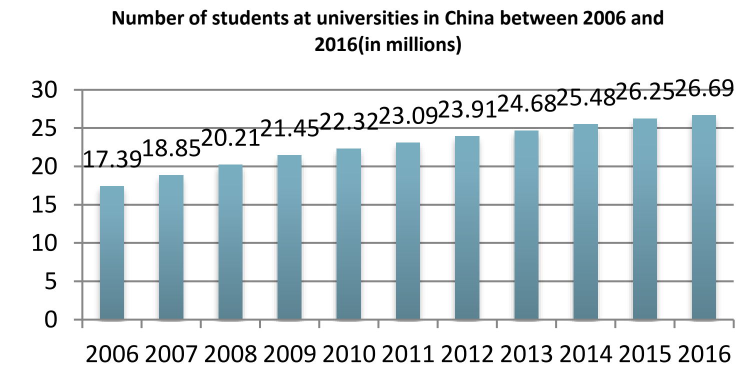
Keywords: higher education, large student groups, learning motivation, education reform
Type of contribution: research paper

1. Introduction

With the accelerating economic development in China many changes are happening in people's life and the society. Among the tremendous changes, the biggest one is the scale of the higher education has developed. Just twenty years ago, studying in one university was so many people's luxury dreams. Now, almost any people can afford to go to a college or a university to pursue their study. The university entrance is definitely becoming more and more open for everybody. The luxury dream that was twenty years ago has already become the young generation's ordinary life (Zhong *et al.*, 2017).

In Chinese higher education the idea of the cultivation had also switched from the elite mode that formed decades ago to mass mode with the increasing student numbers (Tang, 2017). It seems that it is quite equal for everybody to have a chance to go to college and become brilliant while the chance might have been as slim as winning a big lottery in twenty years ago. The number of the institutions and universities are also scaling up with the increasing of the students number. The higher education is developing so fast and all the statistics are so staggering (Graph 1). But in China many problems about higher education are also arising with this accelerating development (Lin *et al.*, 2015)





Graph 1 the statistics of Chinese higher education
(Source: Ministry of Education, China, 2017,)
https://www.statista.com/topics/2090/education-in-china/

While enlarging the building area and student number, how to maintain the students' learning motivation and give them a life-long learning habit will be the fundamental question for the future of Chinese higher education. In this article we will analyze and discuss the problems in higher education in China. The problems will be analyzed based on the data collected from three parts: the class, the teachers and the students. Our core problem will focus on the improving of the students' learning motivation and learning effect under the large student groups' background.

2. Problem Analysis

Since the implementing of the university enlargement policy in 1999, more and more students have entered the universities to pursue their study (Duan, 2016). The universities became much more "crowded" suddenly. And because of the increasing of the student number many problems come along with it. The teachers have to give more classes and repeat the learning content more times which will undoubtedly increase the labor work amount while lowering the learning quality (Zhao *et al*, 2016). The students face a tighter schedule for the rearranged class settings while have fewer chances and time to discuss with each other and with the teachers in and after the class. The universities need more education funding to improve the limited teaching resources while the limited funds are not divided equally between different regions and universities (Li *et al*., 2014). And all the problems come down to one common phenomenon for the students: their learning motivations are affected, the clarity of their learning motivations are decreasing (Qiu, 2010).

In 2017 we did a research project about the learning situation in Chinese universities during our learning period in AAU. The research is about the learning motivation, learning effect and changing designs in Chinese higher education. Many corresponding data are acquired through survey and questionnaires. Herein, we put some of the data to show the main problems about learning and teaching in Chinese universities. For the limited pages of this article, some unrelated details are omitted to show the clarity of the main ideas.

One of our groups did a survey of the class scales and the learning motivations of the students. The data are shown in the following figures and graphs.

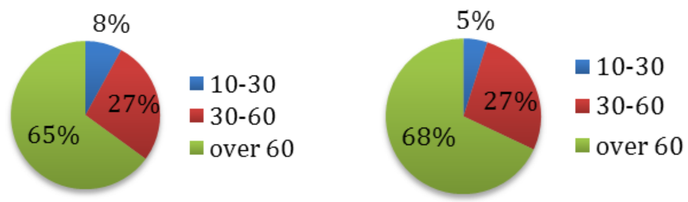


Figure 2.1 Overview of student number in Chinese university class
(left: from students; right: from teachers)

65% of the surveyed students admitted that they were experiencing classes with more than 60 students. The data from teachers also shew that 68% of them had been engaging in big class teaching (Figure 2.1). The data from teachers and students were consistent and could support each other. Just as stated above, big class with many students may be mainly due to the increasing number of students and insufficient full-time teachers since the implementation of enrollment policy in universities.

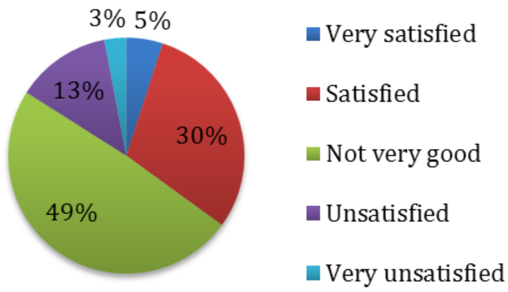
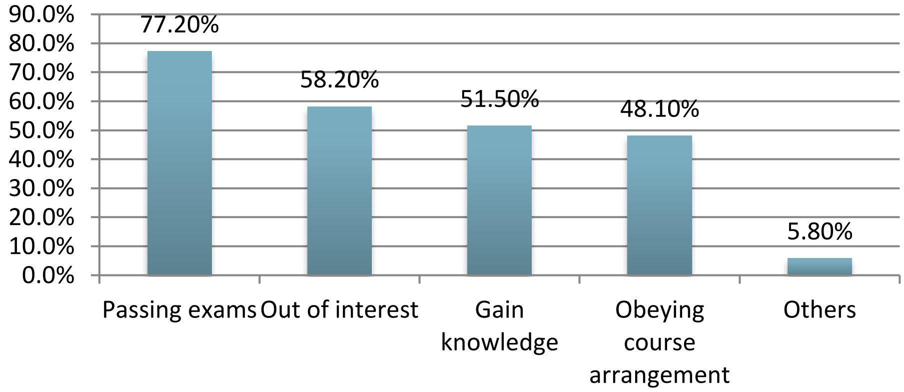


Figure 2.2 Student satisfaction survey results about big class teaching and learning

About the feeling of the big class teaching, according the statistical results only 35% of them felt satisfied with big class (Figure 2). When asked about the reasons, some of them told us: (1) there was less interaction between teachers and students, the teachers even could not know their names; (2) they seldom had time for discussions because the teachers always kept lecturing; (3) the classroom was relatively noisy, and they could not hear the teachers; (4) the teachers' teaching methods was monotonous and mostly lecture-based, and it was very boring.

Figure 2.3 Students' learning motivations



Being asked about why they study and where their learning motivations come from in universities, most of the students (77.2% of 958) chose passing the exams successfully as the answer. Some of them even had no idea why they learned and just chose to follow the course arrangement (Figure 3).

According to the results from our learning group in AAU, the teaching and learning situations about science class are surveyed and some interesting data are collected and shown as follows.

Table 2.1 Teaching formats of teachers (views of teachers)

Options	Participant Numbers	Proportion
Lecturing	**165**	**90.66%**
Group or peer learning	1	0.55%
Student self-learning	3	1.65%
PBL by students	13	7.14%
Total number of participants	182	

Table 2.2 Teaching formats of teachers (views of students)

Options	Participant Numbers	Proportion
Lecturing	**396**	**93.62%**
Group or peer learning	7	1.65%
Student self-learning	1	0.24%
Problem based learning or Project	19	4.49%
Total number of participants	423	

Table 2.3 Main purpose of teaching evaluation (views of teachers)

Options	Participant Numbers	Proportion
Improve students' achievements	6	3.3%
Promoting students' learning and development	**127**	**69.78%**
Improving teaching according to students' examination results	42	23.08%
Evaluation of teachers according to students' examination results	7	3.85%
Total number of participants	182	

In the survey of the role of the students in the learning process, 82.42% of 182 teachers think "students are the main body of study". But when it comes to the teaching formats of the teachers, both the teachers and the students admit lecturing is the main format of teaching (Table 2.1 and 2.2).

Table 2.4 Teacher's main assessment method in teaching (views of students)

Options	Participant Numbers	Proportion
Interviews	29	6.86%
Open-textbook exam	9	2.13%
Close-textbook exam	**373**	**88.18%**
Report	12	2.84%
Total number of participants	423	

Table 2.5 Learning style of the students

Options	Participant Numbers	Proportion
Study well at normal time, review carefully before the exam	66	15.71%
Study not very well at normal time and try to review before the exam	**276**	**65.71%**
Usually do not learn, review before the exam like preview	**78**	**18.57%**
Total number of participants	420	

About the learning evaluation, 69.78% of the 182 teachers consider the purpose is "promoting students' learning and development". But in practice, 88.18% of the 423 students think their main assessment method is "Close-textbook exam" which can only promote their short memory. And because of the monotony of the assessment method, 65.71% students chose their learning style as "usually accumulates less and try to review before the exam", and 18.57% "usually do not learn, review before the exam like preview"(Table 2.3-2.5).

According to the results of two surveys of the teachers' training, about 44% of the teachers did not have a thorough study on the relevant educational and instructional theories, and nearly 80% did not receive sufficient training and teaching practice at the beginning of the teaching work (Table 2.6 and 2.7).

Table 2.6 When you start a teacher's job, which of the following descriptions is more consistent with the actual situation (views of teachers)

Options	Participant Numbers	Proportion
No training, no practice	**21**	**11.54%**
Simple training, no practice	**49**	**26.92%**
Simple training, some practice	**76**	**41.76%**
Some training, adequate practice	36	19.78%
Total number of participants	182	

Table 2.7 When you start a teacher's job, what do you learn from the teaching theory of education (views of teachers)

Options	Participant Numbers	Proportion
Have a deep understanding	14	7.69%
There is a certain understanding	89	48.9%
A little bit of understanding	**61**	**33.52%**
Do not understand	**18**	**9.89%**
Total number of participants	182	

3. Discussion

From the data above we can see that due to the increasing number of the student, some corresponding inner change of the higher education in China should be made:

(1) The traditional teaching way which based mainly on the teacher's lecturing should be changed or at least improved. According to Bloom's taxonomy, lecturing gives the least retention time comparing to other learning methods (Krathwohl, 2002). A new main learning method which is coherent with the situation of large student groups should be introduced to increase the learning effect.

(2) The formative assessment should be paid more attention and used more often in the learning process. With only the summative assessment, the purpose of promoting the students to learn cannot be achieved. Otherwise the students will learn only for the test but not for the improvement and development (Bettina *et al*, 2015).

(3) The teachers should be educated at the beginning and during the teaching career. Only get well prepared for the class is far from being a good and qualified teacher. Continuous professional training for the teachers must be introduced into the universities. The teachers should also have class while give class (Dahms, 2016).

(4) The learning content must be aligned with the students' future employment. Although the theories are important for the learning, what matters most in the future is the student's ability to solve the real life problems. Some chances and time to use their hands should be given to the students to practice and implement what they have memorized in their minds with the purpose to fulfill a full cycle of learning. Otherwise what the students have known is just information but not knowledge (Kolb, 2007).

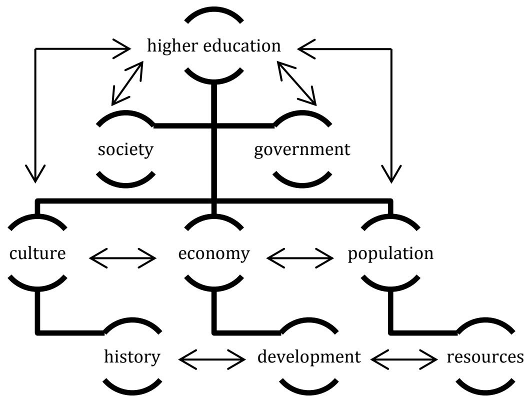


Figure 3.1 the complex structure between higher education and its affecting factors

In the past twenty years Chinese higher education had a tremendous change. But the change mainly occurred in the quantity. Higher education is important because it's the very beginning for everyone to start a real learning and it's the very end for everyone to be taught in real meaning. In other words, only higher education can give the student a life-long learning motivation. And this learning motivation is correlated to many other factors which come from the culture and development of the society (figure 3.1). If we want a real and thorough change in Chinese higher education many other corresponding changes need to be made in other parts at the same time (Rui, 2018). It may take a relatively long process.

4. Conclusion

So how can we improve the students' learning motivation without changing everything in the universities? And why motivation is so important in the learning process?

According to Maslow's hierarchy of needs, the highest need is the self-actualization (Maslow, 1943). Through higher education we should not try to turn the students into somebody else which is usually impossible but to help the students to “find” themselves: find what they want, what they like or at least what they dislike(Pan, 2015).

In other words, through higher education the students should know what they are good at and have the confidence to make it better. Before they become a better somebody, at the first place the students should know how to be a better person that is more practical and useful in the future. The PBL model from AAU and many other universities in the world set a good example to learn from and it’s a practical and useful way to combine learning through real life problems and teamwork in the universities class (Du *et al*., 2013).

To put it into two words: quality education. With the transition of Chinese social and economic development, the transition of the education is lagging behind (Pan., 2003). The quality education that just starts at the elementary school immediately stops at the junior school because of the effect of the university entrance exam. The students tried to cram everything into their brain just to pass the exam and once they get into the university their brains that are used to the “duck-feeding” mode are tired and can’t switch right away. If the teachers in the universities don’t notice this special period of the transition and continue lecturing all the way the students will “shut up” the ears and doze off.

The truth behind the Chinese higher education is the infrastructure and the curriculums are still at the elite mode while the scale and numbers are already at the mass mode. The entrance is for everyone but the inside is still only for very few people. This change of the whole system may take a very long time to occur but we can’t just sit and wait. Since everybody get the chance through hard work to pursue his or her study in the university. Every student needs a chance to be excellent in the university. If they can’t get this chance in the university where else can they get? The elite mode is not suitable for the situation right now in China any more. The poor performance and low motivation of the students must be improved. In the university the students should not only get the facts but the ability to learn. It’s not like a gas station the students come and get more “fuel” to run a little bit further. Through higher education the students should get an “engine” planted in their heart. With this motivation engine started, a true learning process can happen and a life-long learning may happen in the future.

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Pedagogical development for course change and academic staff expectations

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Abstract

Educating engineers to perform in global and changing working places requires revisions to how engineers are educated and a more student-centred curriculum. Change processes in engineering education involve different stakeholders, strategies and resources. Among these are the academic staff and the need for continuing pedagogical development and training. Recently, the Aalborg UNESCO Centre has developed the Aalborg UNESCO Centre Certificate on the Basics of PBL and Curriculum Change. In collaboration with the Universidad de Colombia (Colombia), the Aalborg UNESCO Centre set up a research project to evaluate the course and investigate academic staff motivations and expectations concerning curriculum change processes. This paper reports the first results for the following research question: In what ways do participants expect the Aalborg UNESCO Centre certificate on the Basics of PBL and Curriculum Change to change their teaching practices? By expectations, we refer to participants' beliefs of what will be achieved through the course and what will impact/change their teaching practices. Such expectations are indicative of participants' needs and goals. We used a mixed methods approach in which we collected quantitative data through a survey and qualitative data through a teaching portfolio. The preliminary results show that most of participants expect the course to change their knowledge and understanding of active learning instructional practices and give them the skills to evaluate and improve their own teaching practices.

Keywords: Curriculum change, PBL, academic staff development, expectations

Type of contribution: Research paper

1 Introduction

Educating engineers to perform in global, ever-evolving workplaces requires revisions to how future engineers are educated. New challenges, such as sustainability, automation, digitalization, customerization and innovation, call for more active student learning environments, namely problem-based or project-based learning (PBL), developing a new set of competences. Engineering education institutions and educators must revise and change their curricula and teaching practices to address the challenges stated (Felder, Brent and Prince, 2011). Adams and Felder (2008, p. 240) state that:

> …it is unfortunate and unnecessary that many new engineering educators have to figure out for themselves how to design syllabi and lesson plans and tests, motivate students to learn, teach effectively in small and large classes, help students who are struggling, and deal with classroom disruptions and cheating while at the same time building a research agenda, recruiting students, and meeting service responsibilities.

Consequently, it is necessary to prepare and train engineering teachers as educators for the future. Academic staff training and development courses play an important role in providing in-service teachers with the knowledge and competences to re-design their courses and innovate their teaching practices through more active, student-centred approaches. However, the current approach to academic staff development for teachers seems to be inadequate and ineffective and it does not reflect the new demands on engineering educators. Furthermore, these programmes and courses tend to be transmissive and lecture-based, not reflecting the teachers' needs and goals (Adams and Felder, 2008; Felder, Brent and Prince, 2011; Hunzicker, 2011). It is necessary to design research-based, innovate, effective and adequate academic staff development capable of fostering teacher change and developing a culture of continuing organizational reflection and learning (Felder, Brent and Prince, 2011; Hunzicker, 2011).

The Aalborg Centre for PBL in Engineering Sciences and Sustainability, under the auspices of UNESCO, has over the years been developing academic staff development programmes, courses, workshops and other activities. The overall vision is to contribute to the development of engineering and science education, which calls "for a flexible learning philosophy which can be appropriated by different educational institutions and suits the ever changing and complex challenges of the global society". Furthermore, the Aalborg UNESCO Centre carries out research, among other topics, on engineering education and academic staff development (Aalborg UNESCO Centre, 2014). Recently, the Aalborg UNESCO Centre developed a 5 European Credits Transfer System (ECTS) research-based course entitled "*Aalborg UNESCO Certificate on the Basics of PBL and Curriculum Change*" (hereafter Aalborg UNESCO Certificate). The Aalborg UNESCO Certificate aims to: i) provide basic knowledge on PBL and curriculum change and ii) to investigate staff motivations and expectations in participating in the academic staff development course. The course was designed according to PBL principles and a mixed methods approach was used to collect data from prospective participants.

This paper reports a part of the study conducted in collaboration with the Universidad Nacional de Colombia, Colombia, where the course was delivered for a total of 23 academic staff members. The results are drawn from qualitative and quantitative data collected before the course took place and address the following research question:

In what ways do participants expect the Aalborg UNESCO Centre Certificate on the Basics of PBL and Curriculum Change to change their teaching practices?

By expectations, we refer to participants' beliefs of what will be achieved through the course and what will impact/change their teaching practices; these are indicative of their needs and goals in undertaking the course.

This paper comprises four further sections: a brief description of the Aalborg UNESCO Certificate (section 2), the research methodology (section 3) and results (section 4). We conclude the paper with the answer to the research question and reflections for future studies (section 5).

2 Aalborg UNESCO Certificate for academic staff development

According to Hunzicker (2011, p. 178), "when professional development is supportive, job-embedded, instructionally, focused, collaborative and ongoing, it is more likely to result in teacher learning and improvement of teaching practice". Felder et al. (2011) propose a five criteria framework based on Raymond Wlodkowski's theory of adult learning motivation to design and deliver effective programmes for engineering educators. The criteria are: expertise of the instructors, relevance of content, teachers' choice in application, praxis (i.e. action and reflection) and group work.

Considering the aforementioned characterisitcs and criteria for effective academic staff development and using PBL principles (Kolmos, Graff and Du, 2009) as guiding principles, the Aalborg UNESCO Centre designed the academic staff development course *Aalborg UNESCO Certificate on the Basics of PBL and Curriculum Change*.

The Aalborg UNESCO Certificate is interdisciplinary, exemplary, reflective, team-based, problem-oriented, contextual and experience-based. It aims to provide basic knowledge and understanding of active learning methodologies with a focus on PBL practices, PBL skills and how to implement PBL. The participants are expected to ahieve a set of learning objectives listed in Table 1.

Table 1: Aalborg UNESCO Certificate learning objectives

- Understand active learning methodologies, in particular problem- and project-based learning (**LO1**)
- Understand curriculum design and management (**LO2**)
- Design a PBL intervention for implementation in the classroom (**LO3**)
- Understand and experience PBL as a learning process and the learning of PBL skills (**LO4**)
- Implement or plan an implementation of the designed intervention in LO3 (**LO5**)
- Document and reflect upon curriculum/course change processes (**LO6**)

The Aalborg UNESCO Certificate comprises four modules, in which the different learning objectives are addressed through various online and face-to-face activities, namely self-study activities, group work, thematic workshops, designing and implementing a PBL intervention, supervision, documentation and examination (Figure 1).

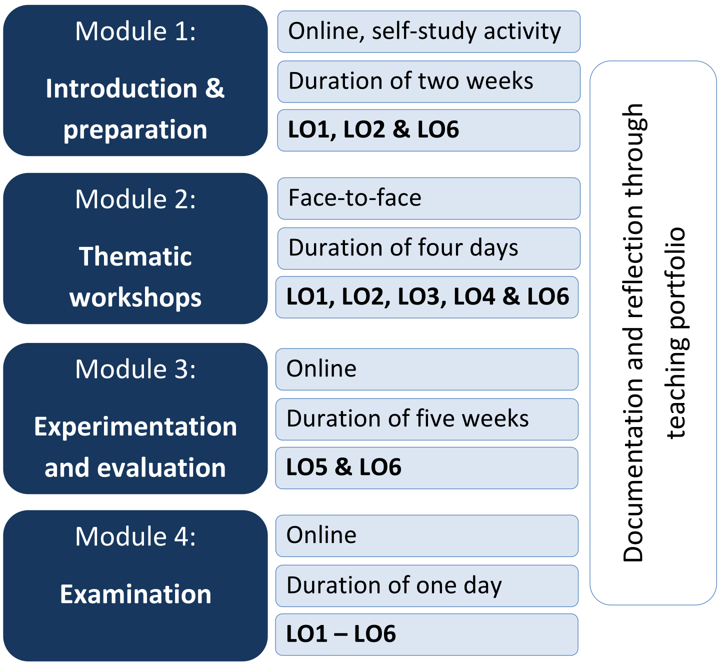

Figure 1: Aalborg UNESCO Certificate course modules and activities

Module 1, called Introduction and preparation, aims to provide basic knowledge through reading recommended literature and an online open course. Module 2 includes workshops on: i) PBL practices and models, ii) Course and curriculum design, iii) Assessment of and for learning, iv) Facilitation and PBL skills, v) Portfolio as a reflective documentation instrument and vi) Design of PBL intervention. Each workshop provides knowledge, exemplary exercises, group work, plenary discussions and feedback to design the intervention. In module 3, Experimentation and evaluation, it is expected that participants implement the PBL design. Participants start in module 1 to document and reflect on their learning process through a teaching portfolio. The portfolio is constructed throughout the certificate and its submitted as the basis for an oral examination in module 4.

The Aalborg UNESCO Certificate has been designed and is delivered by Aalborg UNESCO Centre experts on staff training, engineering education and PBL. It has a duration of approximately 12 weeks and correspondes to 5 ECTS (approximately 150 hours of work load). Once participants have actively participated in all module activities, delivered the required ongoing assignments, submitted a final teaching portfolio and performed satisfactorily in the oral examination, they are granted the Aalborg UNESCO Certificate.

3 Research design

The Aalborg UNESCO Certificate was first delivered in collaboration with the Universidad Nacional de Colombia (Colombia) to 23 academic staff members. Most of the participants were affiliated with the Faculty of Engineering and they enrolled voluntarily. The course started on 12 February 2018 with an online seminar and finished on 1 June 2018 with oral examinations. Besides the four modules which compose the certificate, Universidad Nacional held a seminar before the examination module for which participants produced a poster and reported and shared the status and process of PBL design implementation.

We use a mixed methods approach to collect qualitative and quantitative data at different moments of the Aalborg UNESCO Certificate, using different instruments. The following briefly explains the data collection and analytic procedures carried out.

3.1 Data collection and analysis

Overall, the study of the Aalborg UNESCO Certificate used a mixed methods approach, in which different methods and instruments were used to collect data at different moments of the course, as Figure 2 illustrates.

Prior to the course Quantitative method: survey

- **Aim**: Gather participants' demographic information, expectations and needs for the course.
- **Instrument**: Pre-test questionnaire.

During the course Qualitative method: documentary analysis

- **Aim**: Gather participants' teaching vision, needs and challenges, expectations and motivations for engaging in the course. Gather participants' perspectives and reflections on their own learning.
- **Instrument**: Teaching portfolio (section A).

After the course Quantitative and qualitiative methods: survey and documentary analysis

- **Aim**: Gather course evaluations and participants' perceived learning outcomes.
- **Instrument**: Post-test questionnaire, course evaluation, open questions and final teaching portfolio.

Figure 2: Overview of the research design of the Aalborg UNESCO Certificate on the Basics of PBL and Curriculum Change

The questionnaire was developed and constructed based on previous studies on academic staff development, namely Watt and Richardson (2007), TALIS – The OECD Teaching and Learning International Survey (2008) and de Graaff and Kolmos (2013). The teaching portfolio template comprised four sections and its construction was based on the course goals and literature, namely Dahl and Krogh (2015) and Kolb's (2008) learning cycle.

In this paper, we report the data collected prior to the course and focus on evaluating academic staff expections collected through section A of the teaching portfolio (specifically sub-section A.5: Expectations of the Aalborg UNESCO Centre certificate course) and question no. 16 in the questionnaire. Table 2 lists the 16 items composing the question, of which 15 items are closed responses evaluated through a five-point scale (0 = Don't know, 1 = No change at all, 2 = A small change, 3 = A moderate change and 4 = A large change) and the last is a short answer.

Table 2: Items evaluated in the question: "To what extent do you expect the Aalborg UNESCO Centre Certificate to influence changes in your teaching?"

1.	Your classroom and management practices
2.	Your knowledge and understanding of active learning instructional practices
3.	Your skills in evaluating and improving your own teaching practice
4.	Your knowledge and understanding of curriculum development
5.	Your knowledge and understanding of course design
6.	Your skills in developing and implementing strategies to motivate students to learn your subject matter
7.	Your knowledge and understanding of different assessment formats for different learning outcomes
8.	Your skills in developing and implementing strategies to activate and involve students in lectures
9.	Developing reflective skills about your own teaching practice
10.	Your knowledge and understanding of an evidence-based approach to teaching
11.	Your knowledge and understanding of students' learning
12.	Your knowledge and understanding of students' and teachers' roles in the PBL curriculum
13.	Your supervision skills (individual and/or group)

14. Designing and implementing more problem-oriented and/or project work activities in your courses

15. Other

15.1 Please specify which other

Quantitative data was undertaken in Microsoft Office 2016 Excel, while the qualitative data wre analysed through content analysis. The following section presents and discusses the results.

4 Results and discussion

We present the results separately, starting with the results from the questionnaire followed by the results from analysis of the teaching portfolio.

4.1 Results from the questionnaire

Overall, participants expected moderate to large changes in their teaching practice as a result of participating in the Aalborg UNESCO Certificate, as shown in Figure 3. The means of the answers vary between 3 (item 13) and 3.87 (item 6). Item 15 "Other" presents a mean of 0.65. It should be noted that this item is mandatory, as are the others, and therefore 87% of answers are "Don't know" (61%, n=14) and "No change at all" (26%, n=6).

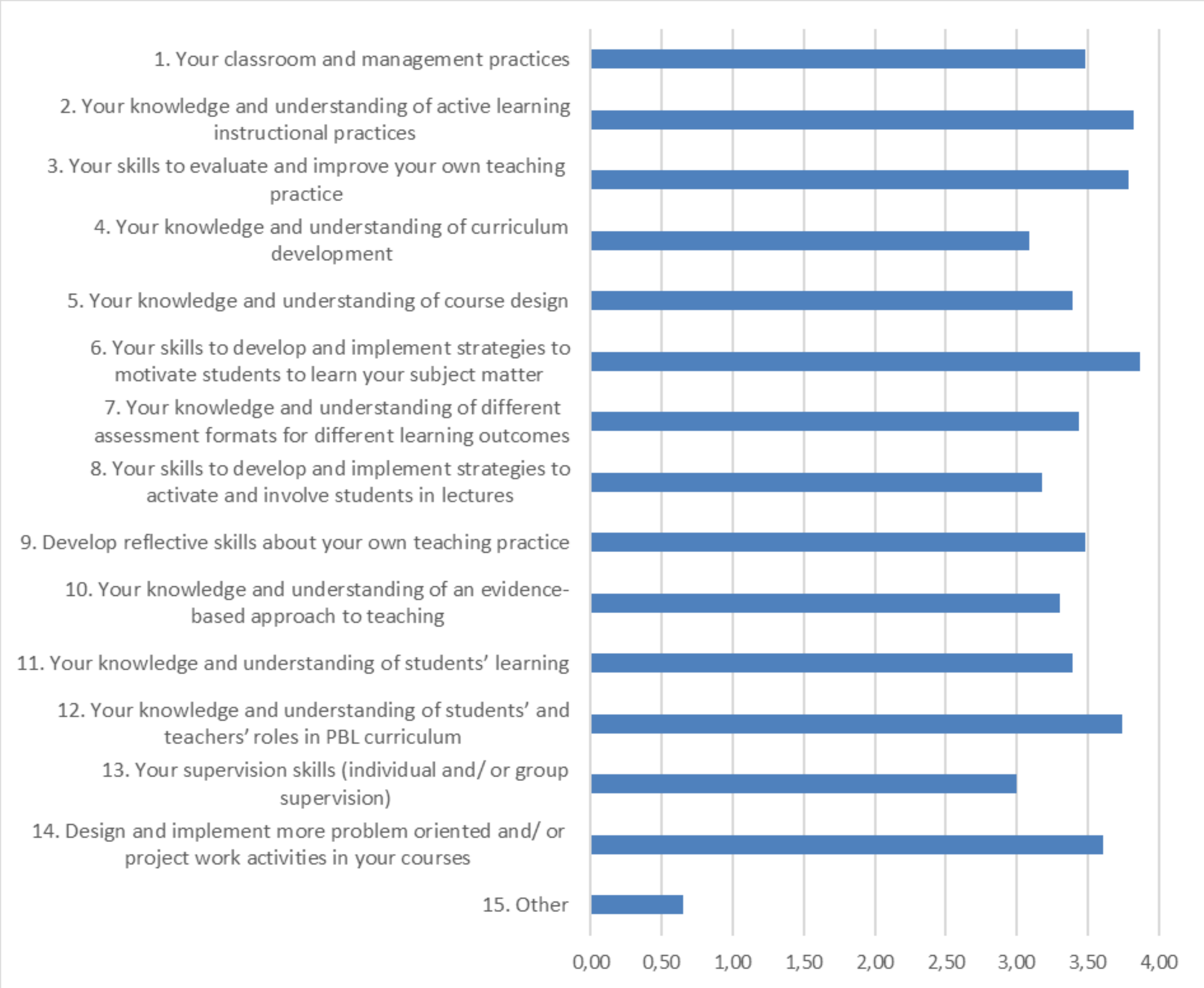

Figure 3: Means of the answer to the question "*To what extent do you expect the Aalborg UNESCO Centre Certificate to influence changes in your teaching practice?*" (n=23).

The results show that there is a variation in the responses given per item. Figure 4 shows the percentage of responses per item. Participants expect “large changes” with respect to items 6, 2 and 12, with 87% (n=20), 83% (n=19) and 83% (n=19), respectively. These items relate to students’ motivation, active learning practices and teachers’ and students’ roles in the PBL curriculum. Participants expected “large changes” related to four more items, which present percentages of 60–80%. These are item 7 (61%, n=14), item 9 (65%, n= 15), item 14 (74%, n=17) and item 3 (78%, n= 18). These items relate to teaching evaluation and reflection (items 3 and 9), PBL implementation (item 14) and assessment (item 7).

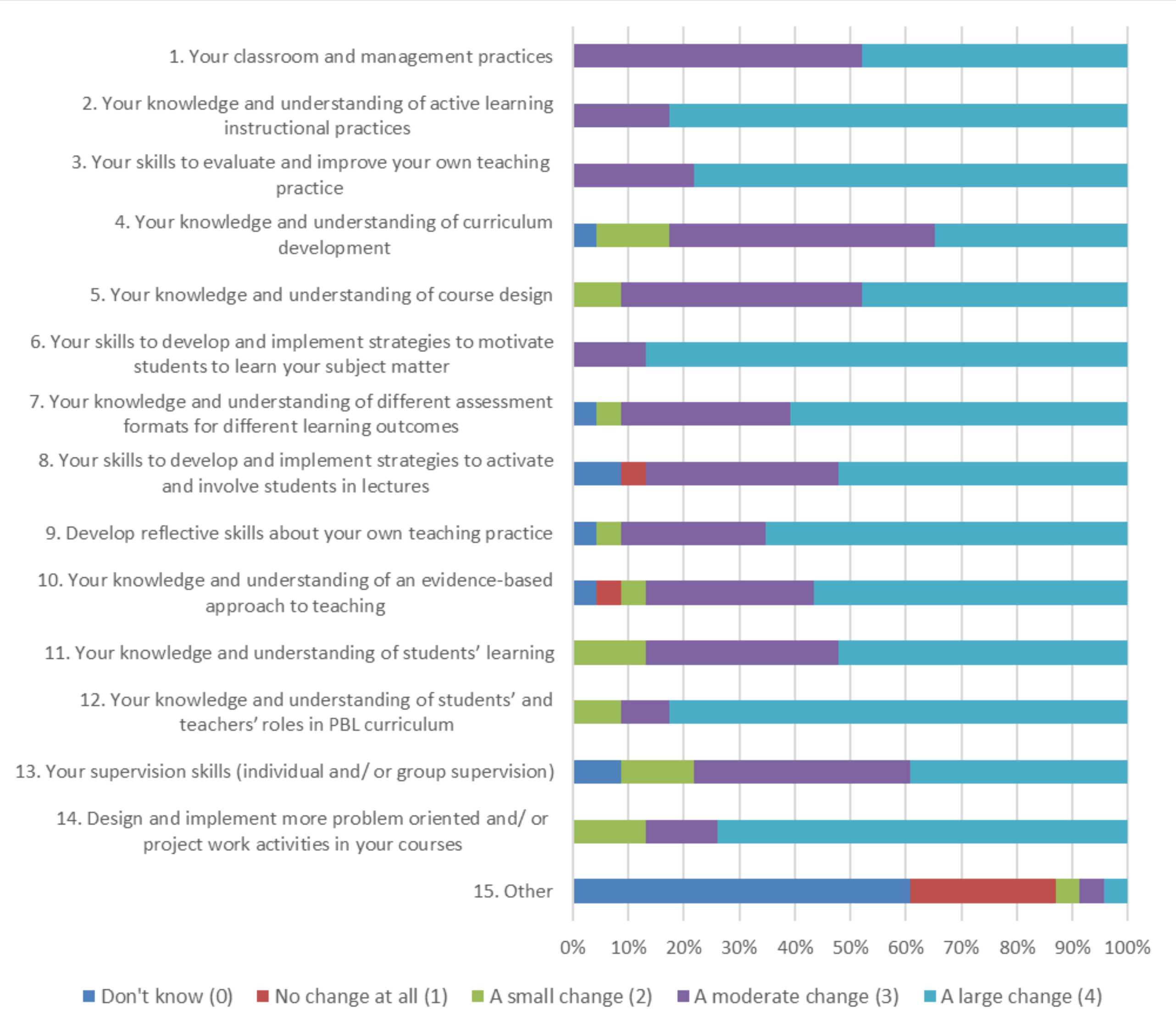

Figure 4: Answers to the question “*To what extent do you expect the Aalborg UNESCO Centre Certificate to influence changes in your teaching practice?*” (n=23).

Items 1, 4, 5 and 13 present relatively high percentages regarding “a moderate change” compared to other items. Furthermore, these items also present the lowest percentages with respect to “a large change”. These refer to classroom and management practices (item 1, 52%, n=12), curriculum development (item 4, 48%, n=11), course design (item 5, 43%, n=10) and supervision skills (iem 13, 39%, n=9).

Ten out of sixteen items include answers denoting “a small change”. These are items 4, 11, 13 and 14 (13%, n=3), items 5 and 12 (9%, n=2) and items 7, 9, 10 and 15 (4%, n=1). Three out sixteen items indicate “no change at all”, namely items 15 (26%, n=6), 8 (4%, n=1) and 10 (4%, n=1). Last but not least, for seven items participants selected “don’t know”, namely items 15 (61%, n=14), 8 (9%, n=2), 13 (9%, n=2), 4 (4%, n=1), 7 (4%, n=1), 9 (4%, n=1) and 10 (4%, n=1).

The above results indicate the kinds of pedagogical topics, knowledge and understanding participants were seeking and expected would change their teaching practice, i.e. they point towards the pedagogical needs participants have before starting the Aalborg UNESCO Certificate. This knowledge provides with the opportunity for the trainees to better prepare and deliver the content of the certificate.

4.2 Results from the teaching portfolio

The individual teaching portfolios (section A, delivered prior to the workshops) reveal more detailed insights into participants’ expectations and motivations for participating in the course. These are identified not only explicitly, but also also implicitly through the teaching philosophy and teaching challenges mentioned. One participant had a PhD in education and participated to observe how engineers are trained in PBL as she had been hired by the Faculty of Engineering to design active learning courses for engineers. Otherwise, it is notable that only five participants mentioned previous participation in short pedagogical training, while all recognized the need for developing pedagogical qualifications. The main reasoning used in the portfolios related to this basic need for pedagogical qualifications, supplemented with a few other categories.

Pedagogical qualifications

For some, the focus is on the teacher’s teaching skills, methods and tools (“teaching students better”), while others focus on the students’ learning (“greater impact on learning processes”) – without identifying contradictions between these points of focus. Generally, there is a strong emphasis on the teacher as responsible for the pedagogical set-up behind developing students’ motivation and learning, but “good intentions are not enough” and it is necessary to “review my work”. Several mention the need for a change from intuitive or trial-and-error approaches towards more systematic approaches, while for several the goal is to complement changes that they already have initiated. Only few mention the need for collaboration among teachers.

Increase students’ learning in aiming for the engineering profession

The learning process is clearly in focus, aimed at “stimulating self-learning”. This also means activating and involving students to develop their motivation and their “capacity to learn autonomously”. Tools for this are teaching strategies such as PBL and active learning, incorporating “real and complex situations and problems”. While only one participant specifically mentions “collaboration with industry partners for student projects”, there is generally a strong determination towards “growth and training of integral professionals”.

Curriculum transformation

One participant expresses the need to “transform our minds”, illustrating that pedagogical development goes beyond classroom performance. Thus, the pedagogical qualifications mentioned above must be seen within a curricular perspective – with or without PBL. Without previous pedagogical training, most participants express that this transformational process must be dealt with based on deeper understanding and careful adaptation. However, a collaborative approach to this is mentioned by only a few individuals.

Teaching challenges

To make a long list short: the focus is on the students, their attention, motivation and learning processes. Although some participants address their own inadequacy as individuals in an educational system geared towards traditional teaching approaches, several participants express a strong desire to be able to initiate and integrate changes – preferably in cooperation with colleagues.

Social responsibility

The last motivational category encompasses ethical grounds. This includes responsibility for "lifelong learning" and for "giving back", alongside a motivation for "improving society" and "making a more just society". Working at a public university in itself is mentioned as motivation for teaching ("giving back") and for participating in pedagogical training. "Becoming a better version of myself" [as a teacher] is perhaps the most profound way of expressing motivation.

Factors not mentioned prior to workshops and interventions

A few issues mentioned during the workshops and the following intervention could potentially influence the participants' motivation and even shift the focus. The teacher role is broadened to include more than the roles of lecturer, laboratory instructor and evaluator. The role of the facilitator appears most distinctly, in close conjunction with the desire to develop students' self-learning capacity. This role also encompasses undertaking formative assessment of students' processes and products, rather than simply making summative assessments. In an even wider perspective, this might also embrace the teacher identity ("transform our minds").

During the intervention, two issues became evident: even small changes in teaching and learning activities take considerable and unexpected time (from research and private life perspectives) and some students oppose changes in the teaching and learning approaches. Both issues will most likely affect teachers' motivation, but they may both be challenged by evidence gathered by the participants: the students did learn from the interventions.

5 Conclusion

At a time in which engineering education is being challenged, for example by sustainability problems, globalization, innovation, automation and digitalization, the emphasis on transferable and digital skills as part of the engineering profile is great. It is of utmost importance to develop and train teachers in order to enable universities and engineering education to adapt and address these challenges proactively. The Aalborg UNESCO Certificate presents such an opportunity. Furthermore, the quality of engineering education and engineering education institutions also includes how their teachers are pedagogically trained and continuously developed. Neverthless, the role of educators in higher education is not sufficiently rewarded and there is a lack of studies in engineering education concerning academic staff training and development, motivations and needs, impact on students' learning, etc. Furthermore, the literature states that most continuing pedagogical courses do not consider participants' needs and are outdated (Adams and Felder, 2008; Felder, Brent and Prince, 2011; Hunzicker, 2011). The Aalborg UNESCO Certificate addresses the aforementioned aspects by first inquiring about participants' expectations before the course and basing it on PBL principles, such that participants develop their teaching skills while experiencing active learning. Qualitative and quantitative data are collected to evaluate participants' expections prior to the course and the extent to which these are met. This paper reports the results prior to the course. Overall, the qualitative and quantitative results are aligned, in that participants' answers highlight expectations related to students' motivation, active learning practices and roles in a PBL curriculum. Furthermore, there is a general concern for pedagogical training as several participants claim not to have had any as university teachers. In general, participants are experts in their own field; however, they also see themselves as educators and have a sense of responsibility in terms of how they educate and prepare students for their professional life. Therefore, it is necessary to implement appropriate courses for academic staff training in which not only is basic knowledge about teaching skills, methods and tools provided, but also spaces for collaboration, experimentation, for success and failure and for reflection are created. Presently, we are receiving participants' answers to the post-course questionnaire, based on which we will be able to evaluate how far the Aalborg UNESCO Certificate met the participants' expectations and what to change and improve. We expect to publish the results during the autumn of 2018.

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Aalborg UNESCO Centre Certificate: A new approach to staff training and curriculum innovation

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Abstract

Worldwide, engineering education is facing challenges, such as sustainability and innovation encompassing automatization. There is a need to develop engineering education accordingly and to educate more innovative graduates, providing them with a suitable set of skills and competences. Problem- and project-based learning (PBL) has become one of the responses to these challenges, together with the application of more active learning methodologies. It is unrealistic to expect engineering educators and teachers to be able to change their teaching practice without any type of guidance and training. Therefore, in curriculum change processes, it is important to "train the trainers". This paper describes the Aalborg UNESCO Centre certificate on the *Basics of PBL and Curriculum Change*, a staff training course with a duration of approximately 12 weeks (equivalent to 5 credits in the European Credit Transfer and Accumulation System [ECTS]), composed of five modules with online and face-to-face activities. The certificate has two main goals: (i) a learning goal, i.e. training and developing academic staff to change their teaching practices towards a more active, student-centred approach; (ii) a research goal, i.e. to investigate academic staff motivations and expectations when enrolling in pedagogical development courses. The way in which the course is designed and structured, including learning theories and principles, provides a framework to fulfil both goals simultaneously. From the staff development perspective, the certificate aims to provide teachers and practitioners with an overview of PBL theory, principles and models and set the stage for curriculum change and innovation through meaningful learning experiences, reflections and active experimentation. From a research perspective, a mixed methods approach is used to collect quantitative and qualitative data to understand the participants' motivations and expectations when entering the course and the learning processes experienced.

Keywords: PBL implementation, curriculum change, staff training and development

Type of contribution: Review/conceptual paper

1 Introduction

Worldwide, engineering education is facing challenges such as sustainability and innovation encompassing automatization. Increasingly, technology is assuming a central role in contemporary society, which will inevitably affect the future of engineering practice, requiring a new set of competences (Organization for Economic Cooperation and Development [OECD], 2017). Technical knowledge is no longer enough; competences such as problem solving, creativity, communication, team work and lifelong learning are part of the qualification profile of future engineers (Ananiadou and Claro, 2009). Consequently, the traditional teacher-centred paradigm and curriculum models, focusing on the transmission/reproduction of disciplinary knowledge, are no longer suitable for engineering needs and it is important to align professional engineering and societal challenges with what and how students learn (Rosenberg et al., 2012). One of the main roles of engineering education institutions is to educate and prepare engineers for the labour market, for example through curriculum change strategies and the implementation of more student-centred, active learning methodologies, such as problem-based and project-organized learning (PBL) (Kolmos et al., 2016).

Curriculum change is a complex process, involving, for example, the revision of curriculum goals, the allocation of resources and the involvement of different stakeholders, namely academic staff. The development of academic staff is fundamental for a paradigm shift in engineering education and in the implementation of PBL. However, current academic staff development courses and approaches are inadequate and it is left to engineering educators:

> …to figure out for themselves how to design syllabi and lesson plans and tests, motivate students to learn, teach effectively in small and large classes, help students who are struggling, and deal with classroom disruptions and cheating while at the same time building a research agenda, recruiting students, and meeting service responsibilities. (Adams and Felder, 2008, p. 240)

Just as it is required that engineering education evolves to address the challenges posed by a ever-evolving profession, so must the professional development of engineering educators also evolve. It is unrealistic to expect that engineering educators can bring about deep and substantial changes in their practice without the support of pedagogical development courses. Consequently, it is necessary to design training courses capable of promoting learning among academic staff and fostering change in engineering education curricula and practice in order to address the aforementioned challenges (Adams and Felder, 2008; McLaughin and Marsh, 1990).

This paper presents a blended certificate course (equivalent to 5 credits in the European Credit Transfer and Accumulation System [ECTS]) on the *Basics of PBL and Curriculum Change* for academic staff development. The course is based on PBL principles and aims not only to train participants in PBL skills, but also to contribute to academic staff learning and practice change.

The remainder of the paper is organized in five sections. We start by briefly presenting the organization responsible for the development of the course, i.e. the Aalborg Centre for PBL in Engineering Sciences and Sustainability, under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO). We describe the course and the PBL principles on which is grounded. Furthermore, part of the course development lies in its evaluation, for which qualitative and quantitiative data are collected. This is followed by an example of the first course implementation and the research methods used for its evaluation. The paper concludes with lessons learned from the piloting of the certificate, aimed at its future improvement.

2 The Aalborg UNESCO Centre and its mission for engineering curriculum innovation and PBL implementation

The Aalborg Centre for PBL in Engineering Science and Sustainability, under the auspices of UNESCO (hereinafter the Aalborg UNESCO Centre), Aalborg University, is a Category II UNESCO Centre approved by the General Conference of UNESCO in November 2013 (Aalborg UNESCO Centre, 2014a). Part of its vision:

> …is to contribute to greener and more democratic global societies. […]. In regard to engineering and science education, this calls for a flexible learning philosophy which can be appropriated by different educational institutions and suits the ever changing and complex challenges of the global society. (Aalborg UNESCO Centre, 2014b)

The strategic mission of Aalborg UNESCO Centre comprises four points which are also indicative of its main activities, namely research and PhD training, capacity building, global networking and staff development and traning. We focus on the third point, which states the following: “providing global formal education and training for academic staff and students” (Aalborg UNESCO Centre, 2014b). Therefore, the Aalborg UNESCO Centre has been developing several resources, workshops, courses, programmes and other activities over the years aimed at academic staff development.

Figure 1: Overview of Aalborg UNESCO Centre activities aimed at staff development and training (based on Aalborg UNESCO Centre, 2014a)

The diverse activities illustrated in Figure 1 present different levels of teaching professionalization and development of knowledge and competences. Consequently, the learning objectives, training strategies and formats, as well as participants’ directiveness, work load and support from the Aalborg UNESCO Centre, differ in the various activities. Furthermore, the activities can be related to different hierarchal levels of teachers’ competences and professionalism, as discussed by Dahl and Krogh (2015). Dahl and Krogh (2015) argue for a transition in the learning of pedagogical competences from being a good teacher to being able to reflect on and relate to theories. In the Aalborg UNESCO Centre, there is a similar intended progression in the formulation of the learning outcomes. Figure 2 illustrates such relationships; however it is important to highlight that the different activities are not limited to a specific level, but rather enable transition to higher levels.

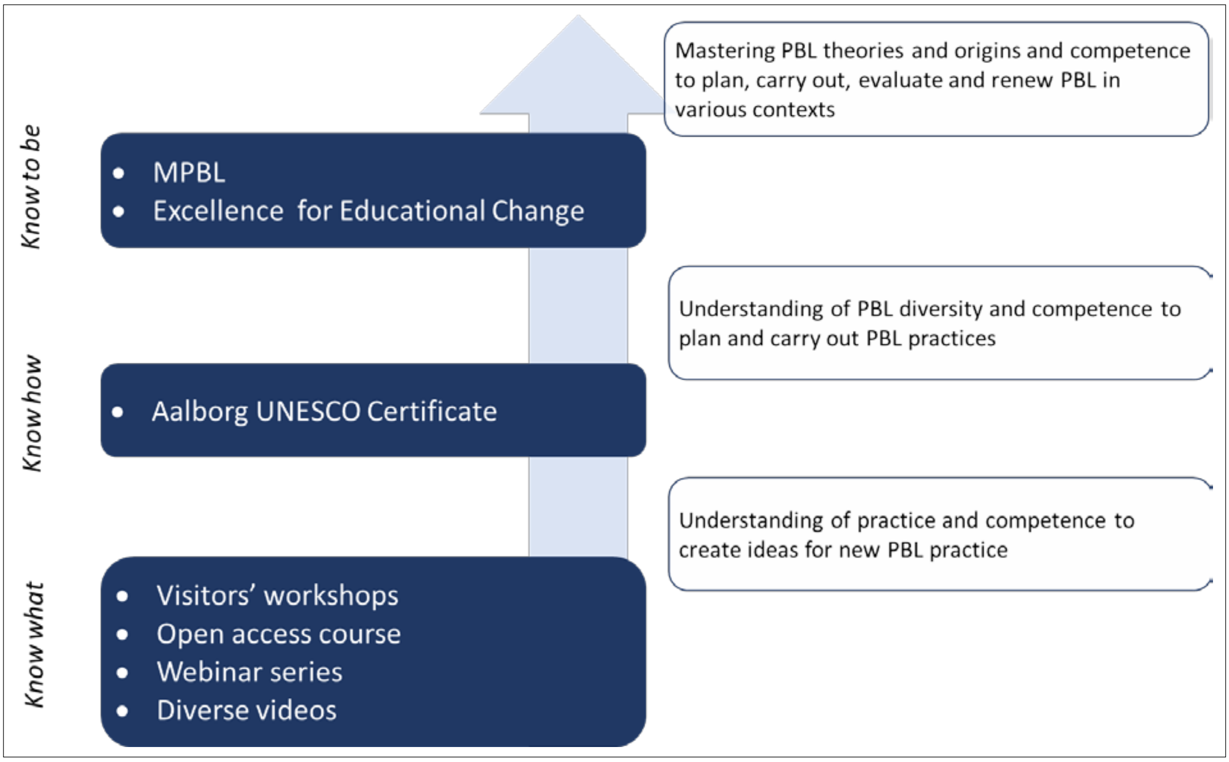

Figure 2: Relationships between the Aalborg UNESCO Centre activities for staff development

Another interesting aspect worth mentioning is the different levels of intended learning and change participants go through in the planned activities. For example, the open access sources and visitors' workshops mainly provide awareness and basic knowledge about PBL, i.e. they are focused on *know what*. This is essentially information about new practice. The certificate course goes further and besides the *know what*, it also expects that participants develop and implement small PBL experiments in their teaching practice and reflect on these, i.e. a focus on *know how*. Ultimately, it is expected that participants of the Excellence for Education Change and MPBL programmes learn *how to be* change agents and become reflective practitioners who innovate and transform their teaching practice. In these two programmes, participants carry out a PBL project and educational research, taking a evidence-based, scholarly approach to change their teaching practice.

In sum, the Aalborg UNESCO Centre provides a landscape of training activities for staff development by addressing different levels of teaching competence and learning and participants' aims and motivations.

3 Description of the Aalborg UNESCO Centre Certificate on the *Basics of PBL and Curriculum Change*

In the autumn of 2017, the Aalborg UNESCO Centre started developing the course on the *Basics of PBL and Curriculum Change*. The need for such a course was identified by the Aalborg UNESCO Centre staff as there was no course that could provide more than the open access sources and visitors' workhsops and existing provision comprised a lower work load and shorter duration than the Excellence for Educational Change and MPBL programmes.

The course has a duration of approximately 150 working hours (equivalent to 5 ECTS), carried out over a period of two months.

The course aims to provide basic knowledge and understanding of active learning methodologies with a focus on PBL practices, PBL skills and how to implement PBL. The participants are expected to achieve a set of six learning outcomes listed in Table 1.

Table 1: Learning outcomes

- Understand active learning methodologies, in particular problem- and project-based learning (**LO1**)
- Understand curriculum design and management (**LO2**)
- Design a PBL intervention for implementation in the classroom (**LO3**)
- Understand and experience PBL as a learning process and the learning of PBL skills (**LO4**)
- Implement or plan an implementation of the designed intervention in LO3 (**LO5**)
- Document and reflect upon curriculum/course change processes (**LO6**)

The course is delivered in a blended mode with online and face-to-face activities. The different learning objectives formulated above are addressed in the different modules by combining different activities and resources. Table 2 describes in more detail the course format, the different modules and their duration.

Table 2: Overview of the Aalborg UNESCO Certificate course on the Basics of PBL and Curriculum Change.

Modules	Format	Description	Duration
I. Introduction and preparation	Online and self-study activities	In the first phase, participants have a two-hour online introduction to the course. The introduction marks the beginning of the course. In the following 10 days, participants should go through the course literature and online resources. The material addresses the topics of: PBL principles and models, other active learning strategies, curriculum design, curriculum change. As part of the preparation, participants also need to start the documentation process through a portfolio.	2 weeks (10 days)
II. Thematic workshop	Face-to-face, thematic workshops	A series of thematic workshops in which participants experience, reflect on and develop further understanding of PBL theory, culminating with the design of a PBL activity. Each workshop provides knowledge, exemplary exercises, group work, plenary discussions and feedback to design the intervention. The workshops themes are, for example: 1) PBL practices and models 2) Course and curriculum design 3) Assessment of and for learning 4) Facilitation and PBL skills 5) Portfolio as a reflective documentation instrument 6) Designing a PBL activity	4 days
III. Experimentation and evaluation	Online supervision sessions, group work	In this module, participants plan and implement the PBL activity designed. The implementation process, as well as its evaluation, must be documented as part of the portfolio. To support this process, the participants have	5 weeks (25 days)

Modules	Format	Description	Duration
	and self-study activities	on-line support and supervision from the Aalborg UNESCO Centre. By the end of the five weeks, participants should upload their portfolios for examination.	
IV. Examination	Online	The examination is done according to the Aalborg University frame of provisions. At least two members compose the examination committee: the supervisor and an external examiner. The grading is pass/ fail. On passing the examination, participants are granted the Aalborg UNESCO Centre certificate.	1 day

4 PBL principles as guiding principles for designing the Aalborg UNESCO Certificate

The course structure and activities are exemplary of the PBL approach. The course has a reflective component in which participants are expected to document the course process through a portfolio and submit it for examination. The portfolio should also include participants' learning processes and reflections. The following sections briefly describe the PBL principles and their relationship with the course.

4.1 Description of PBL principles

Kolmos et al. (2009) define PBL through nine learning principles clustered in three approaches, as illustrated in Figure 3.

Figure 3: PBL learning principles, based on Kolmos et al. (2009, p. 11).

"Problem oriented" means that students learn by solving real authentic problems, carried out through projects. The problem-based approach places the learning in a real context and it is grounded in the learners' experience. The content approach concerns interdisciplinary and exemplary learning and the relationship between theory and practice. Interdisciplinary means that the learning process spans the traditional disciplinary boundaries, while exemplary means that the learning activities and outcomes are exemplars of the overall objectives of the curriculum. The learning process entails an analytical frame in which theoretical knowledge is used to analyse, formulate and solve problems. Collaborative learning refers to team-based and participant-directed learning, namely that it is a social activity undertaken through dialogue and communication in which students learn from each other. Participant-directed refers to students' collective ownership of the learning process (Kolmos et al., 2009).

4.2 Relationship between PBL principles and the Aalborg UNESCO Certificate

The learning principles described above serve as guiding principles for the design of the Aalborg UNESCO Certificate.

Table 3: Relationship between PBL learning principles and the Aalborg UNESCO Certificate course approach.

PBL learning principles	Aalborg UNESCO Certificate course approach
Cognitive approach: • Problem oriented • Project • Experiential • Contextual	**Problem orientation**: The point of the departure for participants' learning is the definition of teaching aims and challenges that they want to address. **Project**: The learning process is not carried out through a project. However, the learning and PBL implementation process is documented through a portfolio. **Experiential**: Several activities are developed and centred on teachers' experiences, namely the definition of teaching challenges, the design of PBL implementation, workshops, hands-on exercises, etc. **Contextual**: By using participants' teaching challenges as the point of departure, learning is placed in the context of their teaching practice with the aim to improve.
Content approach: • Interdisciplinary • Exemplary • Theory and practice	**Interdisciplinary**: Interdisciplinary learning is addressed at two levels: at the content level and at the collaboration level. In module II, comprising thematic workshops, groups are formed which might include participants from different engineering fields. Furthermore, the content of the course relates to a discipline that is not engineering, i.e. learning theories and pedagogy. **Examplary**: The overall goal of the course is to provide basic understanding of PBL and curriculum change. Consequently, the course, especially the workshops, includes hands-on activities which are illustrative of PBL principles and curriculum elements (e.g. facilitation, teachers# and students' roles, assessment and learning outcomes, evaluation, etc.) and how they can be used to design a PBL activity for practice. The frameworks and exercises are exemplary of how constructively to design PBL curriculum. **Theory and practice**: The course includes the design of a PBL activity, aimed at being implemented in practice. The design of the PBL activity

	encompasses theoretical knowledge, for example of PBL curricula and curriculum design.
Collaborative approach: • Team-based • Self-directed and participant-directed	**Team-based**: While module 1 (Introduction and preparation) is individual, in module 2 participants have a workshop on collaborative learning and group formation in which groups are formed for the rest of the course. By working in groups, it is expected that participants will learn from each other, for example, by communicating and sharing points of view, strategies and understandings of PBL. **Self-directed and participant-directed learning**: Participants have ownership over their learning. They are the ones who decide what should be changed in their teaching practice and how.

The course also has a strong reflective component: participants are asked systematically to write individual and group essays on, for example, the most important aspects learned and experienced and how these can be used in their teaching. The reflective component is mainly developed through the teaching portfolio.

In sum, the Aalborg UNESCO Centre certificate course adopts a PBL approach by using its principles as guiding precepts for its design. Furthermore, the organization of the course and some of its core activities can be illustrated using Kolb's learning cycle (Illeris, 2008). This cycle comprises four main stages: concrete experience, reflection and observation, abstract conceptualization and active experimentation. *Concrete experience* refers to the engagement of individuals in doing tasks and activities such as the hands-on activities involved in workshops in module II and the evaluation of PBL activity implemented in module III. *Reflective observation*, the second stage of the cycle, entails participants taking a step back from the "doing", i.e. the tasks and activities, reviewing what has been done, how it went and why. Reflective essays carried out at the end of module I and at the end of each workshop in module II are examples of reflective observation. However, it is through *abstract conceptualization* that individuals interpret and understand the meanings of these tasks and activities by relating them to the "bigger picture", such as learning theories. In relation to this, literature and online materials are provided in module I. Furthermore, participants also have to argue for their decisions and design a PBL activity based on the literature provided in module I. In the final stage of the learning cycle, *active experimentation*, the learners consider what they have learned and how this will be put into practice. An example of active experiementation is the implementation of the PBL activity designed by the participants in module III and the examination in module IV. After this stage, a new cycle takes place, in which learning is actively implemented and experienced through the activities and tasks designed.

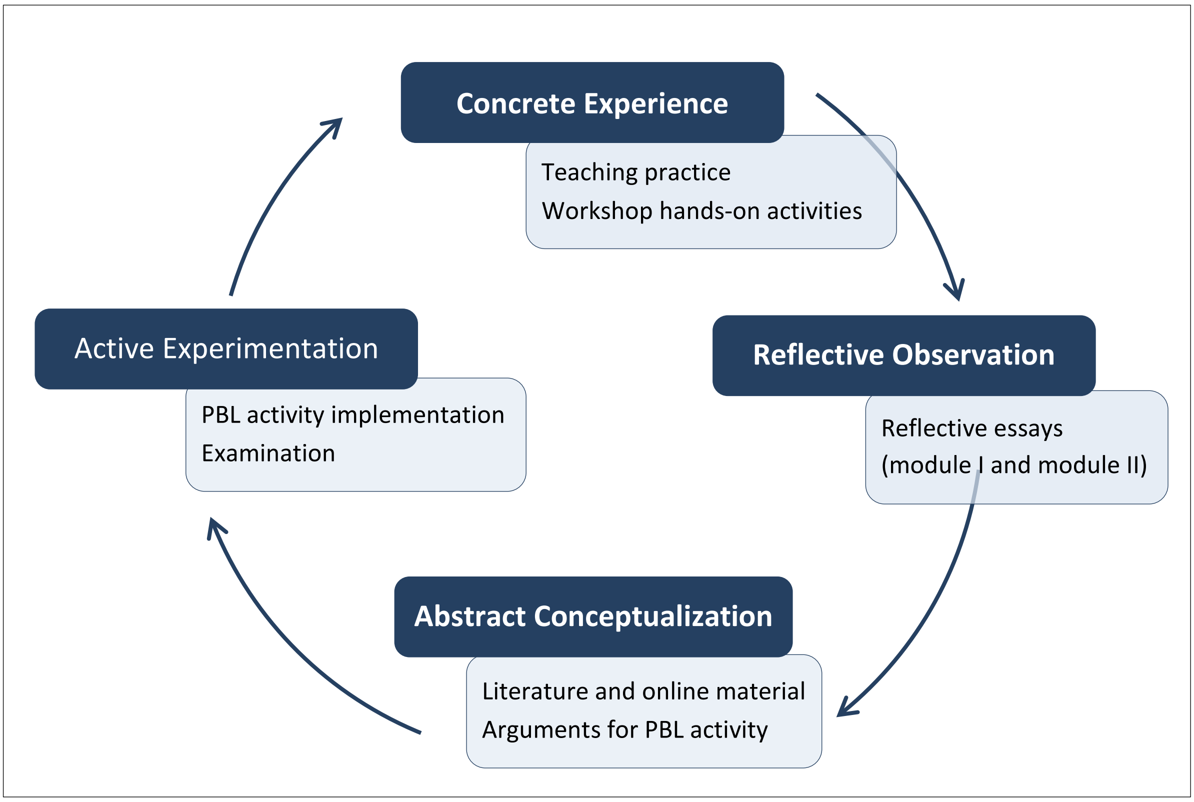

Figure 4. Relationships between Kolb's learning cycle and the Aalborg UNESCO Centre certificate activities.

5 The Aalborg UNESCO Certificate research approach

Presently, the Aalborg UNESCO Centre is piloting the certificate in collaboration with the Universidad Nacional de Colombia, Colombia. The course started on 12 February 2018 with 23 participants and finished on 1 June 2018.

Figure 5: First team of participants of the Aalborg UNESCO Certificate on th Basics of PBL and Curriculum Change.

Running the course at the Universidad Nacional de Colombia for the first time enabled piloting of the course and research on academic staff development. Research on PBL and staff development is another main activity of the Aalborg UNESCO Centre. The course research approach aims to: 1) systematically evaluate and improve the course and 2) understand in-service teachers' needs, expectations and motivations in engaging in staff pedagogical development courses and training. Through these aims, the Aalborg UNESCO Centre closes two existing gaps in staff development for engineering education. First, the systematic evaluation of the course will enable continuous improvement and adjustment so that it can meet the needs of engineering education in training future engineers (Adams and Felder, 2008). Second, it addresses the lack of literature investigating in-service engineering teachers' pedagogical needs, as well as their expectations and motivations concerning enrolment in staff development courses. We propose a mixed methods approach using quantitative and qualitative research methods at different moments of the course. Figure 6 illustrates the mixed methods design for the course.

Prior to the course — Quantitative method

- **Aim**: Gather participants' demographic information, expectations and needs for the course.
- **Instrument**: Pre-test questionnaire, administered before the course starts.

During the course — Qualitative method

- **Aim**: Gather participants' teaching needs and challenges, expectations and motivations for the course. Gather participants' perspectives and reflections on their own learning.
- **Instrument**: Teaching portfolio, comprising different sections and constructed throughout the course modules.

After the course — Quantitative and qualitative methods

- **Aim**: Gather course evaluations and responses concerning participants' perceived learning outcomes.
- **Instrument**: Post-test questionnaire, administered at the end of the course. The questionnaire comprises closed and open-ended questions.

Figure 6: Overview of the research design for the Aalborg UNESCO Certificate for the Basics of PBL and Curriculum Change.

6 Lessons learned from first implementation

The Aalborg UNESCO Certificate was first implemented in collaboration with the Universidad Nacional de Colombia. Overall, the certificate fulfilled its goals and enabled the Aalborg UNESCO Centre to draw lessons and elaborate on future improvements. The main lessons learned relate to planning and organization, participants, participation and self-study, IT interfaces and the portfolio.

Planning and organization

Having already established relations with our partner institution, facilitating the implementation of the certificate, trust and knowledge were already in place. Also, being able to settle the programme details on a face-to-face basis was an advantage. The local leadership was efficient in organizing and responding. However, the deadline for participants' registration was postponed, which delayed the beginning of the course and in turn this shortened time for participants to prepare for the workshops.

We are aware that promotion of an introductory pedagogical course for teaching staff highly specialized in technical areas can be challenging in any educational institution. The convincing examples and arguments need to be embedded within the institution and personal testimonies of improved results may have greater weight than claims about desired and needed changes and improvements in teaching. Such local examples and arguments will not always be available, but we can include evidence from other institutions in the promotional material.

Participants

The initial expectations were set for approximately 40 participants; 32 were signed up by the day of the formal introduction to the course; 24 turned up for the workshops; 22 participated in the exam. It was beyond our reach to influence participants' choices given their individual situations. However, given the results and achievements attained by those who completed the course, we believe that the impact will resonate within the participating institutions. The experience of the Aalborg UNESCO Centre is that the results of improved teaching (following participation in the workshops) usually leads to increased interest in similar workshops and training.

The participants belonged to three institutions and one organization, within which two institutions collaborated. The diversity of departmental affiliations and professional backgrounds is generally an asset; however, we continuously stress that this course is targeted to engineering educators. This means that the examples given are contextualized within engineering education and the participants' own teaching practice is well understood.

Participation and self-study

Motivations for participating are largely driven by intentions to improve student achievement and by several participants' interest in expanding the pedagogical foundation for changes already initiated (for deeper analysis of this, see Guerra and Spliid, 2018).

We did not make digital registration a requirement for individual access to our digital platform. We registered that individuals had delivered the required uploads – mainly on time. During the workshops, we naturally registered the presence of participants while also observing the enthusiasm and lively engagement of participants. For the following online facilitation meetings with the groups, we observed sustained engagement – although challenged by the detailed planning and actual implementation (including assessment and evaluation) and by the workload of teaching.

Language is a vital factor for communication between participants and teachers: a solid English vocabulary (speaking, reading and to some extent writing) is necessary for engaging with the course materials and teachers who do not speak Spanish (in this study, one understood sufficient Spanish to communicate with participants). We experienced a general willingness and proficiency, but there were also a few participants who were reluctant and insecure when it came to speaking English. Nevertheless, participants were largely able to understand us and with the ample time allocated for speaking their mother tongue during the workshops and during the following time for implementation, we conclude that the final portfolios and exams (both in English) often showed more than sufficient evidence of the fulfilment of course ILOs.

Self-study and self-initiated progress is at the heart of the course. To a large extent, the course participants embraced this autonomous aspect. However, the observed autonomous behaviour during the intervention period ranged from absent interaction with the facilitator to almost weekly communication. This pattern is difficult to change as we rely on the participants (as project owners) to seek facilitation when they feel the need; we refrain from taking a directive role and calling obligatory meetings. However, we may have to negotiate this beforehand for future courses as our (non-paternalistic) approach may conflict with participants' preferred approach.

IT interfaces

The Moodle platform functioned as planned. We still need to be aware of functionalities allowing (and encouraging) dialogue among participants and with course teachers; we also need to inform participants of these functionalities. The Adobe Connect room also functioned well, but the connections and/or the bandwidth often obstructed the quality of sound, which in turn hindered the dialogue. We believe that this problem was caused by participants' technical installations.

Portfolio

A template for the portfolio was made available from the beginning, providing a structure and facilitative questions. For sections A, B and C, this gave rise to very few inquiries, while for section D (reporting on the intervention) the participants expressed greater uncertainty about the content required.

It is our experience that when teachers participate in training courses (at whatever academic level), the majority behave like ordinary students, e.g. transferring to a more passive role, expecting hand-held support, misinterpreting information and experiencing uncertainty concerning reporting. As mentioned above, we might improve our support for participants through an early introduction to our expectations concerning their role and approach. Communicating transparent models for the process and the products will neither deprive participants of their achievements nor spare them from the challenges of "learning by doing and reflecting".

7 Conclusion

To address challenges such as globalization, sustainability and automation, engineering education needs to change teaching and learning practices and implement innovative, active and student-centred learning approaches such as PBL. Academic staff training and development plays an important role in fostering such changes by enabling the construction of pedagogical knowledge and competences.

The Aalborg UNESCO Certificate on the *Basics of PBL and Curriculum Change* is a 5 ECTS course, the main goal of which is to provide an overview of PBL theory, principles and models and to set the stage for curriculum change and innovation through meaningful learning experiences, reflection and active experimentation. The course also has a research component, aiming: 1) to evaluate systematically and improve the course and 2) understand in-service teachers' needs, expectations and motivations in engaging in staff pedagogical development courses and training. In this way, the Aalborg UNESCO Centre addresses two gaps in engineering education, namely the provision of innovative pedagogical development courses and understanding in-service engineering educators' needs, motivations and expections concerning pedagogical development.

The first implementation of the course, in collaboration with the Universidad Nacional de Colombia, was a success and it fulfilled the pedagogical goals; in addition, the first lessons indicate aspects on which work must be undertaken for future improvement, as stated in section 6. Now, we will start to analyse the empirical data collected before, during and after the course and we expect to gain a better understanding of participants' experiences, motivations, needs and learning processes to improve the course and contribute to engineering education research.

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UPSI iCGPA Bitara Model: Towards Excellence Of Teacher Education and Professionalism

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Abstract

In line with her history and legacy, Malaysia premier education university, Universiti Pendidikan Sultan Idris (UPSI) from its inception is an institution that strives for teacher education excellence. The curriculum framework and practice in the university is always focused towards producing quality and competitive teachers. Integrated Cumulative Grade Point Average (iCGPA), which was introduced in 2015 is also translated into an excellence teacher education framework. This article describes the UPSI iCGPA BITARA model, tailor-made for teachers' education that is supported by Malaysia Teacher Standard (MTS) and BITARA Educator Trait. In addition, the implications of this model towards teachers' education will also be discussed.

Keywords: iCGPA; UPSI iCGPA BITARA Model ; Teacher Education;

Type of contribution: **Best practice paper**.

1. Introduction

Development of skill and competence of each university students has to start from the first day of their university education. This is to imply that it involves continuous process and should not only happen within limited timeline, especially when it comes to skill and competence acquisition. In addition, it is through formative and progressive, as oppose to summative, one-off dimensions that deemed appropriate to characterize skill and competence development among university graduates.

iCGPA is part of the National Education Philosophy and Malaysia Education Blueprint 2015-2025 (Higher Education) aspirations to develop talent and innovation, whereby academic achievements are not the sole aspect to arrive at a student's final grade point average upon graduation. In particular iCGPA directly correspond to the first shift of the blueprint to produce holistic, entrepreneurial and balanced graduates. Their performance at the end of each semester will be presented in two forms: the listing of subjects and grades as featured in conventional academic transcripts, and a 8-pointed radar graph (similar to that CGPA) characterizing specific skills sets obtained by the students. the 8-pointed radar graph represent Malaysia Qualification Framework (MQF) learning domain as following:

i. Knowledge
ii. Practical skills
iii. Social skills and responsibilities
iv. Values, attitudes and professionalism
v. Communications, leaderships and team skills
vi. Problem solving and scientific skills
vii. Information managements and lifelong learning
viii. Managing and entrepreneurial skills

A recent paper published in the Pertanika Journal of Social Sciences and Humanities and produced by Universiti Teknologi MARA finds that the current Malaysian higher education system primarily rewards rote learning rather than skills better suited to a modern workplace. Rote learning that does not promote any skills among the learners is stemmed from teacher-centred learning in the university. Mass lectures, drilling and intensive exercise that represent traditional delivery of teaching and learning in the university should shift towards student-centred approaches to teaching and learning. To achieved the desired target, a high quality teacher preparation progamme should be a way forwards to UPSI, including innovative teaching and emphasize on student learning rather than teaching.

2. Teacher Education in Malaysia

From teacher education perspectives, student-centred learning is varied from one case and another, but mostly they serve to prepare pre-service teachers to be more relevant in their future teaching professions. Issues such as diversity of students´ background, globalization, liberalisation, inclusive classrooms and ongoing development of teaching and learning technologies (Dean, 1998 and Goodnough, 2006) have changed teachers' role in schools; no longer they serve to impart knowledge, today's teachers are now involved in inculcating creativity, intellectuality, problem solving ability and critical thinking skills among school students. Hence, both in-service and pre-service teachers need to equip themselves with necessary skills, attitudes and disposition in order to correspond with the ever-changing complexity of the school classrooms (Borhan, 2014). The arrival of iCGPA in 2015 is timely from teacher education perspectives in the sense that it will further fortified the effort to produce holistic teachers due to its emphasis on the development of various skills.

3. ICGPA BITARA UPSI MODEL

As a Malaysia premier teacher education varsity, UPSI is always innovate and transform its educational approaches and framework to suit with the current need and demand from the ministry and stakeholders. This is no exception when the iCGPA came in. After series of academic discourse to conceptualize iCGPA based on teacher education framework, UPSI proposes its home-grown iCGPA called iCGPA BITARA UPSI Model that comprises two main elements as depicted in Figure 1:

Academic Performance	Value Performance
• Based on MQF learning domain • Directly contribute to the iCGPA radar graph • All courses are broadly classified as either Developmental Course or BITARA course • Assess by the course lecturer	• To develop a holistic teacher trait based on excellence teachers framework and Malaysia Teacher Standard • Specific teacher traits was determined according to semester • Assess by the Academic Advisor during schedule meetings

Figure 1: Two main component of UPSI iCGPA BITARA Model: Academic and Value Performance

Both students' academic and value performance will be assessed under the UPSI iCGPA BITARA model. The emphasis on both academic and value performance echoed with UPSI Vice Chancellor vision for UPSI graduate to excel in 2A, which are *Akademik* (academic) and *Akhlak* (value). The MQF learning domain component measures the academic performance that represent by the radar graph of iCGPA. As for value performance, the aims is to assess an array of values a pre-service teacher should be equip with before they teach in the school as in-service teachers. Detail explanation on the framework, implementation, assessment and report of both performances are as following.

3.1 The Academic Performance Component

For academic performance, the execution is begin from the existing Course Learning Outcome Monitoring System (CLOM System). Since its inception in 2003, CLOM provides information on the performance of each course's LOs, overall course performance, individual students' performance through Student Learning Outcome Monitoring (SLOM) and programme performance through Programme Learning Outcome Monitoring (PLOM). Although the CLOM system is sophisticated due to its nature that could provide data ranging from individual students' performance until academic programme performance, the baseline CLOM data has been reviewed thoroughly to ensure the system align with the iCGPA needs and requirements. The academic course review has been conducted periodically throughout UPSI faculties and the review is based on the following principle:

i. Align with Outcome-Based Education (OBE) principle

ii. Align with Constructive Alignment (CA) principle

OBE is a method of curriculum design and teaching and learning activities that focuses on what students can actually do after class. In OBE, the learning outcomes of the course does not only focus on students' possession of knowledge, but also on their development of appropriate skills and qualities upon graduation. Hence, the OBE emphasizes on active learning where students are expected to tackle many challenging tasks other than memorizing and reproducing what has been taught. Constructive alignment–a term coined by John Biggs (Biggs, 1999)–suggests that learning activities (student-centred learning) and assessment tasks should be aligned with the learning outcome of the course, resulting in a consistent system as shown in Figure 2:

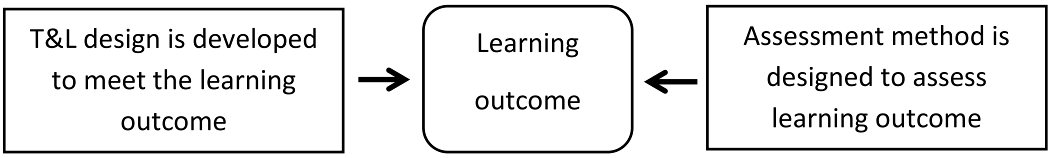

Figure 2: Aligning learning outcome, teaching and learning activities and the assessment (adapted from Biggs, 1999)

Constructive alignment (CA) is an explicit planning by academics to ensure that the activities of teaching and learning, the assessment methods are coherent with the intended learning outcome (LO). Explicit planning on howto achieve a particular LO is vital to create mutual expectation between lecturer and student, guide for students to performs and serve as an indicator of course and programme performance. CA can be conducted both in micro and macro level. At the macro-level of CA, the alignment between Programme Learning Outcome and the MQF learning domain is determine whereas at the course level, micro-level CA involves three main elements within a course whereby the LO is mapped to the type of learning domain (either cognitive, affective or psychomotor), along with the relevant teaching and learning activity and assessment tools used to determine LO achievement. The following Table 1 exemplifies CA practice:

Table 1: The alignment between LO, T&L activity and assessment tool according to CA concept.

Learning Outcome (LO)	T&L Activity	Assessment Tool
Ability to communicate critically on a specific issue	Individual and Group Presentation	Analytical Rubric for critical communication

In the table, the LO calls for students to possess critical communication skills, and the T&L activity is presentation (both group and individual) and analytical rubric is utilize to determine to what extend students has achieve this LO. Both OBE and CA principle are already become integral principle in planning, enacting and documenting curriculum in UPSI educational programme. However, a thorough review of the courses and programme are conducted recently to ensure all parties involve in curriculum matters possess common understanding on iCGPA. To ensure a smooth, full-fledge transition to iCGPA this coming September 2017 session, pilot teas was conducted on two academic programme namely Bachelor in Education (Science Education) and Bachelor in Software Engineering (Educational Software). The findings from the pilot test, be it on either student performance or issues and challenges, will be meticulously scrutinized to minimize hiccups during September 2017 implementation.

At the macro-level of CA, each LOs (in UPSI, a course is normally consist of four to five LOs) of a course is mapped to programme learning outcome (PLO) of the programme. Taking the example from Table 1, the LO is a communication-type LO and hence is maps to second PLO (in UPSI, second PLO (PLO2) normally calls for communication). Subsequently, the PLO2 is further maps to the fourth MQF learning domain that stated as "Communications, Leaderships and Team Skills". The MQF learning domain is the one that will appear in the student academic performance reporting in the form of 8-pointed radar graph. Figure 3 summarises processes involve in academic performance component which resulting in 8-pointed radar graph of iCGPA.

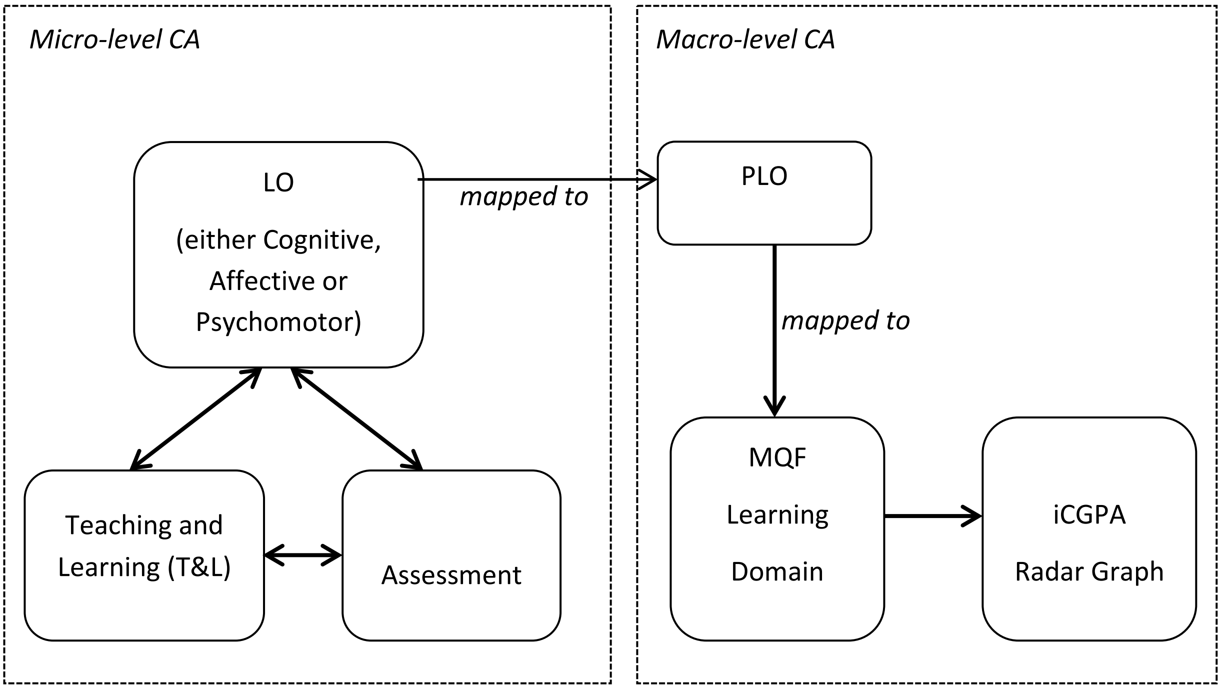

Figure 3: Micro- and macro-level of CA that yields iCGPA radar graph in Academic Performance Component of iCGPA BITARA UPSI Model

3.2 The Value Performance Component

As the one that will educate future generation, teachers should possess set of values to guide future generation that are not only ace in academic, but also equip with value-laden skills. It can be gleaned from a study by SEAMEO INNOTECH in 2009 about teacher education across south east Asia nation, that infuses in students the value of respect and honesty is one of the important classroom management competences a teacher should be possess of. Current reform in south east Asia nations also moving towards producing teachers that are holistic and balance between academic and value achievements. Tapping on teacher education in achieving national aspiration for future generations is important to ensure that pre-service teachers understand, resilient, and putting large efforts towards improving education quality as stated by the OECD:

"... as the most significant and costly resource in schools, teachers are central to school improvement efforts. Improving the efficiency and equity of schooling depends, in large measure, on ensuring that competent people want to work as teachers, that their teaching is of high quality, and that all students have access to high quality teaching." (Organization for Economic Co-operation and Development, 2008)

As in Malaysian higher education landscape, this aspiration has been translated in the first leap of the National Higher Education Blueprint (Pelan Pembangunan Pendidikan Malaysia (Pendidikan Tinggi) that spells out as "Producing Graduate that Are Holistic, Balanced and Entrepreneurships". To address those aforementioned calls for producing graduate, or in particular pre-service teachers that are holistics, the second component if iCGPA BITARA UPSI Model focuses on the assessment of values among the pre-service teachers. The values that will be assessed is derive from the amalgam of value documented in the Malaysia Teacher Standards (MTS) and BITARA Educator Traits. Figure four presents value components made up by MTS and BITARA Educator Traits:

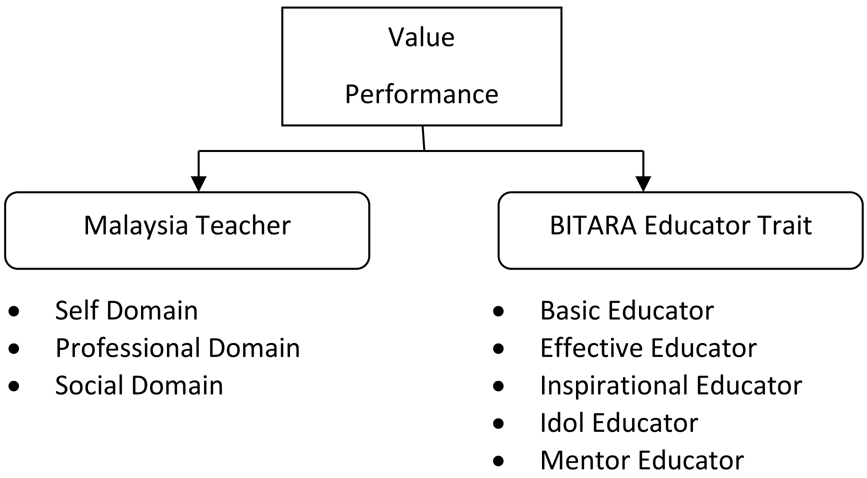

Figure 4: Amalgam between MTS and BITARA Educator Trait form value performance component in iCGPA BITARA UPSI Model.

Echoed with the blueprint, the aspiration to produce such traits of teachers are well documented in the Malaysia Teacher Standards (MTS). MTS outline professional competency a teacher should achieve, and requirements that need to prepare by the teacher education providers to assist teacher to achieved competency standards. Goh (2012) added that MTS aims at establishing competency standards for the teaching profession and to enhance teacher's status in Malaysia. MTS is highly relevant to the teacher education providers (i.e: UPSI) in the sense that it allow:

- Identify Standard achievement level of both pre-service and in-service teachers
- Identify strategies to assist pre-service and in-service teachers evaluate their achievement over Standard
- Identify institutional readiness and training needs to achieve Standard.

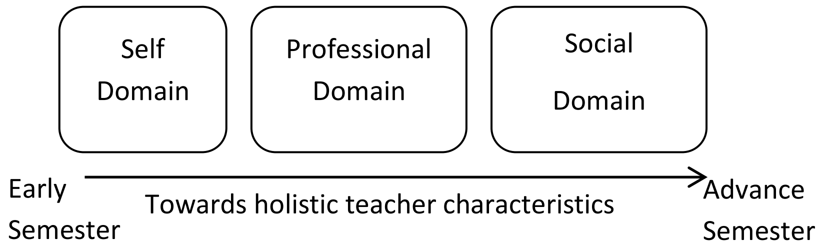

Figure 5: Three domain in MTS in year of study continuum.

As depicted in Figure 5, MTS consists of three domain namely Self, Professional and Social domain. Each domain consist of different set of values that will assess in the progressive manner from the first semester until eight semester. Self-domain that focuses on self-development values (e.g: believe in God, resilience, fair, patience and volunterism) will be assess during the early years (i.e Year 1 and Year 2) of the study period. Professional domain related to value uphold by the teacher in carrying out their accountability as professional teacher will be assess during the mid year (Year 2 and Year 3) of their studies. The social domain nthat spells out values of a teacher as a social agent and human capital coach (e.g: social skills, community spirit, patriotism) will be assess durinf the advance (Year 3 and Year 4) of the study. Ongoing and continuous nature of value assessment is aligned with the notion that values are develop in progressive manner, and not acquired by one-off, summative manners. Second set of values that made up value component along with MTS is BITARA Educator Traits that further specified into five set of values as depicted in Figure 6:

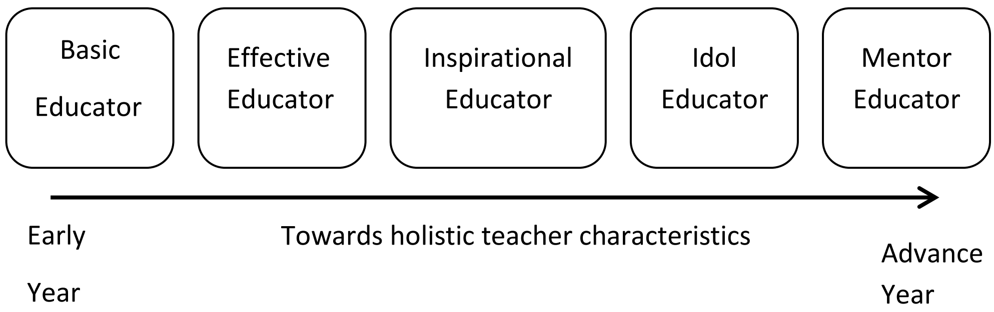

Figure 6: Five educator characteristics in the year of study continuum.

Each educator characteristics consist of set of values that need to be assessed in a specific semester. During the early semester (i.e: Semester 1 until Semester 3), the values that need to be assessed by the academic advisor is the basic value that deemed important as a human being or as a university students. Among the basic values are time management, honesty, passion in knowledge and ethics. It is vital to ensure that students are possess with these set of basic values before they being assess towards more advance, teacher-centric values. As students enroll in their advance semester, the values are more specific towards becoming a holistic teacher. Among the values that will be assessed during advance semester are role modeling, classroom management, pedagogical execution and advisors.

The existing academic advisory system will be fully utilizes as a platform to assess value development (both value from MTS and BITARA Educator Traits) that made up value component of iCGPA BITARA UPSI Model.

Each lecturer in UPSI is appointed as academic advisor to a number of students (academic advisee). According to the current rule, it is compulsory for the academic advisee to meet with their academic advisor at least three times in a semester. During each meeting, the academic advisor will conduct activities to assess value achievement of their academic advisee. In reporting the current value achievement of their academic advisee, academic advisor will uses analytical rubric resulting in 'achieved' or 'not yet achieved" status. This status will appear in students result slips along with the iCGPA radar graph that represent academic performance of a student.

4. Summary

The iCGPA approach is a novel initiative in quantifying students' learning outcome in university. It reflects the need for universities to be responsive to the changing dynamics in the global job market. It attempts to address two critical issues at one go: first, institutional efforts in support of developing the holistic student, and second, issues of talent development in general, and of graduate employability in particular. Assessment of academic competence, character development and non – academic competency development should run parallel every semester throughout their studies.

As it strives for teacher education excellence, UPSI conceptualize iCGPA with the prime intention to elevate standards in teacher education. iCGPA BITARA UPSI Model is not only emphasize on the excellence in academic performance, but also put equal emphasize on the development of value among its teacher graduate as showcase by the value component of the Model. As a prominent teacher education providers, UPSI take on iCGPA create a unique iCGPA approach that are parallel to its vision to produce world class teachers and leading education university in Asia. In ensuring a smooth transition to iCGPA, appropriate programmes and learning opportunities must be designed, trainers and academic staff must be briefed and be familiar with the principles underlies iCGPA, rubrics and criteria for assessment and reporting (top-bottom approach). In congruence, community of practitioners that are like-minded to the innovative approach such as iCGPA will embed a culture of academia that are susceptible to new approaches (bottom-top approach) for the sake of teacher education excellence.

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RESEARCH ON THE COLLABORATIVE RUNNING MECHANISM OF MULTIPLE PROVIDERS IN CONTINUING ENGINEERING EDUCATION

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Abstract

Continuing Engineering Education (CEE) is the expansion and extension of Higher Engineering Education, the training objects of CEE are engineers, its providers includes universities, enterprises, industry associations, government, private training institutions, etc. So compared with other educations, CEE has different features in many ways. The focus of the future development of CEE in China is to improve its quality and management efficiency in a long time. This research integrally applied quasi-public products theory, organization theory and the principal-agent theory to answer the three basic questions of CEE: for whom the continuing engineering education is provided, who provides and how to provide, and to proposal that collaborative running mechanism of multiple providers of CEE is helpful to explore the strategies and approaches of achieving the goal of high quality and efficiency.

Keyword: continuing engineering education; multiple providers; collaborative running mechanism

1 RESEARCH DESIGN

1.1 Research Methods

Thoroughly reviewing all important conference memos and papers of IACEE since 1972,when the Working Group on Continuing Education of Engineers and Technicians(WGCEET)found, and research reporter about engineers of the Chinese Academy of Engineering（CAE），National Academy of Engineering (NAE)and Royal Academy of Engineering（RAE），this paper focus on the problem about school running of CEE after collecting, analyzing and sorting the historical documents.

This research investigated the living status of engineers and analyzed the social background of the formation of their learning demands. The analysis based on over 900 questionnaires from engineers in several industrial enterprises, whose position includes production, design, management, research and so on. The empirical study provides objective evidence to the foundation of school running.

To follow up the above questionnaire, over 30 interviews with headmasters, project leaders, and teachers of CEE were carried out from 2013 to 2015. The purposes of the interviews were to obtain actual conditions of school running, to focus on the exact problems to be solved, and if possible to add new angle to the research of collaborative running mechanism of multiple providers of CEE. In addition, comparative study was through the whole research process.

1.2 Theoretical Basis

"Public products and private products can be regarded as the two extremes of social products or services. In real life, most products or services between the two are called quasi public products, which have characteristics of both of public products and private products (Wang Shanmai, 2000)." Therefore, CEE is a typical quasi public goods, its nature of quasi public goods determines that the product or service of CEE should be the combination of market supply and government supply, under the action of public choice and market rules.

"Formal organizations coexist with informal organizations (groups of people who interact with each other outside a formal organizational structure)." "Benefits of informal organizations include the promotion of communication, cohesiveness, and self-respect "(Barnard, 1971). In order to adapt to the change of environment, the providers of CEE must carry out a series of organizational changes in personnel, structure and technology. In addition, the application of information technology fundamentally changes the organization mode of the main body of the school, makes the organization structure present the trend of networking and virtualization.

"From a methodological view, it world be desirable to find models that yield simpler and sharper answers in such rudimentary organizations as the principal-agent set up, in order to be able to go forward with the analysis and investigate more interesting aggregate question (Holmstrom, 1987)." Due to the complexity and diversity of the continuing engineering education body, there is multi task principal-agent relationship to exist between the government, enterprises, universities, social intermediary organizations and other participating agencies. The multiple principal-agent model provides theoretical basis for their cooperation.

1.3 Research Framework

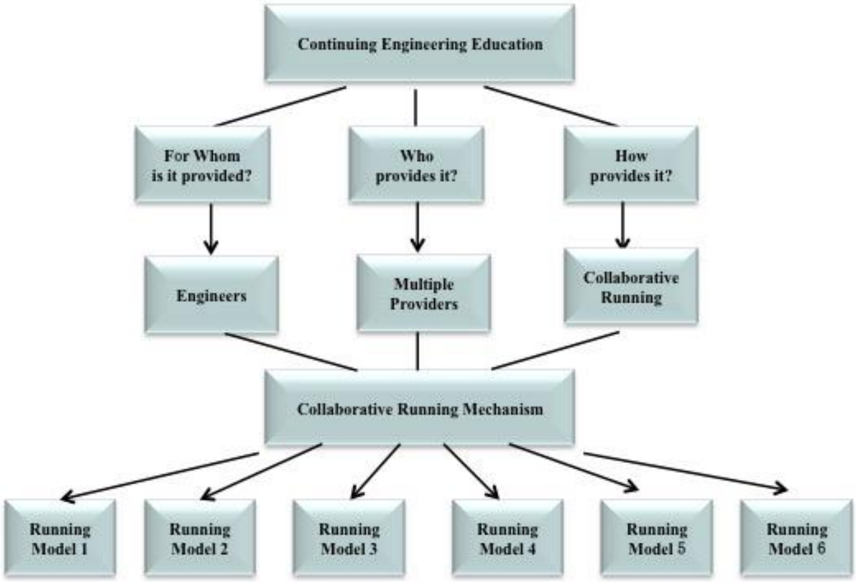

Figure 1 The Research Framework

From 1979 when CEE was introduced into China to the present, the quantities and scales of providers of CEE have been rapidly grown. However, the quality and management efficiency of school-running as a whole should be to improve in the face of challenges all the time. The study and design of the collaborative running mechanism of multiple providers is to explore the effective ways to improve the educational quality and the management efficiency. The system of school running is the key part of educational system, its nature is to assign and reassign of educational rights and resources. Reasonable and practical pattern of multiple providers is helpful to optimization and efficient use of educational resources. The collaborative running mechanism (CRM) can create innovative and diversified provision models. (See the framework shown in Figure 1)

2 THE FOUNDATION OF THE CRM OF MULTIPLE PROVIDERS

Multiple Providers, with related school participation institutions forms an organization system of cooperative development, make a series of organizational reforms in personnel, structure and technology. This innovation system interacts with the environment，promoting the development of CEE.

Most providers of CEE are merely neither independent running educational institutions or departments, nor a simple input-output enterprise. To achieve the whole school running require a number of institutions to participate in it. For example, financial institutions can provide a variety of financial products and services to direct capital flow and increase its usage efficiency. to guide the flow of funds, improve the level of capital profitability. Network technology institutions can provide Internet technology tools to construct of online learning platform and achieve resource sharing. Intermediary agencies can coordinate the relations of CEE in many ways. Through the ability and resources to complement each other, every part of CEE achieves a win-win situation, so as to gain greater interests than that of their own independent condition.

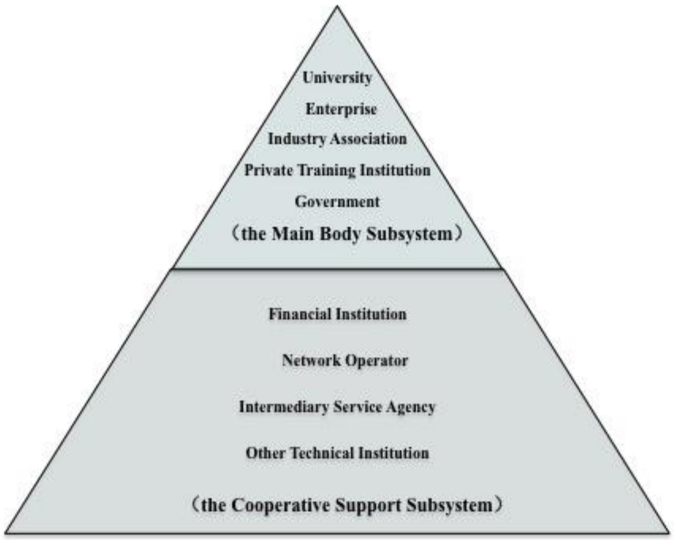

Figure 2 Organization System of Multi Agent Cooperative Mechanism

Mostly based on the project management mode, educational activities of CEE have a certain life cycle and the interval time between the formation and dissolution of the project group is shorter than that of other educations. Therefore, the provider of CEE has been widely considered as a temporary organization. The restriction of hierarchy structure and geographical location has been more and more weaker， and then the arrangement and operation of the whole process of running a school increasingly rely on cooperative and professional training teams across-functions, and across business lines, more than before. As a result, the organizational structure of educational activities should be reformed and even reconstructed, the arrangement of personnel and resources should be in effective and reasonable way, and diversified, personalized education services should be introduced.

Virtual Organization emerges and grows rapidly with the development of Internet. It breaks through the traditional organization mode and management mode of CEE and has brought a great opportunity and wide development space to CEE. However, first, entity of running a school is definitely an important prerequisite for virtual organization. Virtual organization is based on the existence of educational entity, fresh recognition of the boundary of the organization system of running a school is needed to form virtual organization. Second, Information technology solves the problem of information communication in organization management, meanwhile, it also brings the complexity of management, the multi objectives of the organization and the high risk of the process of running a school, it is needed to establish the contractual relationship between the parties of running school, to form a loose organization of contractual risk sharing and complementary.

Organization system of multi agent cooperative mechanism is represented in Figure 2. It consists of two subsystems, the main body subsystem and the cooperative support subsystem. The former is the core of multi agent cooperative organization system, it is formed by colleges and universities, enterprises, industry associations, private training institutions, etc. the latter is prop up multi agent cooperative organization system, it is made up of Intermediary service agencies, financial institutions and network operators and other technical institutions.

3 MODELS OF RUNNING A SCHOOL UNDER THE CRM

If Collaborative Running Mechanism plays a role in running a school, multiple providers can form diversified cooperative relationship to meet the different learning needs of the group of engineers and the individual engineer, then they and their relevant institutions constitute innovative organization structures to comply with organizational environment. As a result, six models of running a school can be put forward as it can be seen from Figure 3.

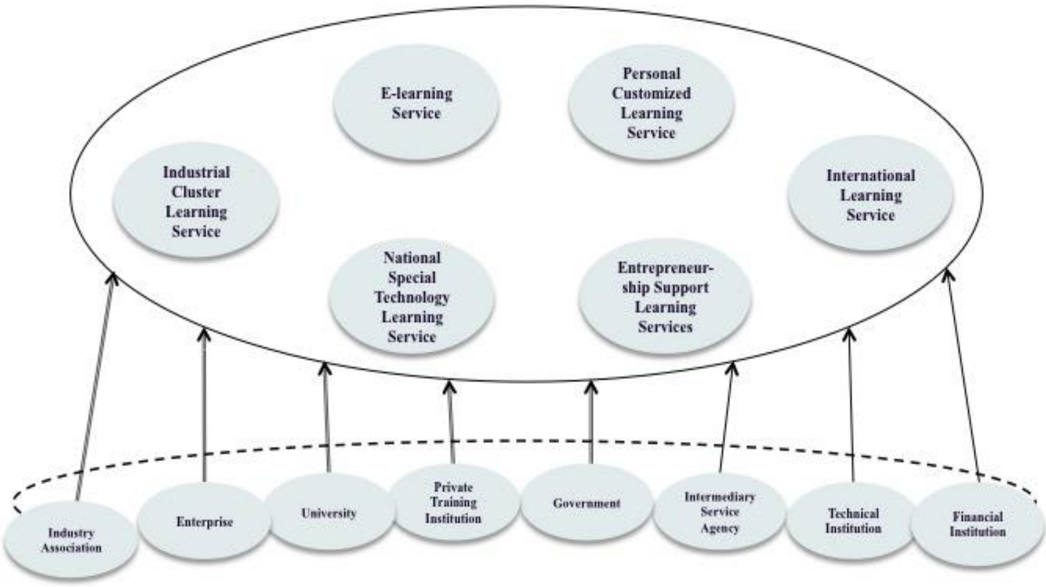

Figure 3 Six Models of Running A School

3.1 Industrial Cluster Learning Service

Engineers in a certain industrial cluster who work under a better professional growth environment, and whose satisfaction for the career and the organization is higher than other engineers. Moreover, they usually are members of specific industrial associations, they get to professional training or gain professional information mainly through these industrial associations. Therefore, industrial associations play a leading role in the industrial cluster learning service. They provide education services or products directly to engineers working for the front, which is benefit for engineers and enterprises in which they work.

3.2 E-learning Service

More and more engineers, especially young engineers self-study on the Internet and communicate with teachers and other learners about learning problems and experience. In the process of learning and simulation training, they can get other services, such as career counseling, planning, and assistance. Because they have long-established networking infrastructures, long-established distance learning programs and rich educational resources, universities are the leading of E-learning Service. The construction, management and operation of online learning platform is a complex systematic engineering to construct, manage and operate an online learning platform, and it needs strong financial support and technical support.

3.3 Personal Customized Learning Service

Personal customized learning service mainly meets the needs of engineers worked in small and medium-sized enterprises and freelance engineers, it provides technical training with high standardization, such as professional qualification and IT software technology certification. Because of flexible school running, strong service awareness and favorable fee, private training institutions are easier to meet with the demand of different engineer group, in order to provide satisfactory training services and value-added services for them than state-owned enterprises. Thus, private training institutions play a role in customized courses and personalized Courses.

3.4 National Special Technology Learning Service

Learners must be engineers who work in important positions of Industrial Enterprises in priority engineering areas of national development, and they are selected through the strict evaluation.

According to China's national conditions，this government-run schooling model will play a leading and exemplary role in quite a long period of time. National continuing education bases are responsible for schooling running to enjoy State funding of nonprofit. It is helpful to alleviate the situation of serious shortage of high-level professional and technical personnel in China, to form a good social environment conducive to the growth of professional and technical personnel.

3.5 Entrepreneurship Support Learning Services

The employment of university graduates is facing great challenge in China, which is influenced by various factors, this model provides a series of adaptive learning activities to engineering graduates who have entrepreneurial intentions and conditions, in order to help them transform from a student to a professional person. These activities include guiding them to develop effective business plan, providing relevant policies to support and consulting services, assisting them to establish a scientific and reasonable business philosophy, and then establishing their own small and micro enterprises. It is important to require the cooperation of all aspects of society, as well as the support of the social environment.

3.6 International Learning Services

Economic globalization has accelerated the international flow of engineers, engineers have strong desire to study abroad and work for some time under the premise of the conditions permitted. International engineering and technical personnel training must follow the international standards and rules, so the international education exchange association and other non-governmental international exchange intermediary institutions are dominant, to play the role of international exchange and cooperation.

4 MAIN CONCLUSION

To found the multi subject cooperative school running mechanism of CEE and implement diversified collaborative school running models, it is effective to resolve the problems of engineering education quality and school running benefit, provide high quality education services for engineers. Meanwhile, the collaborative development of multiple school running subjects of CEE should be related to the introduction of relevant policies and the perfection of relevant laws and policies, it will create a perfect environment and fair market competition environment and make school running to abide by the rules and laws, both rich and varied in order.

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