Educate for the future

PBL, Sustainability and Digitalisation 2021

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8th International Research Symposium on PBL

EDUCATE FOR THE FUTURE:
PBL, SUSTAINABILITY AND DIGITALISATION 2021

Edited by:
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United Nations Educational, Scientific and Cultural Organization

AALBORG UNIVERSITY
Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO

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All the IRSPBL proceedings are available at: https://aauforlag.dk/shop/skriftserier/international-research-symposium-on-pbl/default.aspx
The IRSPBL 2021 proceedings are officially launched during first day of the conference, August 15, 2021.
The IR-SPBL 2021 conference is organised by Aalborg Centre for PBL in Engineering Science and Sustainability under the auspices of UNESCO (Denmark). The IRSPBL 2021 is a virtual event and is organised after the post-ponement of IRSPBL 2020 conference due to COVID-19 pandemic.

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Foreword

It is a pleasure to present the proceedings from the International Research Symposium on PBL (IRSPBL2021), organised by the Aalborg UNESCO centre for PBL in Engineering Science and Sustainability. The IRSPBL has moved around the world to Australia, the United Kingdom, Malaysia, Spain, Colombia, China, and India.

Twelve years after the first symposium, it was our intention to return home and organise the IRSPBL 2020 in conjunction with the PAN-PBL annual conference, the PBL 2020. However, due to COVID 19 pandemic both conferences has been postponed for the summer of 2021, where Aalborg University is hosting an entire week dedicated to PBL, the Aalborg PBL Week 2021 (August 15-20, 2021).

Even though much has been achieved during 2020 regarding vaccination and controlling the spread of COVID-19, we are still forced in isolation and facing several waves of infection. This pandemic change the world, how we connect with each other, and carry out our academic and professional activities. We live now in a “new normal” with digitalisation, and facing social and environmental challenges. Presently, connectivity assumes new shapes and meanings; the aim of IRSPBL has been to share experiences and research results on the transformation in engineering and science education to be more project-organised, and problem-based learning, i.e., PBL.

Additionally, the amount of best practice and research has increased enormously all over the world. The need for change has also increased during these years, from requests for engineers and scientist who are able to contribute to the solution to societal challenges, such as the UN’s Sustainable Development Goals and Digitalisation. Therefore, competencies such as collaboration and leadership have to be learned in inter- and disciplinary contexts as well as in complex problem solving for society, and with society.

The IRSPBL has always been proactive in bringing practitioners and researchers together, in creating communities and enabling collaborations across world. For example, with postponement of IRSPBL 2020, we organised a series of online events in the advent of IRSPBL 2021. We started with a kick-off seminar, entitled ***“PBL in a pandemic world”***, on 18 August 2020, followed by the Flipped IRSPBL 2020 webinar series, entitled ***“Moving towards a virtual PBL community”*** in the fall of 2020. The Flipped IRSPBL 2020, run from October 2020 until March 2021, took the point of departure in the IRSPBL 2020 contributions and provided the opportunity to keep the PBL community ‘connected’. The Flipped IRSPBL 2020 counted with more than 200 participants from 48 different countries and all regions of the world.

Research has also proven the value of PBL and the question is no longer if PBL works, it is now a question of which type of PBL works for which learning purpose and outcome? The variation of PBL is crucial to look into, as projects for entrepreneurship and innovation might need a type of organisation of the student learning process other than projects for understanding the theoretical foundation of a discipline. There is a variation in the use and integration of digital tools for the problem-solving process and the collaborative process. There is a variation in the educational cultures and adaptiveness for co-constructed and student-centred learning processes.

The IRSPBL 2021, the postponement of IRSPBL 2020, will be fully online and free of charge. The overall goals mentioned above remain the same, and we have prepared an interactive, dynamic and comprehensive programme where, for example:

- Conversations with world-renowned experts address trending topics in engineering education;
- Networking sessions aim to foster discussion and reflection among participants, including interaction with students;
- Interactive paper presentations provides our contributors the opportunity to share their work; and
- Young researchers show case their PhD studies, among other activities.

The IRSPBL 2021 has collected 21 contributions from 13 different countries, all compiled in this book. The contributions cover a number of relevant topics: blended PBL environments and online learning; sustainability, creativity and interdisciplinarity; PBL implementation for professional competence development; assessment and management of change.

This book represents some of the newest results from research on PBL and best practice to inspire other practitioners to innovate their teaching and learning activities. We hope that you will find the book useful and inspirational for your future work.

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PBL Implementation - PBL for Professional Competence Development

PBL Implementation, Assessment and Management of Change

Blended PBL Environments
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Analysing Self-Directed Learning at Iron Range Engineering: Framework and preliminary findings

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Abstract

The Bell Program at Iron Range Engineering is an ABET accredited upper division engineering transfer program for students coming from a United States community college or equivalent education experience at a university seeking a Bachelor of Science in Engineering degree. This program model allows students to graduate with 2.5 years of engineering experience. The first half-year is called the Bell Academy which is an intensive growth phase where students learn to work in industry by completing design projects, taking technical courses, and developing professional skills. The Bell Academy is an intensive PBL experience in the Iron Range Engineering model, while the two years of co-op learning also adhere to PBL principles. The following two years are spent taking courses remotely while having the opportunity to work as engineers full time in industry for up to 24 months .

As essential part of the Bell Program is the students involvement in remote courses, and as such, the students ability to direct and regulate independent learning is paramount for their success, and is one of the main foci of the Bell Academy. This study will attempt to measure and map out the development of behaviors and attitudes conducive to self-directed learning in students in the Bell Program, by applying the Oddi Continuing Learning Inventory (OCLI) self-reporting survey on all students currently enrolled (Oddi, 1984).

The study will continuously gather data every 6 months for the next 3 years, collecting answers from all enrolled students. The analysis will evaluate both longitudinal progress of individual student cohorts as well as interventions and changes to the Bell Program by comparing the generations to each other.

This article will present the framework of the study and preliminary results from the first data collection conducted in January 2021.

Keywords: Self-directed learning, longitudinal data, hybrid model, work-based learning

Type of contribution: PBL research

1 Introduction

A concern of adult and higher education research that has recently been highlighted is the absence of quantitative research. While bibliographical studies of the most recent decades have shown a resurgence of empirical studies, the rise has not been a result of more quantitative studies, but rather, almost exclusively, by qualitative ones (Fejes & Nylander, 2015). Even among studies reporting quantitative results, most only apply descriptive statistics from questionnaires, seemingly not applying any other quantitative analytics (Boeren, 2018). This methodological skew hampers the collective field of research to the point where answering some research questions becomes increasingly difficult, and opportunities for research, like those created by the massive automated data collections of big data, are missed (Daley et al., 2018). One approach which could be applied to mitigate the skew is to attempt to reinvigorate statistical instruments developed and applied primarily in the 80s and 90s. Taking advantage of the developments in computational power, statistical software packages, and statistics, such instruments can be validated more easily, reinterpreted, and discussed in greater detail.

For several decades there has been a persistent call for improvements in engineering education as the variety of needed skills for engineering graduates continues to evolve and outpace academia's response. In the early 2000s, the U.S. National Academy of Engineering published the attributes of Engineer 2020 (National Academy of Engineering, 2004). More recently, as the list of new competencies continues to grow, publications continue to call for a wider and deeper set of needs (Goldberg & Somerville, 2014; Graham, 2018; Madhavan, 2016). One such skill that emerges time and again and has an avenue of research that has a long history of applying such instruments is self-directed learning (SDL). SDL is one of the most prolific themes within adult and higher education research. With the proliferation of active learning methodologies like PBL in engineering, it has become even more critical. In this paper, we present the methodological framework and preliminary findings of a study applying the Oddi Continuing Learning Inventory (OCLI) to students of the bell program at Iron Range Engineering. In the discussion, we will elaborate on the potentials and limitations of the suggested methodological approach.

In this paper, we report preliminary descriptive statistics from the study but have so few respondents and cohorts that any analytical conclusions based on these numbers should be drawn with severe reservations. Therefore, this article's contribution is first and foremost to present and discuss the methodological framework, its potentials, and limitations.

2 Background

2.1 The Bell Program

The IRE Bell program was inspired by both the Iron Range Engineering program in the U.S. and Charles Sturt University in Australia (Rogalsky et al., 2020). Iron Range Engineering was started in 2009 as an adaptation of the Aalborg University model of PBL (Johnson & Ulseth, 2015). Similar to Bell, IRE was developed to serve students in the last two years of a 4 year bachelor's degree program after they completed the first two years at a community college (50% of bachelors degree). The focus of IRE was and is to graduate practitioners ready to act as professionals in engineering practice after graduation in Barnett and Coate's category of "acting" (2004). The goal of the developers was to create more balance in the development of professional or work-place competences, whereas engineering curricula at the time were imbalanced preferring the acquisition of technical skills at the cost of developing professional skills (Sheppard et al., 2008). The IRE program attained levels of recognition after less than one decade of existence by, for example winning the ABET Innovation award for the innovative curriculum that was enacted.

While the IRE model had students spend their entire education on campus at the university, in Australia, a new model of educating "acting" engineers was being developed at Charles Sturt University (CSU). In the CSU model, students spend one and a half years on campus in a PBL learning environment and then spend four years in the field working in co-operative (co-op) education experiences while also completing their coursework on-line (Morgan & Lindsay, 2015). By 2018 both IRE and CSU had risen to the point of being recognised as "emerging world leaders" in the Global State of the Art in Engineering Education report published by MIT (Graham, 2018).

Bell was purposefully designed as a hybrid of Iron Range and Charles Sturt (Johnson & Ulseth, 2018). Its design directly takes the curriculum and most of the learning strategies of IRE and its co-op based structure comes directly from Charles Sturt. See figure 1 for a graphical representation of the Bell model.

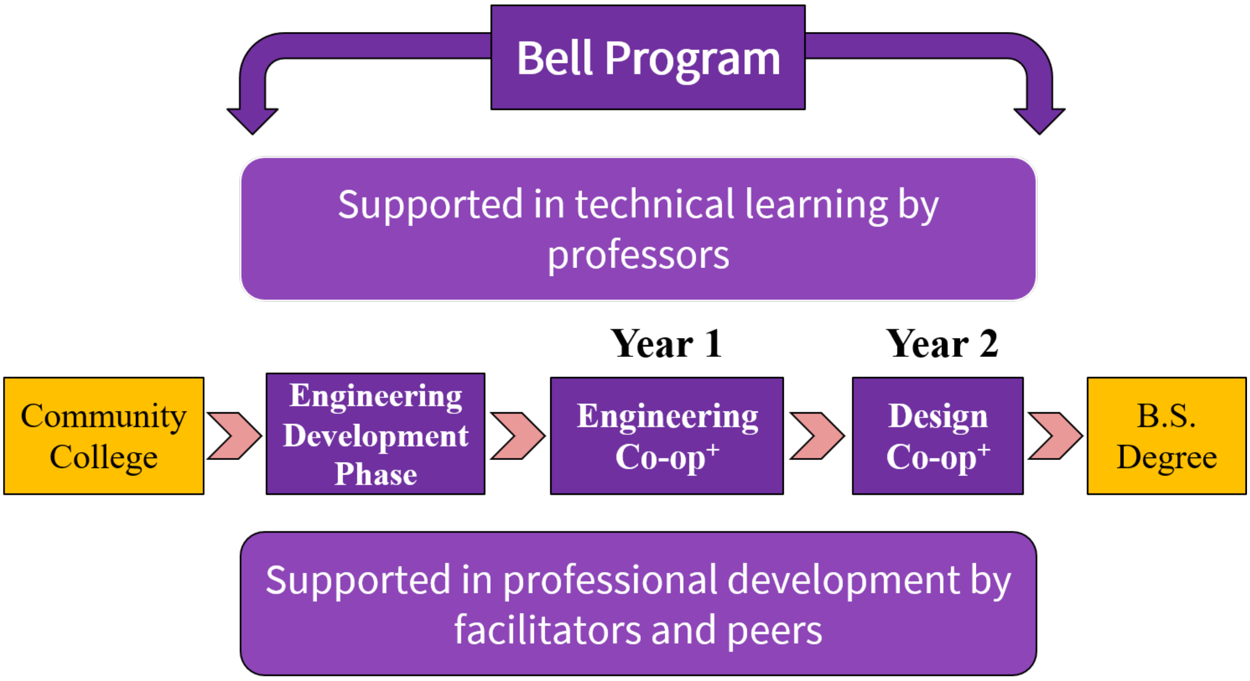

Figure 1. Visual description of the Bell program (Rogalsky, Johnson, & Ulseth 2020).

Bell subscribes to many principles of PBL as described in the Aalborg model (Kolmos et al., 2004). Student engineers spend roughly half of their time on project work, both during the development phase and on co-op and half of their time on academic work. Project work is done in teams. Student projects are facilitated by engineers with experience in industrial practice. The technical, professional, and design coursework are applied in the projects. Finally, as with the Aalborg model, the main focus is that the project sits at the center of the student learning process. As can be seen from this analysis, the Bell program is considered to be a form of PBL implementation.

During the engineering development phase, student engineers spend one hour per week developing a conceptual understanding of many frameworks from cognitive theory. Examples include Bloom's taxonomy, affective traits, self-efficacy, goal setting, self-regulation, resource identification, and reflection. An outcome from this first part of the program is students acquiring an ability to manage portions of their own future technical learning. While in co-op, the working student engineers take one technical course each month for 24 months. Roughly half of these are on-line, instructor-led. The other half are called SLA (student-led advanced) technical competencies. In these, students identify technical content aligned with either their engineering projects at work from their personal passions. They write a course proposal in the form of a syllabus with outcomes, deliverables, and a detailed timeline. After a process of negotiation with, and approval from, a professor, the student spends 3.5 weeks completing all of the learning independently. At the end of the course, they present their deliverables and defend their knowledge in a verbal exam format similar to a thesis defence. Success in these SLAs requires high levels of self-regulation and self-direction.

2.2 SDL

In the past, many different, somewhat overlapping conceptualisations, such as independent learning, self-planned learning, self-teaching, self-directed inquiry, autonomous learning, self-education and self-regulated learning, have all partly, if not wholly, covered SDL (Guglielmino, 1977; Oddi, 1987; Saks & Leijen, 2014). Self-directed learning has a long history in adult and higher education literature, ever since Houle initiated research into the field with his seminal work, *the inquiring mind*, in which he took an explorative approach to self-directed learners, identifying them based on whether their community peers readily recognised them as such (Houle, 1961). Two of his students took up the mantle and continued his endeavour, Malcolm Knowles seeking to create a unified theory of how learners became self-directed and Allen Tough applying a very empiric approach more reminiscent of his supervisor. He linked it to general maturity, reasoning that one type of learner, typically children, were malleable and easily motivated by a kind of pure lust for knowledge and accepted the authority of their elders and teachers, another type, typically more mature and older, were motivated by their understanding of the applicability of the things they learned, and was not as easily swayed by traditional authorities (Knowles, 1975, 1980). Allen Tough contributed to the field in several ways, including a new theoretical approach, self-planned learning, and by the empirical results which showed the extensive nature of self-initiated learning projects. The most impactful contribution was, however, the development of learning project research, especially a set of highly structured interview-schemes that he applied to investigate how active adults were in planning and managing their learning projects (Tough, 1967, 1971). The methodology he developed became so widespread and attained such great success in its goal of proving the extent to which adults undertake self-planned learning, that eventually researchers in the field warned that any further iterations should be avoided. They considered the methodology applied in such a vast number of studies that any additional uses would be redundant and that the deductive approach along with its rigid interview structure, might help reproduce misconceptions cemented in the underlying conceptions of the interview scheme, that other new approaches to the field could help dispel (S. Brookfield, 1981; Caffarella & O'Donnell, 1988).

One of the methods of research to supplement Tough's learning project research was statistical instruments designed to measure SDL in different ways (Brockett & Hiemstra, 1991). To this end, several self-reported questionnaires were developed, most successfully the Self-Directed Learning Readiness Scale (SDLRS) and the OCLI. Lucy M. Guglielmino developed the SDLRS for her doctoral dissertation to, as the name suggests, ascertain how ready individuals were for self-directed learning, based on complementary skills, attributes and attitudes that she had identified through a three-round Delphi survey as being related to SDL. The resulting instrument was a 58-item questionnaire, applying a 5-point Likert scale (Guglielmino, 1977).

Another instrument that was developed to measure SDL, though with a slightly different approach than the SDLRS, was the Oddi Continuing Learning Inventory (OCLI), which was created partly as a reaction to some of the criticisms of previous instruments of measurements. Lorys Oddi adopted a new perspective in developing the instrument in that she conceptualised SDL not as an instructional process but rather as a personality trait that determined certain behavioural tendencies characterised by initiative and persistence in learning over time (Oddi, 1984).

The differences between the SDLRS and OCLI reflect a discussion crucial to the researchers of the field at the time of their development. Several authors were critical of the lack of cognitive perspectives on self-directed learning and argued that the focus at the time overemphasised self-management skills (S. Brookfield, 1981; S. D. Brookfield, 1985; Garrison, 1993). Oddi elaborated her approach to SDL, suggesting a distinction between perspectives on SDL as an instructional method and as the development of learner personality characteristics (Oddi, 1987). She proposed that while the SDLRS and Toughs learning project research might be appropriate ways to investigate SDL as a process, illuminating SDL as an aspect of the learners internal development required a greater focus on the development of motivation and psychological facets such as cognition and affective aspects (Oddi, 1987).

Newer understandings have highlighted the same overemphasis on aspects of SDL related to self-management and self-regulation and called for a greater focus on cognitive and motivational aspects (Garrison, 1997). The fact that the relation between motivation and self-direction is strong but unresolved by research has been painstakingly evident since the 70s, and both Guglielmino and Oddi emphasise the connection in their dissertations on the development of the SDLRS and OCLI (Guglielmino, 1977; Oddi, 1984). A recent review of SDL in PBL has also highlighted the role of affective and conative dimensions to the understanding of SDL, and especially in PBL, where intrinsic motivation is emphasised as an essential driver in the learning process is it essential to consider them (Leary et al., 2019).

3 Method

3.1 Description of respondents

The data presented in this article was collected from students in the bell program, an ABET-accredited upper-division engineering program. The students are all pursuing a bachelor of science in engineering degree through a 2.5 year-long program with a heavy focus on practical experience through internships, co-ops, design experiences and self-directed problem-based learning. The data presented in this study was collected from 3 generations of bell program students. Cohort 1 students have completed the bell academy and their first co-op and are just starting their second. Cohort 2 students have completed the bell academy and are just starting their first co-op. Cohort 3 students have just recently enrolled and are starting their bell academy period.

Cohort	Number of respondents	Response rate
1	17	53%
2	30	76%
3	9	78%
Total	56	69%

Table 1. Respondents and response rate.

3.2 Statistical Instruments

Lorys Oddi developed the OCLI to measure the inclination of continuous and adult learners towards self-direction in learning. She reasoned that previously developed instruments had a too large focus on self-management skills and assessed SDL as a process or set of techniques that the students could apply. Therefore, she designed the items of the OCLI to measure attitudes and behaviours theoretically linked to

SDL, instead viewing SDL as a personality trait typically developed as the learner matures and gains a more self-directed disposition (Oddi, 1984).

The OCLI has been extensively validated in many different educational settings and proven mostly stable across cultural contexts (Harvey et al., 2006; Oddi, 1986; Six, 1989; Straka, 1996). While the performance of the instrument has shown a modest degree of explained variance, the complicated nature of SDL goes a long way towards explaining this, and its covariance with other instruments measuring theoretically related constructs speaks to its construct validity (Boyer et al., 2014; Clausen & Hansen, 2021).

3.3 Analysis

In the presentation of preliminary descriptive statistics from our study, we show calculated mean scores for the OCLI total score and subscales for each of the cohorts. All data was collected through a digital platform for survey distribution, SurveyXact and data management and analysis was conducted in SPSS and Stata (IBM Corp., 2017; Statacorp, 2019). The data is presented to give the reader an idea of the type of output this framework could yield and show preliminary trends. We advise readers to be cautious not to attribute these preliminary results too much weight or to take them as evidence of the students' actual development, as the number of respondents is still far too low to produce any valid or statistical significance results. Given the low number of respondents and tempered expectations for the data presented, no statistical significance tests were calculated.

4 Preliminary results

The results from the first round of the data collection have revealed a trend in total-OCLI scores and subscale scores, as shown in table 2. The trend shows that the further along the students are in the bell program, the higher total-score they report. This development is consistent with our expectations that the program seems to foster heightened SDL. Another interesting trend can be seen in the subscales. They reveal that the consistent rise in total score results from a consistent rise in the ability to be self-regulating and a steep rise from the 2^{nd} to the 1^{st} cohort in avidity for learning. We will discuss other possible explanations for the data trends and limitations to the interpretations of these results in the discussion.

	Cohorts		
	3	2	1
OCLI	115.29	117.09	122.44
- Factor 1: Internal locus of control	34.71	33.57	34.11
- Factor 2: The ability to be self-regulating	14.71	15.65	17.22
- factor 3: Avidity for learning	30.00	30.57	33.33

Table 2. Total OCLI-scores and factor scores for all cohorts.

5 Discussion

Assuming that the trends we see in the data are consistently found in our future data collections, they make up an interesting data point in the debate about the connection between PBL and SDL. While the connection has been consistently argued, there have been empirical evidence to both support and oppose the notion and previous applications of the OCLI have yielded contrasting results in PBL settings (Clausen & Kolmos, Forthcoming; Harvey et al., 2003). One difference between the contexts is how and in which field they apply PBL. The contexts that have shown to foster a rise in OCLI scores are both project-oriented approaches inspired by the application most often applied in engineering, while the study which did not find any rise in OCLI scores had applied a case-oriented approach most often applied in medicine (Guerra & Kolmos, 2011).

5.1 Potential of methodological framework

The methodological framework of this study has many advantages. Because of its longitudinal scope it gives the researchers the opportunity of comparing the collective scores of students in a number of ways. The most obvious is of course the development each generation of students go through throughout their education. This level of comparison could illuminate which elements of the education lets students become more self-directed. Given the bell academy's role in preparing the students for continued self-directed learning during their co-ops, one prominent aspect that will be evaluated with this comparison is whether or not the students become more self-directed due to the first semester. On a more general level we would argue that the ability to evaluate students' SDL is becoming increasingly important to engineering education, given the rise in active learning methodologies such as PBL and other project oriented approaches.

Another analytical approach to the data is to compare between generations of students. Any revisions to the program, changes in external conditions, or differences in student intake might also warrant an evaluation of students' SDL development. An example that hits especially close to home for most people right now might be the impact of precautions against and consequences of the Covid-19 pandemic. Having a statistical instrument to help gauge learning outcomes in a period of turmoil such as the one the present generation of students have been through might help assess if any additional scaffolding of their learning might help mitigate such effects. A more typical use of the between-generations comparison might be to assess the impact of changes to their curricula or choices of co-ops.

5.2 Limitations

There are certainly also limitations to the methodological framework that we propose, and one should always make appropriate reservations when attempting to measure anything as complex as an individual's behavioural inclination or attitude towards self-direction.

One consideration that anyone developing a study resembling ours should have in whether or not a selection bias happens as an effect of any potential dropouts. It could be argued that one should assume that students dropping out of a program that requires them to be good at SDL would also be the students least favourable of SDL. On the other hand, an argument that students favourable to SDL would be less afraid of the prospect of dropping out of formal education could also be made. The bias is certainly something which should be and will be examined when more data collections have been completed and longitudinal analysis is possible.

Limitations, potentials, and usefulness must, of course, be evaluated relative to the amount of time required to apply the framework. One could, of course, entertain a discussion about whether or not a given framework achieves its goal of giving insights about a given construct or if it, in fact, only serves to confuse with half-truths. We believe that with adequate reservations, statistical measures and analysis and a transparent presentation of results and methodology, the OCLI and the methodological framework we have presented in this paper promise to give us greater insight into the development of students attitudes and behaviours conducive to SDL.

5.3 Future directions

Three years of half-yearly data collection are planned as of now, with new cohorts joining for every data collection.

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Exploring Blended IC-PBL Model & Strategy for Course Based PBLs in University: Using a Case Study in Engineering Education

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Abstract

The pandemic situation caused by COVID-19 amplifies the volatility, uncertainty, complexity, and ambiguity of society, suggesting that the unpredictability of this will be further maximized in 2021. Each field in society is selecting and executing digital transformations as one of the strategies to flexibly cope with such uncertainty and sudden changes in an environment that requires different lifestyles to lead daily lives. The education field is not an exception and universities are implementing digital transformations that move from face-to-face education that is held in a classroom environment to online learning in the virtual environment. Hanyang University has developed and operated an innovative teaching and learning model called IC-PBL (Industry-Coupled Problem/Project-Based Learning) to flexibly respond to rapid social changes and to cultivate outstanding individuals with capabilities needed in society. IC-PBL, which has been based on the face-to-face classroom environment, is also in the process of digital transformation due to such environmental changes. Previously, in IC-PBL, the online learning environment played an auxiliary role to support learning. However, as the online learning environment has suddenly been highlighted as the main learning environment of IC-PBL, various issues related to the design and operation of PBL classes in actual education fields are being raised. In this study, the results of participation observations, in-depth interviews with instructors and learners were analyzed through qualitative research on 8 classes in Hanyang University's engineering department. As a result, PBL courses strategies, in accordance with 5G, were presented to make PBL classes in blended environments into successful digital transformations. This demonstrates that PBL courses that have been mostly conducted only in face-to-face environments successfully achieved digital transformation in the post COVID-19 era and have presented strategies that can be used in educational attempts and practices necessary to create sustainable performance as a qualified class.

Keywords: Blended PBL, PBL model, PBL strategy, engineering education

Type of contribution: PBL research or PBL review/ conceptual paper/ PBL best practice

1. Introduction

The change of learning space due to the COVID-19 pandemic revealed uncertainty and complexity in the education field. PBL is considered to be an effective learning method to develop problem solving abilities, which is a core competency of the Fourth Industrial Revolution era. However, as the learning activity environment shifted to online formats, the engineering education field has faced challenging difficulties. Learners had to be able to deal with practical and complex problems, perform cooperative learning, and access learning flows to achieve the same results as before in a virtual space.

Recent studies have focused on how online education was implemented in PBL learning activities during COVID-19 (Elzainy, El Sadik, & Al Abdulmonem, 2020). Several studies specifically suggested what experiences and learning outcomes learners in the field of engineering education experienced when they were conducting PBL learning in a virtual environment (Ak., Bugada, Ma, & Wen, 2021). The researchers discussed whether they could conduct online learning experiences of engineering education with a very detailed level of learning strategy, either macroscopic learning principles or vice versa. Qadir and Al-Fuqaha (2020) presented learning principles based on an educational paradigm that could effectively be used in a COVID-19 environment for engineering students, and Barry and Kanematsu (2020) presented actual learning cases using Zoom and gamification. These series of studies provided fragmentary examples and guides to understand how engineering education has progressed in practical learning in virtual spaces.

However, until now, few PBL activation strategies have been presented based on educational models for designing and successfully operating engineering PBL classes in online spaces. Typically, PBL design models and elements of Jonassen (2000) and Hung (2006) have been, importantly, referenced in development and operation based on face-to-face classes, but it has not been confirmed whether they can be applied equally in online spaces. Therefore, it is necessary to identify the implementation strategy of the digital transformation of PBL in engineering education by analyzing successful class cases by dividing them into each element of class design and operation.

The purpose of this study is to draw an activation strategy of the overall class in order for IC-PBL classes to be effectively digitally converted in a blended environment and operated more successfully in a new environment. Especially, IC-PBL operated by Hanyang University is operated mainly by industry-linked problems to develop practical problem-solving competence of engineering learners; therefore, it is appropriate to analyze effective learning models and strategies of PBL in blended environment using both online and offline learning. This study was conducted based on successful cases of Hanyang University's representative engineering classes.

As a result, it is possible to present a successful class plan and operation strategy of digital transformation of PBL education which requires cooperative learning for engineering professors and learners. In addition, by deriving the blended PBL model of engineering area from specific case analysis results in terms of design, development, implementation, evaluation, and environment, this study aims to suggest important implications for instructors and university officials to prepare blended PBL classes and learning environment designs that consider the characteristics of an online environment.

2. PBL Teaching and Learning Model for Development of Practical Problem-Solving Ability

Problem Based Learning (PBL) is a teaching method that allows learners to solve problems similar to actual real situations that they are likely to face outside classrooms through leading and cooperative learning activities (Barrows, 1996). PBL was found to effectively promote motivation, problem solving ability, self-directed learning ability, high-dimensional thinking ability, and the creativity of learners compared to lecture-style classes (Thomas, 2000; Scott, 2014; Jang Kyung Won et al., 2020). Barrows and Mayers (1993) considered that medical students could learn to think and act like doctors in the process of solving an actual situation that they would encounter when they became doctors, not simply memorizing knowledge through classes that were conducted in this way. In other words, learners can develop practical problem-solving competency effectively in the process of performing cooperative learning activities to solve problems through PBL by activating their knowledge based on actual problems in areas where they will demonstrate their expertise in the future.

As PBL is constructed and operated around these actual problems, problem design is considered a key step in the PBL process (Jonassen, 2000; Hung, 2006; Puntambeakar, 2015). Many scholars also emphasized the importance of PBL problems, saying that PBL is the main learning process and result that starts learning from the problem, motivates learning, and solves the problem (Schmidt & Moust, 2000; Weiss, 2003; Jang Kyung Won et al., 2020). Duch (2001) emphasized practicality, inclusiveness and cooperation as the characteristics of PBL problems. In other words, a good PBL problem should be connected to a real world problem to draw the interest and motivation of learners, should be comprehensive enough to require decision making using various facts and information from learners, and it should be complicated enough to require cooperation to solve the problem. In addition, Duch (2001) said that PBL problems should consider the level of learners' prior knowledge and the possibility of challenge, and above all, the learning goals should be included in the problem. In particular, Bennett et al. (2002) emphasized that the practical problem should be more than practicing the theory, and that it is possible to give a personal meaning to the learner or to find a relationship with the experience of the learner. In addition, various studies in Korea have emphasized the practicality of PBL problems, consideration of learner level and experience, and linkage with educational goals (Choi, 2003; Choi, Jeong-Im & Jang, 2015; Jang, Kyung-Won et al., 2020).

Hanyang University has developed a teaching and learning model called IC-PBL that focuses on the problems that are the core of PBL and the practicality of the problems in the education field. IC-PBL which stands for Industry Coupled Problem Based Learning is based on traditional PBL models and emphasizes the relationship between the university and the real world. In order for PBL to be implemented in various major areas, it is necessary to develop the most important problems properly. IC-PBL aims to develop students' ability to solve practical problems while solving social problems by solving real world problems in classes and sharing the results with the real world through the concept of 'Industry-coupled. The IC-PBL model (figure 1) includes four types of classes: field integrated, field evaluation, problem solving, and field problem, according to the characteristics of the problem covered in class for actual practice in the field of education.

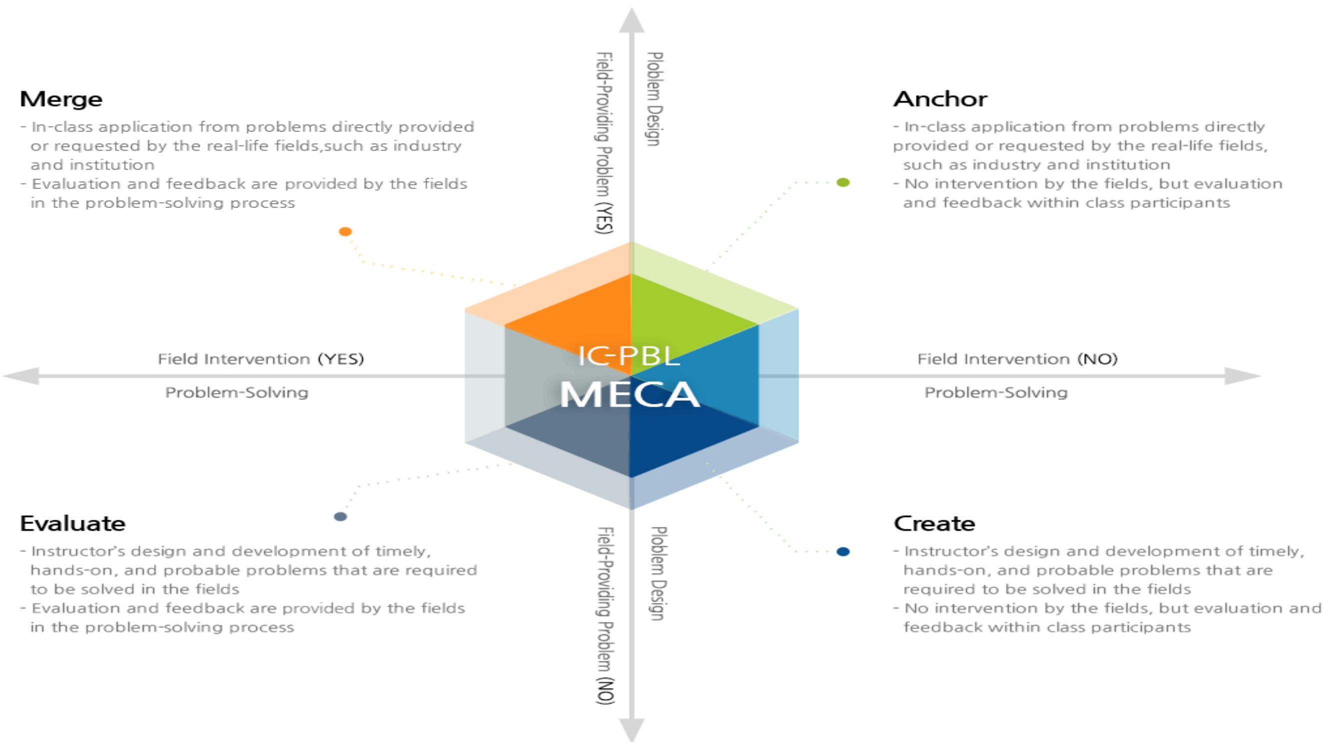

Figure 1: IC-PBL model

This study was designed to find out how the practicality of PBL problem was realized and how learners supported the development of practical problem-solving competency through case study of blended IC-PBL class which utilizes online and offline environment by developing IC-PBL in 2020 and ultimately to derive a blended IC-PBL activation strategy.

The Necessity of Providing a Blended PBL Activation Strategy

Due to the COVID-19 Pandemic, most face-to-face classes at universities, as well as K-12, were converted into remote classes. Since the early 2000s, universities have been using e-learning, blended learning, and flipped learning. However, considering that remote classes are not entirely new forms of classes, the proportion of these types of classes was very low (Kim In-Sook et al., 2020). It is being recognized that the sudden and massive transition to remote education due to COVID-19, is very challenging and confusing, and it is a big challenge for both professors and learners.

In order to proceed with remote classes, an overall change of class is needed (Do Jae-Woo, 2020; Moore & Thompson, 1997). The change at this time should be more than just changing the classroom environment from the classroom to the digital environment, it should be an overall change including the presentation method of educational content, the class operation method, and changes students' learning experiences. According to previous studies, instructors had difficulties in all stages of design, development and operation of online-based classes (Do Jae-Woo, 2020; Han Song-Yi, Lee Ga-Young, 2020), and continuous problems occurred in interactions between instructors and learners (Do Jae-woo, 2020). In order to ensure stable remote classes, it is necessary to search for activation factors and strategies based on the actualities of effectively operated classes (Lim Yi-Rang et al., 2020).

The transition to remote classes has also affected PBL classes that are being operated by universities to develop practical problem-solving capabilities. PBL is a learner-centered learning method and environment in which learners learn through the process of cooperative learning and individual learning and preparing solutions to solve real actual problems. When the whole process of PBL is done in the online space, it is called online PBL, e-PBL, web-based PBL (Malopinsky et al., 2000; Jang Kyung Won & Park Myung Hwa, 2007). In addition, when using face-to-face space and online space together, it is called blended PBL or blended e-PBL (Jang Kyung Won & Park Myung Hwa, 2007). Blended PBL is made by utilizing face-to-face space and online space. Part of the overall learning process is conducted face-to-face, and the rest of the learning process is done online (Graham, 2004). This blended PBL means that it is operated flexibly by using online space in traditional PBL rather than replacing existing PBL or new concept (Smith, 2001; Jang Kyung Won & Park Myung Hwa, 2007). Previous studies suggest that the online environment in PBL can be used in various ways as a problem presentation space, an interaction space between learners and instructors, and a data storage space created during PBL (Orrill, 2000; Sage, 2000; Susan & Min, 2001; Watson, 2003; Chew & Beaumont, 2004; Savin-Baden, 2006). However, in reality, the education field in a university where PBL is mainly operated traditionally through face-to-face classes and an LMS (Learning Management System), which is provided as an online environment, has been used as a sub-space for PBL by instructors or learners only as a minimum requirement. Therefore, as we have seen, it is necessary to convert the online space, which was used only as an auxiliary space, into a blended PBL system that is utilized more effectively and strategically in order to adapt to the environmental change in which the whole university education is converted into remote education. This study aims to explore the strategies for activating blended PBL based on the experience of instructors and students in PBL classes that were developed and operated in a blended form to help instructors easily design, develop and operate PBL classes using an online space, and to promote the development of practical problem-solving competence of learners. The following Figure 2 presents Blended IC-PBL Process and Elements.

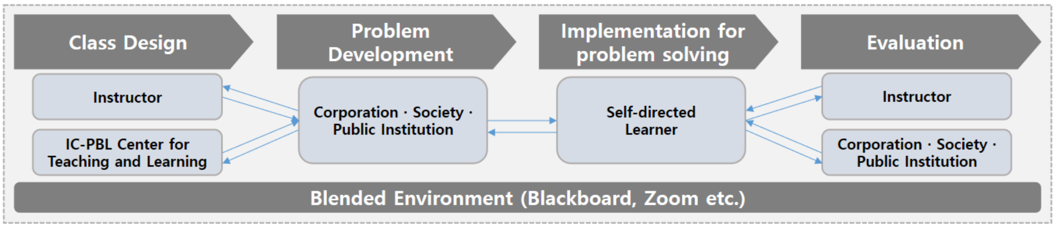

Figure 2: Process & Elements of Blended IC-PBL

3. Research Method

Research Method Selection and Procedure

A case study was carried out to investigate the strategy of activating blended IC-PBL. A case study is a qualitative research method that aims to describe and evaluate specific phenomena by collecting qualitative data through an in-depth observation and analysis of a case (Kim Seok-Woo, 2015). Yin (1994) pointed out that a case study is the empirical inquiry to study current phenomenon within a real life context. This study describes a whole IC-PBL class conducted in a blended environment with a case study method to identify positive factors and obstacle factors and derive activation strategies based on those factors.

Case Selection

Eight engineering college classes consisting of IC-PBL classes in 2020 at Hanyang University were selected as cases for the study. Hanyang University has introduced undergraduate and graduate IC-PBL curriculums since 2018. The professors who were in charge of the eight selected classes of this study have developed and operated at least one IC-PBL class since 2018.

Data Collection and Analysis

The data was collected through class observation, in-depth interviews, and a researcher's reflection journal. The researcher reviewed and examined the whole process from the application process, class openings to the results in the end of class report. The classes were observed more than once to identify actual class activities. After a class observation, the researcher wrote a reflective journal and recorded the actual IC-PBL class operation in a blended environment and its significance. In addition, in-depth interviews were conducted with eight instructors who were in charge of the eight selected classes and 14 students as examples. Semi-structured in-depth interview questionnaires were developed in two versions; teaching and learning methods. The data on IC-PBL class experiences in blended environments were collected through the in-depth interviews.
The collected data were analyzed through three stages: coding, classification, and categorization (Creswell, 2015). The contents of the recorded in-depth interviews were transcribed, and then they were coded in order to find the meaning unit and derive common keywords based on the transcript. Based on the results, the elements which activated the blended IC-PBL class were classified and categorized.
In order to secure the validity of the data analysis results, the study confirmed the relevance of the research method and the research process with three experts who have a Ph.D. in educational engineering or education and have more than three years of work experience in the university teaching and learning center. Based on the opinions of experts, the researcher integrated the classification results and modified the categories.

Table 1: Research Subject and In-depth Interview Participant Information

Affiliation	Name of Subject	Instructor	Student
Engineering	Smart Building Production	Instructor A	Student 1
			Student 2
Engineering	Introduction to Fusion Plasma	Instructor B	Student 3
			Student 4
Engineering	Adventure Design	Instructor C	Student 5
			Student 6
Engineering	Electronics	Instructor D	Student 7
			Student 8
Engineering	High Frequency Medical Device	Instructor E	Student 9
			Student 10
Engineering	Application in Data Analytics	Instructor F	Student 11
			Student 12
Engineering	Industrial Engineering Capstone PBL (Mechanical Learning and Deep Learning Application Study)	Instructor G	Student 13
			Student 14
Engineering	Climate Change and Impact Business	Instructor H	Student 15
			Student 16

4. Research Result

As a result of conducting research to explore strategies to activate blended IC-PBL classes, a total of 10 subcategories were derived, focusing on the total 5 upper categories of class design, development, operation, evaluation, and teaching and learning environment. After confirmation by the expert verification and analysis data, some revisions were finally arranged as follows.

Table 2: Summary of Research Results

Upper category	Subcategory		Activation strategy
Good Design	1	Presenting ways to achieve class goals through blended PBL	Clear presentation of blended PBL based class objectives
	2	Designing blended PBL environment-based learning activity	Designing learning activities considering the characteristics of 'blended' and PBL
Good Development	3	Development of Online Lecture Contents for Blended PBL Activities	Development of online lecture content that is organically linked to actual problem-solving activities
	4	Providing learning resources for blended PBL	Development and connection of learning resources to create customized learning experiences for academic fields in a blended environment
Good Implementation	5	Real world context for developing real problem-solving skills	Providing practical learning experiences and connections between classes and real-world context by presenting problems using field experts and field data
	6	Providing an interaction strategy for real-world problem-solving activities	Providing an environment for actual field, learning content, and interaction with professors to solve practical problems Providing time and space for team building and team-specific interaction for collaborative problem-solving activities
	7	Structuring the Activity of Blended PBL Class Tutor	Structuring and sharing tutor's activities to support learners' learning activities Structuring and sharing of tutor activities to support professors' teaching activities
Good Evaluation	8	Use of various evaluation methods	Utilization and announcement of various evaluation methods for evaluating online learning activities and offline learning activities as a result of personal learning and team problem-solving activities
	9	Fair evaluation for learning activities in blended environment	Presentation of preventing dishonesty strategies when evaluating online Developing and utilizing evaluation methods to prevent free-rider in team activities Ensuring fairness through evaluation of outsiders such as field experts
Good Environment	10	Building Infrastructure for Blended PBL Operations	Building and delivering a reliable and effective infrastructure Establishing and providing individual spaces to easily participate in online learning Creating a quality content production environment

4.1. Good Design

When face-to-face class is converted into remote class using online environment, it is not only adding the use of digital platform and digital media. Therefore, it is necessary to design a class based on blended environment, PBL process and PBL characteristics. The results of this type of class design should be organically linked to the development, execution and evaluation performed by the instructor. Students have decided to take PBL classes after clearly presenting the goals to be achieved through PBL classes, and determining how learning for this purpose would be done in online and offline environments, and what kind of advantages learning activities in each environment would be made.

Design of Learning Activities and Presentation of Teaching Goals through Blended PBL

Even students who are familiar with face-to-face PBL did not have a significant impact on the selection of PBL classes in a blended environment. Rather, students chose to take the course based on the strengths of the PBL class operation method, and decided to take the course by focusing on the strengths of the advantages given to them by learning goals and online environment. In other words, the students selected the blended PBL class according to whether the objective was designed to obtain what they want to obtain through the class by utilizing environmental characteristics.

"Considering the remote situation, real-time and recording lectures were planned appropriately, and outside symposiums, academic conferences, and field specialist lectures that could be linked to the field in a remote manner were arranged to present a weekly plan that would be a more practical experience" (Student 9).

This is related to the result that the role of the instructor for effective remote instruction suggested by Lim Yi-rang et al., (2020) as a course designer, that is, the teaching method of the instructor and the learning method of the learner should be appropriately designed to the learning environment.

4.2. Good Development

Based on the blended PBL class design, it is necessary to develop class contents and materials by also considering online and offline connectivity. Most of the students learned about theory or program in an online environment before entering into a problem solving activity in earnest. The students studied the learning contents about the environment or program which will be used in the theory, background knowledge, and actual problem-solving activities needed for problem solving. These contents were found to be useful for problem solving activities as well as inducing the interest of learners in problem solving activities that will actually be carried out in the future. Especially, providing the program and the environment to be used for actual problem-solving activities was helpful and the learner who can practice it.

Developing online content and providing learner resources considering blended environment

Online contents for blended PBL classes should be organically connected to learner-centered problem-solving activities. Moreover, it is necessary to provide various learning experiences through online lectures by providing various learner resources or developing and providing programming using lab environment or virtual tool kits that will be used for problem solving based on the characteristics of college classes such as engineering.

"The final goal of the class was to effectively implement line tracing under various environmental conditions using LEGO® Mindstorms EV3 according to the necessity of autonomous vehicles. To do this, we needed hardware improvements and programming tailored to the project, and we learned the basis of the programming needed here through the recording lecture. Without the lecture, I would have had difficulty in solving the problem of the project due to difficulties in programming" (Student 4).

Hong Sung-Yeon and Yoo Yeon-Jae (2020) emphasized 'meaningful learning' which is the variable that has the greatest effect on learning performance in both face-to-face and remote educational environments. Meaningful learning involves cognitive activities and should not cause worry about the decrease in learning performance in the remote environment if the learner can utilize the contents learned in the class effectively and adapt to other contexts. Therefore, online contents provided in blended IC-PBL classes should be strategically developed to enable meaningful learning.

4.3. Good Implementation

A blended IC-PBL class is a teaching and learning model that focuses on the development of the practical problem- solving ability of college students. Therefore, it is necessary to provide learners with real world context in the execution of the class and to support learners to implement various interaction and problem-solving activities. In addition, effective use of tutors should be provided to effectively support teaching and learning activities.

Providing real world context

In the case of this IC-PBL class, the real-world context was provided as follows. First, the participation and evaluation session of field experts (company representatives, engineers, researchers, etc.) was conducted. Second, the online work space and simulation tool kit that could be used in the form of problem solving by actual experts in the area were provided. Third, the field data used for practical problem solving and related media data was provided.

"Through special lectures by field experts, participating external conferences, and the sharing of various research materials conducted by professors, I was able to see how my study was applied in real society and I was able to carry out the project considering that" (Student 9).

Promoting interaction in various categories

The problem-solving activities in IC-PBL classes were conducted through various interactions between learners, learners and field experts, learners and instructors. In order to achieve the class objectives, the instructors provided various channels such as real-time video small group meeting rooms using a platform, discussion rooms using SNS (Social Network Service), a bulletin board available 24 hours a day, team data storage, e-mail, etc., as well as providing related environments and programs in advance, and conducted interactions with students.

"On the online video conference system, speakers were able to ask appropriate questions to induce listeners' reactions or participation, and based on that, they were able to actively interact with each other by participating in classes through microphones or chats" (Student 16).

"Each week, we monitored the problem-solving situation, work distributions and progress checking to see if the team members were communicating cooperatively with each other" (Instructor A).

"The private space for each team was used as a communication space for problem solving activities by setting up to enable real-time team programming through the use of Blackboard Collaborate and Google Collaboration" (Instructor F).

The Application of Tutors for Teaching/Learning Activities

Tutors in the blended IC-PBL class, effectively supported both the teaching activities of the instructor and the learning activities of the learner.

"The professor conducts basic classes, and the tutor directly shows how the learning contents are applied in real

situations and helps learners to understand. The questions were presented directly and effectively supported, and various channels were used to receive detailed help" (Student 6)

"We tried to cultivate their problem solving ability through providing appropriate hints and periodic progress checks, so students did not give up problem solving by actively utilizing the class tutor. This method was effective" (Instructor C).

According to the study on effective learning space utilization strategy for blended PBL (Jang Kyung-won & Park Myung-Hwa, 2007), the online space is mainly used as a problem presentation, learner interaction, and interaction space between learner and instructor in blended PBLs. In the blended IC-PBL, real world context was provided effectively based on the online environment, and various channels were used to confirm that various categories of interactions were made for problem solving activities. In addition, it was necessary to structure tutor activities to support learning activities, such as Lee Hye-Jung and Jang Sun-Young (2010)'s study that developed scaffolding guidelines for tutors supporting learners who perform PBL online and determines how to provide them, and when to provide them.

4.4. Good Evaluation

Evaluation is a highly important issue in face-to-face environments. Blended PBL was mostly based on the blending of theory and experiential learning, online learning activities and offline learning activities. For this purpose, learners were required to evaluate learning content and each performance and to evaluate the learning process thoroughly. It was found that the use of various evaluation methods, the free-riders, and the fair evaluation of the degree of participation and effort were emphasized.

<u>A Fair Evaluation of Online and Offline Learning Activities Using Various Evaluation Methods</u>

"The project progress was evaluated by making a video. In addition to class time, all of the activities online and offline for the project were presented, providing sufficient data for fair evaluation" (Student2).

"It was decided that individual evaluation was necessary for the minimum basic knowledge acquisition effort, team result evaluation for teamwork was necessary, and individual activity evaluation was necessary within the team" (Instructor G).

Hong Sung-Yeon and Yoo Yeon-Jae (2020) pointed out that for students with high learning flow, it is necessary to conduct a program that can have a high effect so that students can actively participate and achieve results even in a limited environment. Blended IC-PBL is limited in a remote environment, but it is possible to create learning outcomes that are as good as face-to-face environments if it is presented and implemented together with a fair evaluation strategy as a teaching method that maximizes participation and creates high results.

4.5. Good Environment

Environmental factors are also highly important in face-to-face PBL classes. For example, whether the classroom environment where the instructor and the learner can interact smoothly, whether the data is easy to share, whether various resources are provided for practical problem solving, and whether the environment where the practice and work are possible can affect the problem-solving process and the result of the learner. In the blended environment, IC-PBL classes should be provided with environmental factors in order to proceed smoothly.

"Even if you don't go to school, there should be an environment where you can use the software to solve problems" (Instructor F).

"Basically, the platform of the school is well-established, but there are various free platforms and each of their

characteristics is different, so I hope that they provide guides about these things" (Student 10).
Kim In-sook et al. (2020) emphasized that basic infrastructure for remote class operation is needed through research and especially stable remote educational environments such as spatial requirements and a content production environment should be provided. As a result, the strategies to active blended IC-PBL classes are presented as shown in Figure 3.

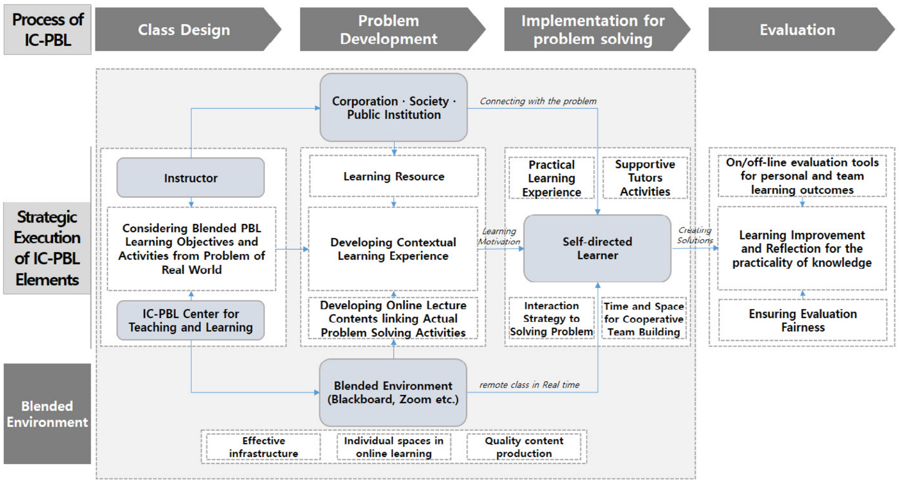

Figure 3: Implementation of Blended IC-PBL

5. Conclusion

This study derived strategies for activating IC-PBL classes in the areas of class design, development, execution, evaluation, and environment based on the actual experience of the instructors and students who developed and operated blended IC-PBL. First, it is necessary to design the class to suit the blended-based PBL aims and how this goal can be achieved. To develop the practical problem-solving capability that PBL is aiming for, theoretical learning and learner-centered learning should be arranged, the class environment design based on considering the characteristics of online and offline learning environment, and the learning activity design should be done, and a blueprint for the entire blended IC-PBL class should be presented.
Second, based on the previous design, online content development should be built considering the association with learner-centered problem-solving activities. Since it is not a face-to-face situation, it is necessary to develop content considering effective content and connectivity with problem solving activities in future online situations, not to produce and distribute content, and to develop and provide materials for learners to connect to various learner sources by utilizing connectivity and accessibility, not to be restricted by the online environment.
Third, when the problem-solving activity is actually implemented, the instructor needs to provide learners with real world context to induce the interest of learners and to induce the flow through the leading problem solving activity. In addition, the environment and structure should be designed so that various categories of interaction can be achieved, and activities such as questions, quizzes, and presentations that can lead to learners' participation should be strategically utilized. Especially, since learners can work together as a team without ever facing each other, it is necessary to prepare small group team meetings frequently in the early stage or to provide a foundation for understanding each other through a learning style diagnosis in order to carry out a cooperative learning based on smooth communication, mutual accountability and consideration. In addition, it is necessary to provide appropriate support for teaching and learning activities through structure of tutor

activities that can utilize tutors efficiently and effectively. Fourth, regarding the evaluation, learners expected that every single one of their activities would be evaluated, and unfaithful learners should be evaluated accordingly. Therefore, it is necessary to evaluate various layers of learning activities using various tools in relation to the structure of blended IC-PBL, and to make fair evaluation activities through evaluation of field experts and peer evaluations. Finally, it is necessary to create an environment where all these activities can be carried out smoothly, which includes infrastructure construction, providing space for learners who perform various learning activities, and creating an environment where teachers can develop high quality content.

Although various studies have already been conducted on blended PBL, web-based PBL, and e-PBL considering the characteristics of the online environment, there is a widespread perception that PBL will be effective and possible when it is conducted face-to-face in a university education environment. Through this study, it was confirmed that although the blended PBL was performed without sufficient recognition of the advantages of online-based learning, and both the instructor and the learner were involuntarily prepared with sufficient preparation due to COVID-19 Pandemic, they were establishing the next plan for better classes in various trial and error and reflection processes. If the factors such as instructors, learners, media, and environment are organically connected in remote environments, educational effects and achievements as much as from face-to-face classes could be achieved (Hannum, 2001; Khan, 2001; Symth, 2005). The activity of grasping the actualities of various types of education derived through digital transformation already in the field of education and presenting activation strategy based on it, can provide meaningful information to an instructor planning a PBL class in a future blended environment. In the future, it will be necessary to establish a blended IC-PBL teaching and learning support system by conducting an implementation guide for blended IC-PBL classes, exploring effective learning space utilization plans, and developing tutor education content.

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Application of a data-driven design-thinking approach to an industry-coupled problem-based learning course: The case of LG Electronics-Hanyang University in Korea

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Abstract

Prior studies have highlighted the importance of adopting problem-based learning methods in online technical courses and engaging learners in problem-based learning tasks. However, it is difficult to design and apply problem-based learning courses in collaborations between universities and industry. Therefore, the purpose of this paper is to introduce the IC-PBL (Industry-Coupled Problem-Based Learning) method, which aims to help learners actively solve real business problems that are then evaluated by firms. This paper reports the best practice of an exploratory case study of an online IC-PBL course conducted with a global-leading home appliance company (LG Electronics) in Korea. The procedure of IC-PBL proceeds as follows. First, the corporate leader and mentors present the specific problem facing the company and provide the class with relevant internal and external data. In this case, the problem was the development of a new smart home service employing a design-thinking approach and using data analytics. In the class, learners gained relevant knowledge in creative thinking, the design-thinking process, and some technical skills such as web-crawling, python programming, and text mining. Integrating IC-PBL into the technical online course with a design-thinking approach made the course more collaborative, creative, and efficient. Moreover, with the participation of mentors from the company, learners were able to actively determine what to learn and how to apply it to business problems by maintaining a close relationship with the mentors. This study suggests key strategies for the application of IC-PBL in blended technical courses and concludes with a discussion of how design-thinking approaches could be applied to PBL courses.

Keywords: PBL, IC-PBL, Data-driven Design Thinking

Type of contribution: PBL best practice

1 Introduction

Problem-Based Learning (PBL) has been highlighted as a learning strategy that can provide learners with skills that are suitable for society and professionalism while maintaining the essence of education (Choi, 2007). Through PBL, learners not only gain academic knowledge but also develop skills that have recently become important in the labor market, such as problem-solving skills, self-directed learning skills, and advanced thinking skills (Kim, 2001; Lee, 2014).

Design thinking has emerged as a method for creatively solving human-centered problems. It is a field-based education methodology that has been applied effectively in various areas such as business, engineering, education, art, and society (Dunne & Martin, 2006). Previous research has emphasized that design thinking is a useful methodology across several business activities, including in the development of new products and services, from the customer's point of view beyond the theoretical approach (Brown, 2009).

As design thinking is an exploration process used to discover creative solutions, investigating the object and defining the problem is critical for generating worthy ideas at an early stage. In particular, converging the collected data and interpreting it in the defining stage is important and requires significant effort (Social Innovation Lab, 2015). Systemic analysis and scientific methods are essential for scrupulous observation to empathize with social issues and reveal fundamental problems. However, existing design-thinking methodologies are often not properly utilized in the data analysis process (Park & Oh, 2017).

Therefore, this research presents a case study that applied a new framework called data-driven design thinking, which can derive creative ideas and make up for the shortcomings of the qualitative approach. We have applied a scenario-based education strategy called IC-PBL (Industry-Coupled PBL) that can help learners understand and solve practical problems aligned with enterprise. In addition to the traditional design-thinking process, technical lessons on methods like keyword analysis, trend analysis, topic modelling, and text mining were conducted to supplement the shortcomings of the qualitative analysis. Moreover, the design-thinking approach is often considered to be effective only in a face-to-face format to derive meaning from data analytics and foster deep interactions between team members. Nevertheless, this case study offers several implications because, although courses involving design-thinking processes and technical tutorials are traditionally considered to be effective only in traditional face-to-face education, this course was conducted online.

2 Literature Review

2.1 IC-PBL

PBL was first proposed in the early 1970s at McMaster Medical School in Canada. Since then, Barrows (1996) established and developed a theory of PBL for medical students in the US. PBL classes present real-life problems, tasks, and issues instead of direct knowledge through lectures, and learners engage in self-directed learning to solve the problems, actively participating in the problem-solving process mutually and cooperatively with their peers (Barrows & Howard, 1985).

IC-PBL is a type of PBL used in Hanyang University's education framework that allows learners to solve problems that occur in the field through connections between industry, the community, and the university led by University President Kim Woo Seung (Hanyang University IC-PBL Center, 2020). IC-PBL is an advanced method of PBL in which education scenarios are developed from actual cases through the alignment between industry and the learning needs of the students.

This framework is a teaching-learning model that effectively promotes problem-solving abilities, one of the core competencies of creative education. In addition, this educational model extends the scope of knowledge acquisition and can be implemented in the industrial field beyond the classroom setting. Table 1 shows different types of IC-PBL. Hanyang University currently offers these four types of IC-PBL classes in its undergraduate and graduate schools. Each semester, there are an average of 300 such courses in the University's undergraduate schools and 100 courses in its graduate schools.

Table 1 : Types of IC-PBL

Type	Contents
Merge	Project on solving actual industrial problems that have been received from an enterprise or local society and evaluation of the outcome by field officials
Evaluate	Project on the problem by instructors and evaluation of the outcome by field officials
Create	Project on the problem developed by instructors and evaluation of the outcome by instructors
Anchor	Project on solving actual industrial problems that have been received from an enterprise or local society and evaluation of the outcome by instructors

2.2 Design-thinking Approach

Design thinking refers to a process of problem solving that uses designers' unique sensitivity and methods (Brown, 2008). It is a systematic and collaborative method used to identify and creatively solve problems (Luchs et al., 2015) and involves taking an abductive approach and using an empathetic attitude to find hidden user needs and then explore opportunities to solve them (Follett, 2016).

Design thinking is a framework that can aid in the conception of unique ways to approach problems outside of normal business boundaries. It provides a lens to identify and understand the user-specific goals. Design thinking has three important principles: first, it is a human-centered methodology. The design-thinking approach does not see users as a group of people with similar demographic characteristics but as humans with their own unique thoughts and emotions. Second, it is important to generate creative and intuitive ideas in design thinking. The method emphasizes creative intuition rather than logical analysis. Third, design thinking emphasizes rapid failure as a source of learning. Design-thinking methodology does not seek a perfect solution from the beginning. In this approach, it is important to experience failure quickly and learn from numerous small failures to create a more complete solution that can solve users' problems.

Companies that use business thinking typically first employ political, economic, social, and technological (PEST) analysis techniques used in strategic management to predict changes in the environment in the market and create a business strategy by interviewing industry experts. In the design-thinking approach, it is important to identify and address needs by gaining deep insight into people to provide new experiences to customers and eventually bring innovation. In an era in which customer needs are rapidly changing, the design-thinking approach is effective to carry out business strategies, considering various factors such as balanced thinking, visualizing ideas, and providing specific experience.

Since there are many cases in which design thinking has yielded successful solutions for the real-world problems of enterprises and local communities, various educational institutions are providing design-thinking education. One of the most well-known design-thinking frameworks is the model of D.school at Stanford University in the US. D.school's design-thinking process is characterized by a method in which learners with various majors and experience voluntarily select topics of interest, recruit members, and present alternatives through collaboration. This procedure consists of five steps: empathizing, problem definition, coastal policy design, prototype development, and evaluation (Stanford d. School, 2010).

3 Case Study

3.1 Context

The case was conducted among thirty students at Hanyang University, a four-year university in Seoul, Korea. The students were majoring in three subjects: big data, industrial engineering, and business administration. This IC-PBL class, which was called "Field Data-driven Service Design Strategy," lasted fifteen weeks in the spring semester of 2020. It was a major subject conducted in cooperation with a large domestic home appliance company that was introducing a smart home application service. This was a "Merge"-type class to maximize the effectiveness of PBL. In this type of class, a company or community proposes problems at the actual site and the students attempt to solve them; after the class, the field officials evaluate the results of the students' work. As a result, the final learning objective was set to derive smart home application improvements through the design of a prototype using the Python programming language based on consumer demand analysis.

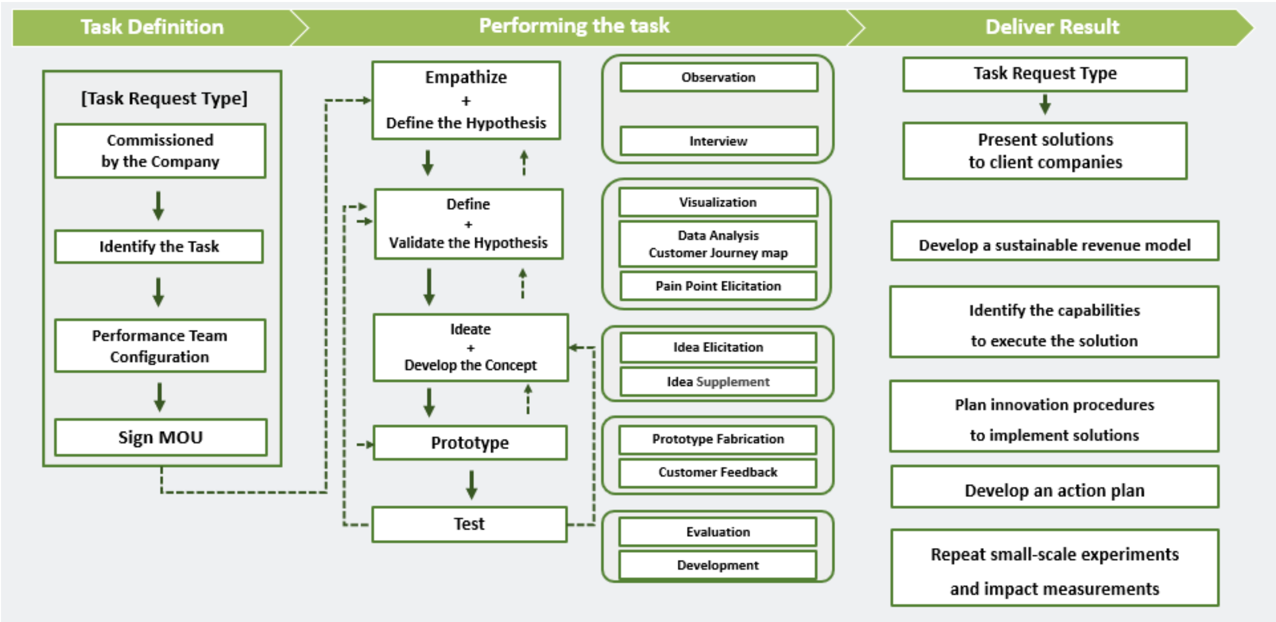

Figure 1: Course process as a research model

Figure 1 shows the course process as a research model. Before applying the design-thinking method to the class, LG Electronics practitioners and instructors discussed and presented the scenario to the learners. The company specifically defined the problem at the beginning of the class. An MOU (Memorandum of Understanding) was then signed between the enterprise and the school, and the class development team was formed. The lecture was designed by combining the design-thinking process and the PBL class model, and data analysis technology was introduced during the hypothesis verification phase so that ideas could be derived in a more logical manner. The derived results were presented to the headquarters of the company, and the outstanding results were linked to joint patent applications, enterprise internships, and linked projects.

3.2 Class Design Framework

We designed the class content by combining traditional design-thinking methodologies and the PBL learning model of Barrow and Myers (1996). The first step in PBL, the problem presentation phase, aims to capture the most important characteristics of PBL, and the instructor should present or guide complex and unstructured problems in the following scenarios.

> *"LG Electronics has started to install Wi-Fi sensors in all the home appliances it has produced since the last year for its smart home business, and has been preparing customers' new lifestyles and probability strategies through smart home services. However, customers often do not install or*

delete ThinQ apps that must be installed for smart home services. Therefore, it is difficult to determine how to develop smart home services in the future. It is necessary to analyze the reasons why customers do not use this technology, and the problems encountered in the use of the ThinQ app, identifying customers' needs to establish a new service scenario strategy for the ThinQ app in the future. Learners should segment smart home customers, establish hypotheses through empathic processes such as observing, experiencing, and interviewing their personas, perform app usage review crawling, and app usage log data analysis to validate the hypotheses and present new service improvement strategies."

In the problem planning phase, which is an important step in PBL class, learners are required to plan to solve the problem. At this stage, learners are typically asked to identify what they know, what they need to know, and present hypothetical solutions. In this class, data analysis technology allowed learners to make hypotheses and continuously conduct activities to verify data through a re-exploration process on a circular basis.

The class also included an autonomous learning stage that allows learners to identify and acquire the knowledge and information they need to solve the problem on their own and share the results through small group activities online. Learners were encouraged to use online collaboration tools and team-specific discussion boards on LMS to explore or share the knowledge and information they learned with their team members and utilize this knowledge to find solutions to solve problems. The instructor monitored online activities and evaluated the students' participation.

Each team presented solutions in various ways, and in the organization and evaluation phase, based on the results presented by each team, inter-team evaluation, team member evaluation, and self-evaluations were carried out, and organizing activities were conducted in the wrap-up session.

3.3 Class Process

This class focused on design-thinking procedures to analyze the cases of home appliance companies that introduced smart home application services and derive implications and strategies for improving such services. During the design-thinking process, ideas for smart home application service improvement strategies were developed by combining app review data analysis, trend analysis, persona, and social listening analysis. Next, the justification of the idea was reviewed by adding a prior study review and expert feedback. There were six teams of five people in the first week, and from the second week, the smart home application service improvement strategy was designed to be developed for fifteen weeks according to the design-thinking process.

First, through interviews and observations, learners identified the personas using smart home applications and what is important for them. Since interviewing is a qualitative method for collecting customers' opinions, and can provide a deep understanding of their context, it is widely used to reflect the persona's pain points in the empathy phase of design thinking (Mohaddam & Moballeghi, 2008; Stanford D. School, 2010). In addition to collecting customers' opinions, learners visited the Signature Showroom, where LG established a smart home environment for promotional purposes, with the practitioners to understand their product planning intentions.

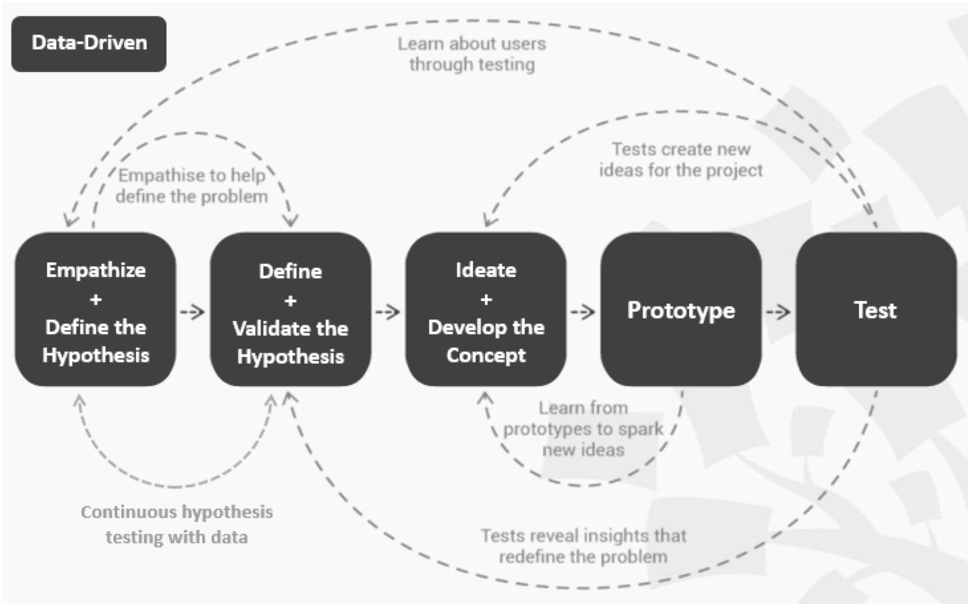

Figure 2: Design-thinking process research model used in the class

Figure 2 visualizes the design-thinking process research model used in the class. The specific processes identified in Figure 2 are shown in Table 2. To help learners understand the data-driven design-thinking method, special lectures were presented by design-thinking experts, and social listening data analysis classes were held. On the one hand, the students learned about the differences and strength of the design-thinking process through the special lecture. On the other hand, they learned how to use trend analysis tools provided by leading portal sites such as Naver, Goolge, and Daum, and how to use text mining. Learning both design thinking and social listening allows learners to derive ideas from the customer's point of view.

Table 2: The Specific Class Process (Class topic)

Week	Class Topic	Detail	Data-driven design thinking
1	Class introduction (weekly class schedule, learning objectives), introduction of professors, formation of teams	Team-specific meetings and introductions Icebreaking – Team assignment – Team mindset and goals. Present learner's capabilities	Scenario presentation and motivation
2	Smart Home Service Planning in the Phonosapiens Era	The Design of Smart Home Services in the Phonosapiens Era: What is home?	Individual activities
3	Big data analysis	Using Naver Data Lab, Google Trends, and Social Metrics, Finding Business Insights through SNS Search Word Analysis for Smart Homes	Problem analysis using data analytics
4	Data-based design-thinking process	Design-Thinking Approaches Activity by team – Problem Definition First Step – Setting Up Persona (Facts, Goals, Pains, Behavior)	
5	Business & service direction in the Fourth Industrial Revolution	Digital transformation from manufacturing to service	
6	Visit LG Signature Showroom	On-site knowledge acquisition for the empathy process – Field Survey of Smart Home Service Exhibition Hall, Customer interview and observation, Expert mentoring	
7	User review collection and problem identification through customer response data collection	Google Play app review data analysis - Acquire web crawling tools and skills	

8	Special lecture from design-thinking specialists	Special lecture from design-thinking specialists	
9	"Think Big on their Behalf" – Problem definition and system thinking	Create and share Customer Journey Map systems thinking – pain points, concerns	Problem definition phase with data evidence
10	What is the most important customer benefit? - Concept development	Problem definition – Concept board materialization Output –Press release, FAQ Group ACTIVITY: DISCUSS & MERGE Ideas- What happens if the assumption is wrong?	
11	Mid Presentation (Problem definition)	Q&A and feedback from working mentors ALP enables teams to organize and share their needs and deficiencies	Solution development phase
12	Derive and share solution ideas – Concept iteration	Share and give feedback on solution ideas through discussions by each team	
13	Final Idea Selection	Final selection of solution ideas through discussions with each team	
14	Create prototypes and reflect customer and feedback	Prototyping – Visual fabrication or mobile app prototyping	Prototype development
15	Final announcement and prototype demonstration	Final announcement and prototype demonstration	
16	Share results and suggestions for future classes	Share results and suggestions for future classes	Evaluation

In the problem definition phase, students classified and visualized personas based on the information derived from the empathy phase and defined their features. Those features were then visualized through customer journey maps. Customer journey maps are tools that show the customer's whole process of experience and their moods at each experience phase (Stickdorn, 2011). The customer journey map was used in this case because it is useful to define and visualize the locations at which customers experience pain points.

In the solution phase, learners ideated the services according to each persona's needs and pain points, and those ideas were then improved with the domain expert's feedback. All six teams developed ideas on smart home service improvement strategies and conducted presentations based on the lessons they had drawn from ten weeks of empathizing and problem defining. To share ideas and provide expert feedback in a practical direction, all presentations were shared with all learners, instructors, and practitioners through online video conferences using an Learning Management System (LMS) system. After the prototype development process that was conducted considering the literature and expected effects, learners were asked to present the steps of their evaluation phase and they received a final assessment from the instructors and practitioners.

Another unique aspect of this course is that the whole process was conducted online. Knowledge-based lectures, which aim to deliver objective knowledge such as text mining techniques and social listening skills, were conducted using recorded lectures, to make it easier for students to review content. However, communicating lectures, which aimed to share ideas or feedback, were conducted in real time online to enable immediate communication. All lectures were conducted using the Blackboard system, an online lecture system of Hanyang University. Using the system, the instructor created a team discussion room that allowed learners to have online meetings, upload related materials, and add comments to other team members' posts (see Figure 3).

Figure 3: Blackboard system used for online meetings and lectures

4 Findings

In this research, we conducted a case study with the class and adopted design-thinking methodology in the data-driven service strategy development process. The performance of the class was assessed from the perspective of learners, the professor, and the company based on the students' lecture evaluation and mentors' feedback during the wrap-up session.

Learners were given the opportunity to address complex and unstructured problems that exist in real-world corporate sites. Through the combined format of PBL and design thinking, learners were able to improve their problem-solving skills, such as their team collaboration skills and data analytics capabilities. Second, this course encouraged learners to actively and voluntarily solve problems. Since the class was conducted in a manner that encouraged students to solve problems in a two-sided direction instead of receiving knowledge in one-sided direction, the class allowed learners to participate in collaborative teamwork and share information with each other. As a result, various practical solutions were derived in the classroom, thus reducing the issue of knowledge learned in school tending to differ from the actual field.

In this class, the instructor acted as a guide and facilitator to help learners learn, providing equal and interesting learning opportunities for all learners instead of teaching them directly. Because the class was composed of learners from various majors, it was able to derive a creative combined perspective, and the instructor's role in managing their different interests was essential to deliver consistent results. As a result, the majority of learners felt satisfied with the class regardless of their major, and selected the class as the best of 549 IC-PBL courses at Hanyang University in 2020. The final score for the course evaluation was 96/100(A+), and the detailed score for each evaluation question is depicted in Table 4. The enterprise was able to obtain a new perspective in defining customer pain points and deriving solutions. Second, the active participation of mentors from the company in the course was found to be important. Learners were able to experience real-time problems encountered by the enterprise, which they could not have learned at school. In other words, coupling industry with PBL (IC-PBL) was effective in reducing the gap between theoretical knowledge and practical applications. Third, the enterprise saw this combined course as an opportunity to view problems and derive new solutions with learners. Although the learners' solutions may not be immediately viable, the enterprise assessed that there were many suggestions that were likely to be realistic with some improvements. Figures 4 and 5 visualize prototype samples made by the learners.

Figure 4: Prototype Sample

Figure 5: Prototype sample

Table 4: Evaluation Questions

No.	Evaluation Questions	Average
1	The professor specifically guided the IC-PBL classes and their methods.	4.7
2	The professor tried to promote students' IC-PBL activities.	4.7
3	The professor's feedback helped solve the problem.	4.73
4	As a team member, I was able to understand the importance of teamwork.	4.7
5	IC-PBL team activities helped me understand the learning content.	4.7
6	The professor presented objective evaluation criteria for IC-PBL classes.	4.77
7	The problem-solving process and results of IC-PBL activities were evaluated fairly.	4.67
8	My self-directed learning skills were improved through IC-PBL classes.	4.73
9	It seems that the contents I learned in the IC-PBL class can be applied to actual problems.	4.73
10	My motivation for learning improved through taking the IC-PBL class.	4.67
11	I actively participated in all IC-PBL activities (team activities, problem solving).	4.77

5 Conclusion

This research started from an interest in competency education, which is gaining attention for its ability to foster future talents. This study validates the effectiveness of IC-PBL as an alternative teaching method that has become increasingly relevant following the Fourth Industrial Revolution and university education innovation. Moreover, the study examined the use of a teaching method that combines design-thinking methodology and IC-PBL into a data-driven service strategy derivation process while conducting university education online.

All participants were satisfied with the class configurations employing IC-PBL. Combining PBL and design thinking allowed learners to solve practical problems without engaging in external activities such as internships or private projects. Instructors were given a new role that could not be replaced, and enterprises were able to view problems and ideate solutions from different perspectives. In addition, IC-PBL has positive educational effects in that it encourages active teamwork, knowledge application, and problem solving.

This class structure also supplements existing design-thinking methods. As a qualitative method, design thinking has the disadvantage of relying heavily on individual subjectivity in the derivation of results. However, combining data-driven strategies with design-thinking methods allows learners to find a quantitative basis to derive more objective and clear solutions. Moreover, data-driven design thinking fosters cooperation between business students, who are familiar with constructing business strategies, and engineering students, who are specialized in analyzing data. Through this cooperation, IC-PBL can yield interdisciplinary human resources and train them in collaborating with people from other fields.

However, this study has several limitations. First, it is a meaningful case to suggest directions for diversifying university education, but it is difficult to generalize a single case. Future studies may suggest further cases that apply IC-PBL in different fields, subjects, and contexts. Second, the measurement of educational performance in design-thinking-based classes is still at an early stage. Therefore, efforts to discover and verify more effective details will constantly be required.

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Sustainability, Creativity and Interdisciplinarity in PBL

Expin48 in the Pandemic: How did Students Rebuild their Learning Network?

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Abstract

The development of a project can be regarded as a learning network. Students can interact with each other and interact with teachers from different areas and experts outside the school. Also, students interact with devices, software, and tools. Such means can be considered as components of a learning network where the knowledge is shared along. Expin48 is an event which promotes the development of short-term projects with 48h that includes students from technical high school, undergraduate courses, and graduate schools in CEFET/RJ, a center of technology education sited in Rio de Janeiro, Brazil. In the 2019 edition, the authors studied the learning network developed by the students during the in-person event. However, during the 2020 pandemic, it was necessary to develop an online edition. What are the differences between the learning networks built by students when comparing these two editions? A new research was done in the 2020 digital edition through 3 stages: observation of student's interactions, application of a questionnaire and a focus group to discuss the experience. Some elements from network theory were applied to discuss results and understand those teams as socio-technical networks. In general, the pattern of the collection of information was maintained. Few differences were observed in the role of mentors and the use of the YouTube platform, due to the reduction of the prototyping stage of solutions.

Keywords: Learning Networks, Hackathons, Innovation, PBL in pandemic, Collaboration

Type of contribution: PBL research

1. Introduction: PBL and Short-term projects

Recently several creative industries have been using hackathons as a strategy to create new products. It is a particularly important strategy to promote new ideas, new markets and to identify future possible players in a consolidated market. Hackathons are agile projects developed in a short period of time. All the stages to develop a project are necessary, however, there is a time constraint, which is a characteristic of the new creative industry, based on competition fast obsolescence of products and useful amidst crises situations. Short-term projects can provide solutions to address critical problems, such as, the vaccine development amidst a pandemic.

In the event, students experience working with such kind of problem-solving projects which is also a challenge for educators. Educational hackathons have been practiced worldwide and it has been a new challenge for educators. The fundamentals of PBL philosophy can supply consistent support to these platforms. PBL enables students to use prior problems experienced from their environment background to stimulate their creativity and provide direction to the construction of autonomous learning skills through project development (Graaf & Kolmos, 2007) (Bender, 2014) (Kokotsaky *et al*., 2016).

According to methodology, the teachers do not propose the specific problems which need to be addressed in the event. Broad themes are proposed based on the student's environment background and presented to them. Students are encouraged to observe the reality of their communities and bring specific problems related to the broad theme. Freire (1996) calls this stage of the learning process "reality reading". In the following step, students are arranged in groups to research for *ad hoc* information to solve the specific problem. The teacher becomes a mentor providing advise without offering solutions. Consequently, students realize what they need to learn in order to find a solution which addresses the specific problem through collaborative knowledge sharing and structuring. Given the assumption that the solution to big problems starts on a small scale, prototyped in neighborhoods and communities. Hence, the idea of holding similar events in schools where students will have the opportunity to develop socio-emotional, technological, and entrepreneurship skills.

2. Knowledge Networks in Short-term PBL

The development of a project can accomplish through the assistance of a learning network. Students can interact with each other and interact with teachers from different areas and experts outside the school. Also, students interact with devices, software and other tools which are active elements. During the process of a student interacting with a tool in the lab, a learning experience is expected. The more interactions take place, more knowledge can be acquired and shared.

During a project, knowledge is shared among students through several interactions. A good project is one where knowledge shared freely.

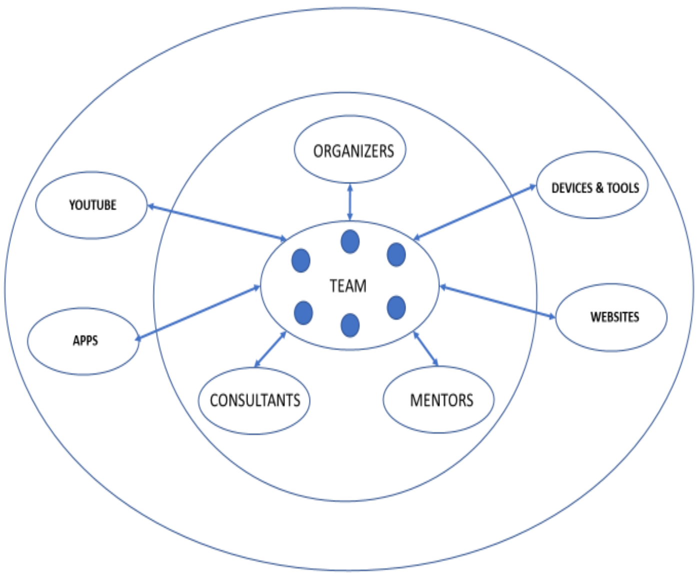


Figure 1. The project network with human and non-human actors

A knowledge network is made of several actors, human and non-humans, (Latour,1988) (Callon,1986) where it is possible to obtain information which feeds the project.

The first one allows dialogue in person, with teammates, mentors, consultants, lab technicians, and organizers, as shown in figure 1. The second includes apps, software, websites, devices, tools, from which it is possible to consult information, Newspaper's websites, TV networks, etc. This knowledge network is linked with the team and provides the project with information (Braga & Schettini, 2019) (Braga & Guttmann, 2019).

In all kinds of projects, we can think about the work using a network with layers of interactions. The first one is among the students. The second one is between students and mentors, consultants, and organizers. The last one is between students and non-human actors.

3. EXPIN48 (Experience in Projects of Innovation – 48 hours)

Expin48 is an educational hackathon developed by the CEFET/RJ Centre of Technological Education of Rio de Janeiro (Brazil). This institution has three levels of formation in 8 campuses spread for the State of Rio de Janeiro: Technological High School (THS), Engineering undergraduate courses, and graduate schools. The EXPIN48 is an event that gathers students from all levels working together to solve technological problems, majority linked with the city's life. It is an opportunity to experience the development of a project that focuses on innovation. After a period of application, there is an evaluation where 36 participants are selected (dividing proportionally the students in the three levels of education and promoting diversity).

The activities began a week before the event where the broad themes are presented to the participants.

These themes are linked to the sustainability of urban life in big cities or small communities. Students have a week to study those themes and chose at least 3 options. Some examples of large themes are 1) Floods and Landslides. 2) Tropical Urban Epidemics (Dengue, Chikungunya, Zika). 3) Urban Mobility. 4) Life of Seniors. 5) Production of Renewable Energy. 6) Waste Management. 7) Production of Foods in Big Cities. 8) Sanitation in poor communities.

At the first moment of the event students have to form their team taking in consideration that each team has to work with a different theme. These students form their group based on the broad theme they have interest. They are asked to form teams of only 6 members and to have at least one student from each level (High school, Undergraduate, or graduate). This process demand negotiation and flexibility on choosing and can induce diversity.

The event has 4 stages: a) Interaction - Students selected themes and interact with each other forming teams; b) Design - The team should define a problem and present three possible solutions for mentors who have the mission to help them to choose the best solution; c) Prototyping - The team develops a prototype for the chosen solution; d) Presentation - The team should prepare three kinds of presentations for the judges: video ("Elevator Pitch" in 90 seconds), White paper (brief technical description), and conference presentation (10 + 5 minutes).

At the end of each stage, there are meetings with mentors where all teams participate checking the project's status (Cooper,2008). It is a meeting where all teams present and discuss their projects.

On the meeting that takes place after the design stage, all teams should present three specific problems, its requirements and the 3 proposed solutions for each problem. Afterward, they must choose which problem/ solution will be carried out in a funnel system (Clark & Wheelwright, 1992). In the following meetings, they only check with the mentors the status of the project.

The mentors are professors from CEFET-RJ with Ph.D. or MSc specialized in project management or entrepreneurship who help the students with project development during the process. They all know that it is not allowed to propose solutions. The dialogue aims to offer options and questions about the economic, energetic, and environmental feasibility of the projects in order to shape realistic solution outcomes.

The students rely on the support of their advisors specialized in several subjects from CEFET-RJ and other universities and research institutions that can be called provide some consulting. These experts do not participate directly in the event, only if they are needed, they will be consulted. They provide support with specific information related to their profession.

A board of 6 reviewers from the industry and universities at the final presentation to choose the best project, the best presentation, and the best innovation.

4. EXPIN48 in two editions (2019 and 2020).

In 2019 the event took place in person at CEFET Maracanã Campus headquarter where only students from this campus participated. It occupied 3 project rooms, mechanics and electronics laboratories and a room for presentations which was used by the 6 teams. Mentors could walk around the project rooms talking to students during the process. In the laboratories, there were always technicians available to assist with equipment. A group of consultants were available in case their assistance was needed.

In 2020, the event organizers faced a great problem. Due to the Covid-19 pandemic, schools and universities were closed on March 16th. Then the schools and universities started to discuss the solution for remote activities. As CEFET/RJ was already using the Microsoft Teams platform for meetings and for classes too. The institution has a large number of students who live in less economically privileged communities. Also, there was no data about those students' internet access. Remote academic activities could discriminate some of the students due to their economic conditions at home. The decision was to return slowly in October making the monitoring of access and trying to supply those with problems of access with modem devices. However, it was noted that only a few students had internet access restrictions.

The organizers of Expin48 start to work in June with two options: in-person event and remote event. The second option would need the creation of a new event. The first step was to study the platform to find out solutions for teams' rooms, the participation of mentors and consultants. After that, due to the impossibility of using the labs in the prototyping, it was important to figure out how students could work together and develop prototypes out of labs, even though participating from home. At labs, most pieces that they use in the projects come from reusable materials considered as disposables for the industry or individuals. Now there was the possibility to develop digital prototypes, a new tool that they could learn to use. But in short term projects this is a quick stage.

The platform selected was Microsoft Teams®. In this platform, it is possible to create several rooms for interaction among the students in each team and special rooms for presentation and organizers meeting.

The mentors could visit the teams. The organizers asked students to avoid using another platform for exchange information between themselves. In Brazil, WhatsApp® is widely used among young people. It is considered very friendly platform by students and the creation of a group on that platform would be very natural for them.

The positive aspect was the possibility of students from several campuses could join the event and work together using the Microsoft Teams®. Also, the fact that there were mentors from each campus.

5. Research Problem

Many issues can be raised when we compare these 2 experiences. We decided to divide the issues into groups. In this work, we will deal with only the learning network. What were the differences between the 2019 and 2020 editions in terms of building the learning network? What were the student's strategies created to rebuild their learning network in the 2020 online edition? What were the sources of information more relevant where they gathered data to develop the project (2020)? Do they keep the same sources? If not, what did change?

6. Methods and Instruments

The data was collected through the triangulation of different methodologies.

a) The researchers participated as observers during the activities, taking notes of their impressions in the logbook.

The event was a short-time project but an intensive experience for 48h. The first methodology of research was ethnography that has base on the observation of interactions among the actors (Callon,1986) (Latour,1992) (Geertz,1973). The traditional ethnography is based on the insertion of the researchers in the community to be studied making observations and getting field notes. In recent times the ethnography absorbed new approaches with the use of video recording (Goldman-Segall, 1993) (Jordan & Henderson1994) (Derry *et al*., 2010). In this research we used both data collection methods.

In 2019, the researchers were in the same space with the teams watching the discussions among the teammates, their movements, and the interaction among teams. The teams created groups on WhatsApp in order to communicate among themselves between the environments (labs and the design room), as well as, for the period out of college to interact in the evening exchanging ideas about their project. With team's agreement, the researchers were added to those groups. The researchers stayed in silence all the time only observing the exchange of information. The movements were recorded by cameras installed in the design rooms. These movements allowed understanding the interaction using network analysis tools.

In 2020, the researchers stayed all time in virtual rooms. With camera turned off and microphone on mute, it was possible to observe the discussions taking place between students and mentors. Through MS Teams it was possible to notice information exchange through the chat records. The researchers recorded all the activities with prior authorization from students. Most of the work time, students kept their cameras turned off.

b) Students answered an open-ended questionnaire after the event.

For both years 2019 and 2020, students were sent a questionnaire through Microsoft Forms after the event. The questions were built to understand how was their experience at each stage of Expin48. In 2019 the event had 36 students shared in 6 teams. However, in 2020 only 16 students divided into 4 teams participated. There were 2 students, from the previse participated in the two seasons.

19 responses (53%) were received from the 2019 participants, and 13 (81%) from 2020.

The responses were compared and discussed by the researchers.

c) Researchers promoted one focus group with the students that participated in 2019 and 2020 events to discuss the process of work.

Students were invited by the researchers for the interview with the excuse that we need to know what should be improved in the next EXPIN48.

The focus group was developed by the internet during the pandemic period. The analysis of results was made through the transcription of the students' speeches and its analysis of content.

7. Data Analysis

Since the event took place online, several aspects were new to us. We chose to analyze three aspects that we had doubts about success when using the online model. We divided the analysis into three levels:

7.1 The first level: collaboration between students

The first source of information comes from the collaboration between students, between teammates and between teams. In collaborative work, the teammates exchange information all the time. However, in the case of EXPIN48, it would be natural to think that the difference between academic levels would generate a significant discrepancy between teammates. The students have different approaches in their formation. Those from THS have a training closer of practice while the undergraduate and graduate dominate theoretical models more sophisticated. In this sense, in problems that demand solutions more concretes, the THS students have advantages over their colleagues. Also, most THS students living in less privileged communities of the city and have contact with specific problems of their neighborhoods. Consequently, students have complementarity in terms of knowledge. They realized that fact at the first moment of discussions and used it to their benefit.

When they were asked about differences in academic levels this, for 74% the academic level difference was excellent, 21% thought it was good, and only 5% state that is regular.

Despite competing, the teams were encouraged to collaborate. However, this did not happen very often. Most of the teams have kept closed in their problems. However, in 2019. there was a small collaboration because students had other teams working physically close. The few interactions took place in the prototyping stage. The answers about the reasons for their interactions and demands for information with other teams, the students answered.

a) 47% interacted with other teams asking for help because they did not know how to make something.

b) 16% changed their ideas after looking at other’s team work.

c) One student justified as a curiosity.

d) 25% of the students said did not interact with other teams because they did not find themselves welcome by other teams. Based on the field observation, the interpretation of researchers for this attitude is due more to a concentration on their own work than to a position of deliberate avoidance promoted by competition.

In 2020, there was a lower level of exchange between the teams. The platform closes them in digital rooms. Different from the 2019 event there was no going around as they did at the moments of distractions it happened on 2020 event.

7.2 The second level: the mentors

Generally, mentors visit teams in their room to talk about the project. At the end of the event in 2019, many teams requested organizers to use fewer mentors and fewer visits. They argued that there were several contradictions in orientation from mentors and many explanations to give during the work due to frequent visits. For 2020, the organizers reduced the number of mentors and created a new category called consultants. The consultants stayed off during the event, but they could be activated by the team to give information about their expertise, only in case of needs. The event had 5 mentors and 17 consultants (engineering, sciences, sustainability, social and human sciences, arts).

When consulted about the most important factor for the success of the project, they responded as shown in figure 2.

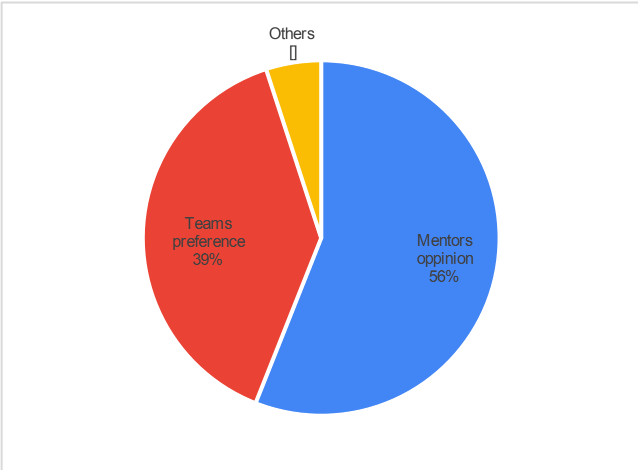
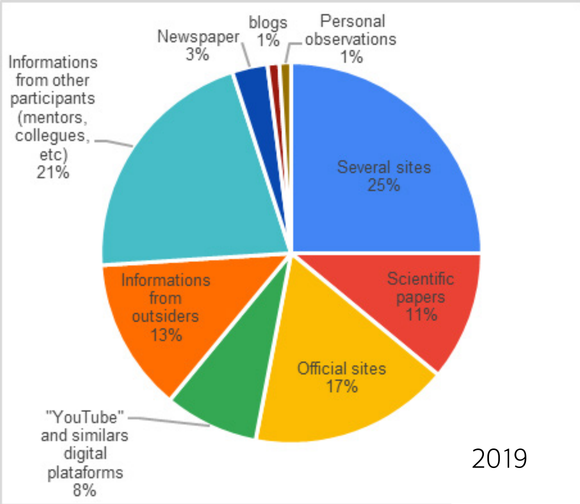


Figure 2: Factors that influenced the development of the project.

At different times, they allowed students to realize that some proposed solutions were not feasible from an economic, environmental, energetic point of view or even in terms of time constraints. Students recognized this as a significant contribution.

7.3 The Third Level: Internet

When we make a comparison between the two graphics of sources of information (2019-2020), it is possible to realize that there was a pattern. The sources were almost the same. Students used different sites on the internet to search for information. However, if we add up all the digital sources cited (different sites, official sites, YouTube-type digital platforms, blogs, and newspapers), we reached 66% of the search preference in 2019 and 72% in 2020. This increment was 6%. It is can be explained by the virtual platform. In 2019, the students had the internet on their smartphones and only one desktop available for consults. The remote experience has allowed complete access, while the number of accesses has been larger than in 2019, the distribution was similar, as shown in figure 3.



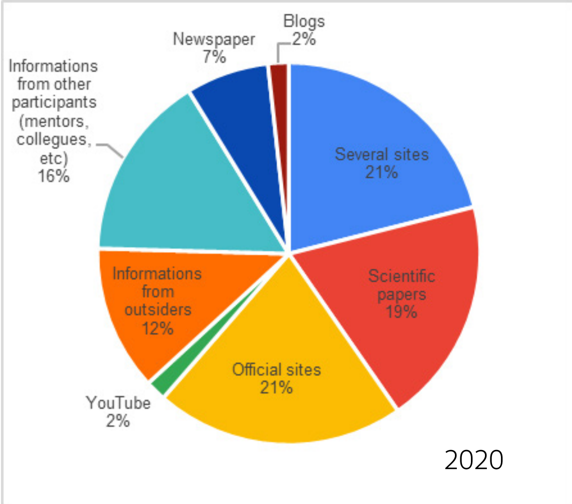


Figure 3: Most important internet sources of information in two editions.

YouTube has seen a considerable decline in queries. This fact can be justified by prototyping being restricted to the digital level. Generally, videos of similar cases are sought so that one can learn "how to do this?" Most of the project development was spent designing the artifacts or processes digitally and simulating their operation. Even knowing that there can be the need for consults in channels specialized for the design and simulating, in most cases they try operating the software using trial-and-error approach.

8. Conclusions

The remote edition blocked the flows of information between teams. In-person editions allowed an informal flow of information. When students go to the restroom or stand up to get a cup of coffee with cookies in the coffee shop, they look around and see other teams working. Many times, this observation is an informal exchange of information. It is possible to get new ideas or have a conversation with some colleagues. This exchange is part of the learning network. In remote edition, this kind of network was impossible. The only moment that students can know the other projects is in the status review with mentors when all teams are together. But this moment is the last minute to prepare the presentation of their team. All attention is concentrated on this goal.

Mentoring as a source of information did not have considerable changes. The platform kept access to rooms where the teams were working. The mentors followed the process of providing orientation for the projects. This part of the learning network did not change.

The information captured from the internet kept the same pattern as the in-person edition. As all process was done remotely, it was not possible to measure the accesses to the information. In 2019, students could use their smartphones with only one desktop for the team's research. This means while one uses the others have to wait. In remote mode, many of them had other options at home.

The remote edition allowed the work of students from several campuses in different cities works together. The model thought to be implanted in 2021 would be several teams working from different campuses with a project and showing the results at the end through the internet for all other teams. The edition of 2020 allowed another model, with students from several campuses working together on the same project. The organizers will take in consideration what can be extracted from this experience and applied in the 2021 edition. The learning network became more diverse in the 2020 model.

The pandemic brought for the PBL model of education new challenges. In all cases, it is necessary to incorporate the lessons learned into traditional practices understanding the limitations of the current tools applied in order to improve them.

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Development of the Characteristics of an Entrepreneurial University based on the PBL Strategy: The case of Interdisciplinary Projects Workshop

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Abstract

The entrepreneurial university must promote entrepreneurship education, which is directly linked to problem-based learning (PBL). Entrepreneurial university accumulates and highlights the learning achievements during its education and research activities, and applies them to knowledge transfer, consulting and entrepreneurship, this is the third mission of the university. To achieve the scaling process of entrepreneurship it is necessary from the university two key actors participation, they are the industry and the government, and then it is necessary to facilitate the relationship between them to configure what is known as the triple helix: collaboration between the university, industry and government. The curricular course Interdisciplinary Projects Workshop (TPI by its acronym in Spanish, hereinafter TPI), uses problem-based learning to work with the triple helix generating solutions to problems through innovation and entrepreneurship projects, which also creates regional and national development. TPI is a strategy based on PBL to contribute to the entrepreneurial university consolidation.

Keywords: entrepreneurial university, third mission, triple helix, entrepreneurial education

Type of contribution: PBL research

1 Introduction

Entrepreneurial universities seek to support the creation of a society where knowledge and innovation drive economic growth, job creation and increased competitiveness in global markets (Audretsch, 2009), this set of effects is known as the "third mission" of universities (Philpott, Dooley, O'Reilly & Lupton, 2011).

The entrepreneurial university can achieve the third mission by directing training and research towards entrepreneurship; focusing simultaneously on fulfilling teaching, research and entrepreneurship activities, for these reason it has the ability to innovate, recognize and create opportunities, work in teams, take risks and respond to challenges (Kirby, 2005), it then becomes a natural incubator that provides support structures for academics and students to initiate new intellectual projects (Etzkowitz, 2013).

With culture and entrepreneurship education in place at the university, and with research process oriented towards the creation of value-added products and services, can be started the scaling phase of entrepreneurship at the university; It is there where the entrepreneurial university facilitates the interaction of internal actors with the outside, to achieve collaboration between universities, companies and the state according to the "triple helix model" (Etzkowitz & Leydesdorff, 2000), to find exits for their products or services, this is done by knowledge transfer offices, consulting and entrepreneurship programs.

This document first shows the important concepts of "entrepreneurial university", "the third mission" and the "triple helix", and relates them to entrepreneurship education and to the PBL methodology as a fundamental aspect of all the above described. It also shows the structure and statistics of the course TPI and its education practices based on PBL, to develop an entrepreneurial culture at the university, creating products and services (Mian, 2014) with companies and government entities to solve real problems.

TPI uses PBL to consolidate the entrepreneurial university and contribute to achieve the third mission, this is because PBL is relevant for entrepreneurship education programs as it creates a learning environment that allows students to tackle real entrepreneurship problems (Wee, 2004). Additionally, the adoption of PBL by different higher education programs goes along with the inclusion of some of the key principles of learning: learning as a constructive process, learning as a self-directed process, and learning as a contextual process (Moust, Berkel & Schmidt, 2005). Entrepreneurship education emphasizes the development of key competences such as opportunity identification; social, business and industry-specific competences; and entrepreneurial self-efficacy (Lans, Blok & Wesselink 2014).

The entrepreneurial university and the third mission

The entrepreneurial university plays an important role as an organization that produces and disseminates knowledge. Guerrero et al. (2011) and Kirby et al. (2011) mention that an entrepreneurial university is defined as an organization adaptable to competitive environments, with a common strategy aimed at being the best in all its activities (having good finances, selecting good students and professors, producing high-quality research). In this way, it is more productive in establishing links between education and research.

Recent studies have shown that the determinants of entrepreneurial activity in universities are marked by three main factors: 1) individual factors of the students themselves, 2) the entrepreneurial climate in the university and 3) the regional context (Bergmann, Hundt & Sternberg, 2014). The third mission of the universities, according to Campos and Fernández (2007) should consider three fundamental actions: 1) promote knowledge transfer process to creates innovation, 2) promote R&D training to technical managers and scientists (science and technology) who are induced to be agents of innovation in the context, and 3) promote the scientific and innovation culture required by the knowledge society.

The triple helix model

It is a model resulting from the evolutionary economics and chaos theory, it is the best alternative to improve the innovation conditions, it is a model with a nuance of public service to promote social change by universities (Messana, 2015). In this way Philpott et al. (2011) defines the entrepreneurial university as one that develop its role inside of the triple helix, contributing to regional and national development.

For Gómez and Rodríguez (2020), triple helix model emphasizes the interaction that occurs in university, industry and government, as a key to promoting innovation, it focuses on the analysis of relationships and interrelationships between their actors. Within triple helix, the university's role is to develop knowledge (Canales & Encisio, 2012), promote economic growth and generate changes for sustainable development (González de la Fe, 2002), and use knowledge to create new businesses (Dzisah & Etzkowitz, 2008).

2 The Problem-based learning Model and Entrepreneurship

PBL is increasingly integrated in the teaching of sustainability and entrepreneurship. An argument for this integration is that education in both fields is increasingly training students to be agents of change, to be able to work in teams, and to produce relevant knowledge in context (Rivas, Bonzanini & Amaral, 2020). The adoption of PBL by higher education programs takes the principles of learning as a constructive process, learning as a self-directed process, and learning as a contextual process (Moust et al., 2005).

First, constructive process is introduced as a stimulus for learning, thus learning is implemented through discussion, note taking and answering questions. Second, learning as a self-directed process stimulates the student's prior knowledge and help them to engage in the sense-making process with their peers. In order to solve a given problem, students need to plan, monitor, and evaluate their own learning, and learning is therefore self-directed. Lastly, learning as a contextual process, a PBL setting provides context by integrating previous knowledge as a benchmark to measure learning goals and by building a social framework in which students collaborate and share common goals or responsibilities.

Programs that share these design characteristics tend to have a strong focus on the learner's experience, students who take responsibility for their own learning, a close relationship between theory and practice, interdisciplinarity, a strong focus on the learning process, instructors who act as facilitators rather than experts, and students who are capable of self-assessment (Savin-Baden & Major 2004; Dochy, Segers, Van den Bossche & Gijbels, 2003). PBL has also been discussed in the literature of entrepreneurship education, and in this way, it shifts the conceptualization of entrepreneurship. Entrepreneurship is commonly understood as the process of starting an organization from scratch (Wee & Lynda, 2004). At this perspective, researchers have argued that entrepreneurship education should train students with competences to recognize opportunities others have overlooked (San Tan & Frank Ng, 2006).

Regarding entrepreneurship education, it is increasingly relevant to fulfilling a set of objectives to develop skills to adapt to the change and learn in an ever-changing context. This is achieved through a pedagogy where the learning is partly carried out in collaboration with stakeholders beyond the classroom and through learning by doing, which manifests in internships and new ventures developed during entrepreneurship courses (San Tan et al., 2006). In entrepreneurship programs, including those that use PBL as a learning approach, problems are structured with the aim of giving students greater freedom to self-direct their knowledge development. Similarly, problems are authentic, this intensifies learner's inspiration to search for knowledge gaps. Students are thus in close contact with businesses and their problems (Rossano et al. 2016).

3 The Interdisciplinary Projects Workshop (TPI)

It is a course of the Faculty of Engineering of the National University of Colombia in Bogotá, is one of the largest number of students and the greatest interdisciplinarity, the semester average is 315 students from 11 different professional careers. TPI wants to achieve: a teamwork learning and a collaborative and supportive spirit based on interdisciplinarity; The development of strategic thinking and other higher mental abilities; The development of soft skills; The development of the ability to propose and develop solutions to problems from an ethical and sustainable perspective; The promotion of an entrepreneurial and innovative culture. To achieve the above there is a TPI Route with 4 Phases as follows:

Ambientation or Setting Phase (3 weeks): The rules are proposed and work teams organized, key issues such as teamwork, negotiation, communication, interdisciplinarity, sustainability and ethics in projects are discussed. The students become familiar with the chosen problem, they select their experts and begins to “falling in love with the problem”. Teams choose their project problem, 30% of the teams chose problems proposed by students, and 70% chose problems by external partners: companies and organizations.

Inspiration Phase (4 weeks): The work starts on the problem contextualization, antecedents, environment, problematic situation and actors are identified. The state of the art and the expert’s opinion are sought. It is expected to have alternative solutions with interdisciplinary work, with strategic analysis and practicing soft skills, communication and negotiation, and the entrepreneurial and innovative approach.

Formulation Phase (6 weeks): Analytical methodologies are used to choose the best solution, taking into account the chosen project modalities: research, entrepreneurship, consulting, and innovation. Technical, legal, organizational, market, risk, environmental and financial studies are carried out; objectives, indicators, deliverables and schedules are defined. Prototypes are made to validate the technological concept and laboratory tests; technological maturity level 5 (TRL 5) is expected.

Presentation Phase (2 weeks): It uses communication, argumentation and synthesis skills to "sell the solution", pitches are made containing design and engineering resources, and strategic, functional and operational arguments. In this phase the TPI + EXPOIDEAS Fair is held, project pitches are presented to 60 external evaluators and the 10 finalists to a jury. Eight other University courses using PBL participates.

Integration with the triple helix is done with internal and external alliances. Internal allies are: InnovaTE Technology-Based Entrepreneurship Program, engineering laboratories, VIVELAB Bogotá Laboratory, PE Electric Project Student Group, ANEIAP Student Group, Faculty of Medicine (Physiotherapy), School of Industrial Design and School of Graphic Design, Industrial Design Laboratory, Peace Laboratory, UN Innova, Knowledge Transfer Unit, and Entrepreneurship Acceleration Program Méntor.

The external allies are: Oracle Innovation Lab, Oracle Academy, Google, Fondo Emprender, Tecnoparque SENA, Compensar Caja de Compensación Familiar, Colsanitas Medicina, Bogotá Chamber of Commerce, Colombian Air Force, Fedepanela, Colombian Aeronautical Industry Corporation CIAC, SOMEC Cooperative.

3.1 TPI statistics

The most representative statistics are presented below. The components of the course: interdisciplinarity and integration with the triple helix, can be highlighted.

Table 1: Components of the TPI Course by Period

TPI Components			
Component	Detail	2020-I	2020-II
Students	Engineering	320	310
	Industrial Design	7	7
Teachers	Engineering	16	16
	Industrial Design	2	2
Coordinator Group	Monitors	6	6
	Teachers	1	2
Projects	Total Projects	64	61

	External Projects	24	16
Juries	External	65	50
	Final Presentation	7	7
Allies	Internal	12	13
	External	12	12
	External Evaluators	75	80

Source: TPI 2020 Annual Report

The following is the distribution of the project modalities according to the student's choice. The table shows a decrease in research project modality, and there is an increase in consulting projects, this can be explained because of the growing interest in working with external allies.

Table 2: Project Modality per Year

Project Modality TPI 2019 vs. 2020				
2019	10%	29%	13%	48%
2020	3%	29%	33%	35%
	Research	Entrepreneurship	Consulting	Innovation

Source: TPI 2020 Annual Report

Below you can see the most relevant deliverables and its qualification: infographic, pitch, prototypes, and also teamwork is evaluated. The evaluation is carried out based on rubrics designed based on PBL.
Infographic: It is a tool for the synthesis of the problem, it shows the relationship of the actors and factors that make up the problem situation and is the starting point for problem-based learning. Inspiration Phase.

Table 3: Evaluation Criteria and Qualifications of Infographic by Period

Infographic Evaluation			
Criteria	2019-II	2020-I	2020-II
Problem	3,44	4,35	3,25
ODS	3,56	4,25	3,1
Background	3,36	4	3,35
Context	3,18	4,2	3,35
Actos and Stakeholders	3,21	4,2	3,31
Possible Solutions	3,54	4,2	2,91
Bibliography	3,68	4,2	3,35
Texts and Images Presentation	3,58	4,2	3,58
Infographic Oral Presentation	3,88	4,3	3,71
Average	3,52	4,25	3,31

Source: TPI 2020 Annual Report

The minimum passing grade is 3.0, on a 0 to 5 scale, the average grade is 3.69. In 2020-II there is a decrease in the rating, from 4.25 to 3.31, this is explained by the mobilization and relationship difficulties generated by the confinement due to the pandemic in 2020.

Pitch: It is a short executive presentation with visual aids. It is carried out in the Presentation Phase, in the semifinal contest to external evaluators, in the final contest and in TPI + EXPOIDEAS Fair in front of the juries. The best qualified evaluation criteria: Current Needs, the Description of the Problem or Problematic, the Description of the Beneficiary and the Proposed Solution, aspects on which PBL emphasizes.

Table 4: Evaluation Criteria and Qualifications of the Pitch by Period

Pitch Evaluation			
Criteria	2019-II	2020-I	2020-II
Problem or Problematic	3,73	4,2	3,89
Beneficiary Description	3,48	3,95	3,62
Solution Proposed	3,48	3,97	3,39
Aspects of Viability	3,04	3,58	3,18
Interdisciplinary work			3,4
Actual Needs	3,14	3,87	3,39
General Presentation	4,07	4,42	3,91
Average	3,49	3,99	3,54

Source: TPI 2020 Annual Report

Prototype: In the Presentation Phase, the prototypes are exposed. The evaluation is carried out by teachers and by external juries. The average grade of prototypes is 3.79, and there is a decrease in last period, this can be explained by new forms of work imposed by the virtual environments forced by the pandemic.

Table 5: Evaluation Criteria and Qualifications of the Prototype by Period

Prototype Evaluation and Qualification Criteria			
Criteria	2019-II	2020-I	2020-II
Relationship to the Problem	3,69	4,37	3,94
Progress in its Construction	3,79	4,06	3,36
Materials	3,75	3,81	3,43
Knowledge	3,73	4,09	3,76
Executive Summary	3,64		3,64
Prototype		3,95	
Interdisciplinarity			3,44
Average	3,71	4,06	3,6

Source: TPI 2020 Annual Report

Teamwork: This evaluation is carried out among students, assesses teamwork skills among members. Students care about maintaining open communication, continuous collaboration and establishing agreements to develop the projects and fulfill commitments.

Table 6: Evaluation Criteria and Qualifications of Teamwork by Period

Teamwork Evaluation and Qualification Criteria			
Criteria	2019-II	2020-I	2020-II
Student to Student	4,13	4,41	4,51
Group to Student	4,13	4,7	4,7
Group to Group	4,13	4,6	4,6
Average	4,13	4,6	4,6

Source: TPI 2020 Annual Report

4. Course Evaluation

The evaluation is carried out with two instruments: The first one is the evaluation of the Multiple Offer Perception given by the allies, and the second one is the Perception of the Course applied at the end of the semester. Both instruments have shown reliability and statistical validity during the last four semesters.

The Thematic Conferences and the Multiple Offer (talks, conferences and workshops) are evaluated. In total the amounts were: 21, 30 and 28 for 2019, 2020-I and 2020-II respectively. Conferences that encourage professional development and project construction have a high rate.

Table 7: Acceptance Rate of Conferences by Period

Conference Acceptance Index				
Ethics Talk		82,4	79,8	95,3%
Multiple Offer	78,3	85,5	89,3	90,2
Prototyping Alternatives			88,1	64
Soft skills		89,8	90,7	90
Laboratories			86,1	86,1
How to make a good pitch	91	89,4	96,2	95
Period	2019-I	2019-II	2020-I	2020-II

Source: TPI 2020 Annual Report

Multiple Offer develops specific topics, soft skills and design are always well qualified, this is explained by the dynamism of speakers, and by the value that students find working in interdisciplinary environments.

Table 8: Acceptance Rate of Multiple Offer by Period

Multiple Offer Acceptance Index				
Marketing			92,3	93,3
Design Thinking	90	87,4	88,3	88,8
Entrepreneurship	82,5	87,5	92,4	87,4
Knowledge Economy	72,1	85,5	92,4	92,5
Soft Skills		96,6	95,1	93,8
Technology and Society	68,7	70,8	75,6	85,3
Period	2019-I	2019-II	2020-I	2020-II

Source: TPI 2020 Annual Report

To finalize the statistics, below the global assessment of the course, taking into account all the above, the students have the following perception:

Table 9: Global Assessment of the Course

Global Valuation				
Evaluated Factor	2019-I	2019-II	2020-I	2020-II
Methodology	68%	64%	72%	74%
Teaching Performance	79%	76%	76%	83%
Impact for Professional Development	58%	54%	65%	79%
Impact for the Development of Entrepreneurial and Innovative Capacities	54%	56%	63%	72%

Development of Interdisciplinarity	75%	71%	75%	97%
Average	70,5%	66,25%	71,75%	82,5%

Source: TPI 2020 Annual Report

Global assessment of TPI has improved, this is explained by the greater interaction with the triple helix, and because using virtual technologies that make communication between mentors and students more agile.

5 Discussion and Conclusions

Each activity developed by the student in TPI is designed to improve the entrepreneurial spirit and become students able to get roles that allow them to promote their ventures after finishing the course.

Triple helix student's interaction outside the university increases the interest of students, likewise the entrepreneurial spirit is more easily developed, as well as communication skills and other soft skills.

TPI allows student to establish roles to prototype and develop their projects, with direct contacts to companies, society and government in order to solve problems, all this transforms the student's mentality.

The course structure, the PBL project-based learning, and the way of the course evaluation encourage the development of teamwork and interdisciplinarity among students. The basis of design thinking and PMI methodology in projects allows students to face real problems and help them growing in their professional and personal education.

The development of the course TPI over the years has allowed the adoption of PBL practices for the consolidation of the entrepreneurial university with the triple helix support. TPI's overall findings and results have created a learning environment that allows students to tackle real entrepreneurship problems as Wee said (2004), and has enabled work on key principles of learning: learning as a constructive process, learning as a self-directed process, and learning as a contextual process as Moust, Berkel and Schmidt (2005) have identified in higher education programs with PBL practices.

Based on the results and conclusions of TPI mentioned above, we observed coincidences according with Bergmann, Hundt & Sternberg (2014), about the entrepreneurial university that identifies: individual factors of the students themselves, the entrepreneurial climate in the university and the regional context. In addition, as Campos y Fernandez (2007) indicates, it can also be identified tree fundamental actions which are: promote knowledge transfer process to creates innovation, promote R&D training to technical managers and scientists, and promote the scientific and innovation culture required by the knowledge society, the above are the reasons that shows that the Interdisciplinary Projects Workshop it is very valuable for Engineering Faculty of the National University of Colombia, it induced the students to be agents of innovation in the context.

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A Case Study for Project Work Effects in Creativity

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Abstract

Idea generation is one of the main aspects of problem-solving in the engineering design task. Notably, during the early stages, when students formulate the problem and proposing its solution, creativity is required. This article reports the incidence of PBL on the fluency, flexibility, usability, and originality of the ideas of a group of students in an introductory engineering course within a university with a PBL-based curriculum. That group of 47 first-semester students answered a creativity questionnaire, after which they were trained in project-work and idea management as part of the regular course program. At the end of the semester, the same questionnaire was applied to paired answers to analyse the variation in creativity. The results showed a significant increase in the fluency $t(17)=5.17$, $p=.004$, flexibility $t(17)=4.33$, $p=.01$ and usability $t(17)=3.33, p=.01$ of the ideas, but without any significative variation in the originality aspect of ideas $t(17)=1.83, p=.2$. Consequently, the research discusses potential recommendations for the curriculum.

Keywords: Problem-based learning, Creativity, Design, problem-solving, CEDA

Type of contribution: PBL research

1 Introduction

Creativity is one of the competencies currently required for professional engineering work. Its simplest definition involves idea generation. The ideas are not just simple expressions, and they should be helpful, connected to a statement or solution of a problem. The engineering problem at all stages involves proposing alternatives, methods, and possible solutions. This process also demands choices, with cases where it requires innovation from them.

Creativity also involves several concepts. Some believe that creativity is cognitive, linked directly to individuals' minds, while some believe that creativity develops in the human being; therefore, it is a human competence (Runco, 2014). Thus, creativity can be learned and included among the transversal competencies that the learning outcomes should have.

In his definition of creativity, Rhodes (1961) categorized four development areas: person, process, product, and press. The former involves neuropsychological aspects, just as learning happens. The process consists of functions leading to an individual to be creative like transversal competence does. The product consists of the material or immaterial result of the creative process mediated by the person who in education is the learning outcome; finally, the press is the environment making active or passive pressure for this to happen, that is, the format of educational practice.

This study addresses how educational practice fosters creative development in individuals with PBL, which has ingredients to promote creativity. Reports show that characteristic of PBL, but most of them use learning outcomes or performances as support. However, this study introduces some factors to understand what kind of activities make it works.

The study evaluated four aspects of the creative process: fluency, flexibility, originality, and utility. The results will discuss from the point of view of the PBL learning principles from an institutional model.

2 Problem-based Learning

The PBL at Aalborg University began in 1974. Throughout its history, it has demonstrated efficacy supported by five original learning principles, (1) real, (2) Self-directed learning, (3) interdisciplinary, (4) exemplarity, and (5) solved in groups. These principles are grounded in Illeris learning ideas (Kolmos & De Graaff, 2015; Servant, 2016). Applying these principles uses various teaching strategies that determine the course format for the defined pedagogical approach.

Illeris argues that learning occurs with three dimensions, content, incentive, and social. In the content dimension, persons learn from the knowledge of something or about something. In the incentive, individuals will spend energy to move towards learning, or towards social aspects.

The PBL learning principles linked to Illeris learning dimensions can show the course format in several areas. That allows seeing how intensive a learning practice is regards an intellectual learning belief. That is, localization links an intentional or not pedagogy from a curriculum (Rodríguez-Mesa, 2018). Figure 1 shows the learning principles in the Aalborg model linked to the Illeris triangle.

The four vertices of the triangle indicate extreme points for learning acquisition and an underlying theory so that some cognitive or psychological mechanism operates from the approach they address. For example, the theories of Piaget, Kolb and Bruner address mechanisms based on acquisition through mental schemata, experience or problem-solving focused on individual activity with some degree of social interaction. This social interaction has a greater emphasis on Vygotsky's sociocultural theory. Meanwhile, Team learning introduces cooperative and cooperative learning approaches, which constitutes an elaborate aspect of Vygotsky's theory for projects. In PBL student-centred learning, the mental incentive represented by the will to learn comes from humanistic theories such as Rogers'. In Self-Directed Learning (SDL) is expected that the motivation and control of students in their learning process for problem-solving (Hmelo-Silver & Lin, 2000)

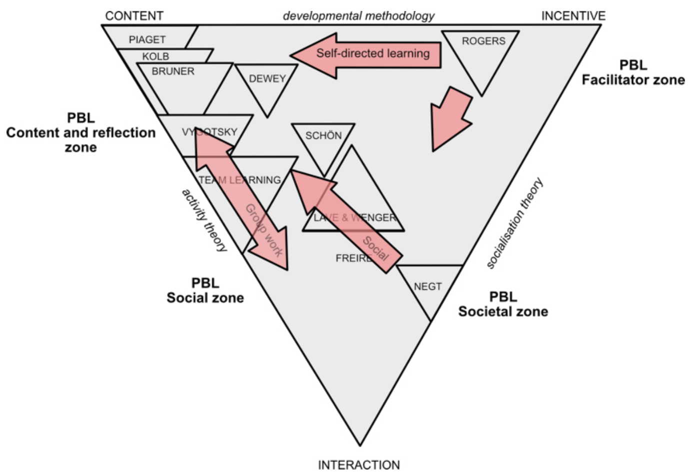

Figure 1: Illeris’ triangle with PBL principles. From (Rodríguez-Mesa, 2018)

3 Creativity

Several competencies determine creativity for engineering design: (1) Fluency, (2) divergent thinking, (3) convergent thinking, (4) metaphor, analogy, and association, (5) abduction, (6) lateral thinking, and (7), finding problems. Fluency is the generation of ideas that an individual has. Divergent thinking causes different views of solution in response to a stimulus (Rittel & Webber, 1973). Contrary, convergent thinking relies on the age of conventional, knowledge-based ideas to solve problems (Guilford, 1968); association orders one's thoughts and those of others, analogy changes ideas from one context to another, and metaphor forms parallels between various concepts (Gentner & Markman, 1997; Holyoak & Morrison, 2012; Mednick, 1962). Two of these competencies correspond to inferences trying to solve a problem. On the other hand, abduction causes disjointed ideas to explain events or solve problems (Dunbar & Klahr, 2012). Lateral thinking is to change patterns or take them to different contexts (de Bono, 1970). Finally, problem finding is the ability to observe and abstract problems from context (Chand & Runco, 1993).

The seven creativity competencies stated above are difficult to measure independently. For example, fluency can include ideas that fall within any or none of the other categories since it is about the number of ideas. However, the domain from which creativity measures affects perceptions about lateral thinking, abduction, metaphor, analogy, and problem-solving. Besides, the ability to find problems works differently as it usually operates on already defined products.

Consequently, to facilitate the evaluation of creativity, ideas can be grouped bipolarly into convergent and non-convergent or flexible. The former considers known and expected ideas about the solution of a problem. The second considers ideas that are contrary to the conventional.

Additionally, creative competencies should produce useful ideas that are generally related to problem-solving. In turn, those ideas are situated since one assessing context could or not determine if they are traditional solutions for the field or novel. In some cases, ideas are perceived as originals.

4 Methodology

Creativity measurement was performed with the Creative Engineering Design Assessment or *CEDA* (Charyton, 2014). *CEDA* is an instrument that measures divergent and convergent thinking, the quantity and variation of ideas, satisfaction, and the ability to find and solve problems. During the evaluation, the variables can be grouped into the four categories mentioned above. This instrument's reliability index is $r = .85$, and the retest correlates $r = .56$. To evaluate it, it uses judges since it assesses the usefulness and originality of the ideas (Charyton & Merrill, 2009).

CEDA proposes three fundamental design problems on three pages. The problems are proposed to find designs that produce sound, communication, or transport from basic geometric solids. It ask for the description, materials, problems than it solves and users. Then the ideas are counted, the variation of ideas, the proposals' usefulness, and their novelty to score creativity.

The creativity analysis focuses on the variation between the two tests. For this, the pairing t-test will be used if the sample meets normality criteria with the Shapiro-Wilk tests and homoscedasticity with Levene's test. Otherwise, the analysis will use Wilcoxon's nonparametric test.

5 Sample description

The analysis use data obtained from first semester students within the program "Maskin og Produktion" (machinery and production). In this way, the students come from different backgrounds, the majority without prior experience in the PBL model. The format is detailed in Mosgaard & Spliid (2011).

The syllabus is designed for students to complete two projects during the first semester. The first project (P0) lasting four weeks is focused on identifying and posing a technical problem, having designated teams of seven students with one technical supervisor assigned to them, being allocated a private study-room. Its purpose is to provide initial exposure to the university environment and to develop strategies for teamwork, reflection, creativity, peer learning, and project management – in combination with exposure to technical problem-solving, technical supervision and report writing.

For the second project (P1), students compose new teams of seven members selected by themselves. The students are provided a catalogue of 10 semi-formulated engineering challenges with brief descriptions. After selection of a challenge, a new supervisor is assigned to supervise the team in their designated study-room. The teams must resolve the problem in 12 weeks and deliver a technical report and a process report. Students must manage tasks and resources, analyze and formulate the project's problem, select methods for problem-solving, and prepare required prototypes, documents and reports. The assessment is organized as a team-based session where two examiners inquire into the reports' content that students previously delivered, and the outcomes are to be aligned with general and specific learning objectives.

6 Results

According to the CEDA guidelines, the tests were applied in a classroom simultaneously for all students for 30 minutes. The pre-test collected (44/49) answers from students of the Maskin og Produktion course and (26/49) post-test from the same group. The Figure 2 shows the three pages of a typical response from one of participants.

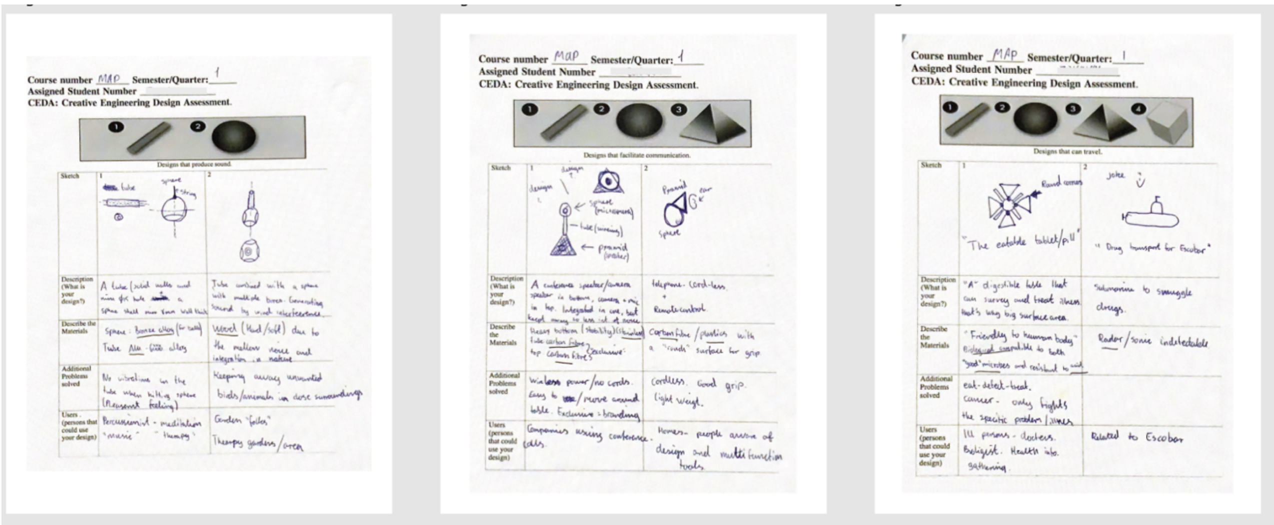

Figure 2. A CEDA typical answer from one of participants.

The data were paired in 18 pre-test (α=.91) and post-test (α=.88) treatments. The Shapiro-Wilk test indicated that the sample is normal ($p<.05$). Levene's test indicated that homoscedasticity in the variance. Therefore, a t-test was applied, the results of which are shown in Figure 2.

Table 1: CEDA differences between post-test and pre-test

				Difference		Conf. 95%			Cohen.d	
Variable	t	p	mean	SD	SD error	inf	sup	inf	effect	sup
Fluency	3.3	0,00	5.17	-7,10	1,56	1,87	8,47	-1,42	-0,73	-0,02
Flexibility	2.79	0,01	4.33	-6,49	1,55	1,06	7,61	-1,35	-0,67	0,03
Originality	1.48	0,16	1.83	-4,53	1,23	-0,77	4,44	-1,07	-0,40	0,27
Usefulness	2.8	0,01	3.33	-5.98	1,19	0,82	5,85	-1.23	-0,56	0,13

n=18, DF=17, two-tiled

The fluency has a statistically significant variation *(t (17) = 3.3, p <.05, d =. 73, M = 5.17, SD (7.1))* with a high effect. The flexibility of the ideas also increased *(t(17) = 2.8, p <.05, d =. 67, M = 4.33, SD (6.5))* and the utility *(t (17) = 2.8, p <.05, d =. 56, M = 3.3, SD (6.0)).* With a smaller effect, there a significative variation in originality, *t(17) = 1.48, p = .1, d =. 41, M = 1.82, SD (4.5).*

7 Discussion

The PBL learning process culminates in the realization of a product. The 4ps consider the creativity of an individual from intrinsic and extrinsic factors. These can be related to each other when the individual is considered both an object of learning and creativity. The PBL learning process tends to produce the acquisition of knowledge and skills during a problem solution. In the 4p's of creativity, these skills are competencies to the creative process that an individual consciously or unconsciously uses to demonstrate his or her creativity using his or her cognitive abilities. Nevertheless, the same effect occurs during skill acquisition, which according to Illeris, is due to mental mechanisms of cumulation, assimilation, accommodation, and transformation (Illeris, 2007).

The creative process to produce creativity has also been instrumentalized. It uses tools such as TRIZ (Altshuller, 1984) to stimulate the generation of ideas from the mental schemata and the analytical capacity of an individual. The mental mechanisms that it employs could the same processes of assimilation and accommodation like Illeris explained.

In PBL, the product intended to show learning results, but in creativity, that product evaluates the usefulness and originality of the solution.

The PBL model determines several circumstances that facilitate learning, including social interactions, supervision, and culture. These exert an influence on the acquisition of learning and competence. In the 4p's, this is called the press, which is the environment affecting creativity,

Consequently, there is a direct relationship between PBL and the 4ps' creative model. Thus, the same Illeris triangle could explain creative competencies. Because of this relationship, PBL should inherently develop creative competencies when solving problems.

According to the results, the Aalborg PBL model encourages creative skills in all aspects except originality. The statistical test is reliable considering that the effect is slight but significant, even indicating some cases where there was no variation in the students. Next, it will try to explain what happened based on the literature review. However, the research did complementary semi-structured interviews with the students to understand this process. They will be part of the second part of this writing.

Problems have the intrinsic property of forcing solutions and methods to be proposed, forcing ideas to be generated. The PBL uses Bruner and Kolb's theories in the content zone of the Illeris' triangle accompanied by reflection methods. During the PBL training sessions, aspects related to brainstorming are explained, which is a known technique that may or may not be applied by students. In the P1 project, students learn various known techniques to generate ideas, which appear to have had their effect.

In the CEDA test, students are not allowed to use any of these techniques. The test is individual and lasts half an hour. Since the results showed a positive variation, the results are related to the development of creativity.

The response to flexibility was less than the response to fluency. In CEDA, fluency summarizes all ideas, but flexibility just the ideas with that property. Also, brainstorming sessions use to have fluency, not flexibility. Techniques like image and sketching looking for more ideas and alternative solutions.

First semester students come from different places and educational institutions. Since they have no antecedents with the Aalborg model, the teams are heterogeneous. Diversity favors the generation of ideas (Nederveen Pieterse et al., 2013). However, this diversity was partial since they have been working with other students in the project P0.

The facilitator was able to depress creativity because of the strategy. If the facilitator proposes ideas or controls the process voluntarily or involuntarily, the generation of original ideas is depressed. Also, the stress caused by the supervisor could have negative effects on originality (Tian et al., 2020).

Additionally, originality could be affected by the type of tasks performed by the students. During the weekly joint sessions, the supervisor's intervention could affect the way the project activities led to the product. This intervention in the solution could affect originality since it depresses flexibility (Brophy, 2006).

8 Conclusions and perspectives

The work found that the project work encourages creativity with several aspects: the flow of ideas, the flexibility of ideas, their usefulness. The study did not find any significant PBL effect on originality.

The work reflects on the factors that can depress the generation of ideas. The course format suggests that the facilitator should use additional strategies and decrease the level of control or perception of it.

A study on the form of facilitation focused on creativity outcomes could help formulate strategies in the future.

Likewise, fine-tuning the methods with which the project is developed, focusing it on a problem with a greater degree of uncertainty, could contribute to developing flexible and valuable ideas in introductory engineering courses.

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Harmonizing Creative Process and PBL alignment: an understanding of fostering creativity in Engineering Education

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Abstract

Creativity grows in importance, and it is considered one of the skills that an engineering curriculum should be instilled in future professionals. Creativity is crucial for engineering, given the growing scope of challenges and complexity, and the diversity of technologies. However, creativity has not been sufficiently included in the engineering curricula because it is considered innate to the area. Consequently, we observe barriers to creativity in engineering education like lack of or poor conceptualization of creativity by students, little attention to creativity by teachers, and 'insufficient time' for activities aimed to develop problem-solving and creativity skills. This work focuses on presenting how the creative process and research on creativity can be integrated into Project-Based Learning (PBL) approaches. Thus, this paper intends to relate the creative process, the five Ps model of creativity (Person, Process, Product, Press, and Phases), and the aligned model proposed by (Kolmos, de Graaff, & Du, 2009) that considers seven elements. For example, we observe a close relationship between the elements of the PBL alignment model and the creativity integration as explicitly part of a curriculum; the element progression, size and duration, and creative process; the element spaces and organization, and environments for encouraging creative thinking, only for citing some matches. Likewise, we observe an important link between creativity for problem-solving in a novel way and PBL as a learning approach for solving problems under the exemplarity principle. The analysis seeks to create a general framework to enhance the comprehension of creativity in engineering education when a PBL approach is considered. The goal is to show the distinctive characteristics of PBL that favour the encouragement of the creative process and how the PBL alignment model's elements correspond to crucial elements and factors of creativity.

Keywords: Fostering creativity, Creative process, Engineering education, Project-Based Learning, Creativity model

Type of contribution: PBL research / conceptual paper

1 Introduction

In recent decades, engineering education has focused on seeking alternatives to promote knowledge and different skills, including communication and teamwork, among others. For this, the study of different learning approaches is recurrent. The inclusion of new variations on these approaches to achieve that students assimilate and have skills for the current era. Moreover, the 4th and 5th revolutions generate new challenges and demand new capabilities. These new challenges require flexible and dynamic technologies. In turn, it demands ICT engineers with the continuous growth of their technology and transversal skills, especially in the current digitization era where engineering design and tools aim to versatile products. The solutions to these challenges have large engineering components.

The new challenges turn around the global goals and grand engineering challenges, and appear engineers' crucial role in solving problems. The National Academy of Engineering (NAE) of the USA says: “The solutions to these challenges will all have large engineering components. Although engineers cannot solve these challenges alone, neither can the challenges be solved without engineers. It is necessary to consider higher education and engineering roles to encourage students to lead creative solutions to sustain novel solutions for contextual challenges. The curriculum design's importance is an important educational issue where the problem-solving appears as creativity results remarkable” (Katehi, Pearson, & Feder, 2009). Fostering creativity is a challenge, and It is still an in-force discussion topic in engineering education research. The design in engineering needs creativity; the alternative problem solutions are workable with fresh perspectives. Design is at the heart of engineering, and engineering is properly considered as a design profession (Dowling et al., 2020).

In other words, to recognize creativity as a fundamental skill that precedes innovation. We can observe a direct relationship between the strengthening of training in creativity and technological development. And therefore, a strong relationship between engineering education and fostering creativity and innovation. This means understanding problem-solving as a crucial skill to promote social and economic development, and creativity as an opportunity to stimulate idea generation and subsequently implement novel procedures, practices, or products. In (Fletcher, 2011; Hodge & Lear, 2011), the authors point out how Higher Education has recognized that to remain relevant and responsive to industry needs, creativity and innovation need to become a critical part of the curricula.

If creativity and innovation are crucial in engineering, why is it not an obvious part of every university's engineering curriculum? To understand the need to include creativity in the curriculum, some question us can help us to rethink the importance of creativity in Engineering, its importance, its need, and its contribution: Why should engineering organizations, their leadership, their professionals, as well as educational institutions be concerned with creativity in engineering? What do engineers do that require creativity? Why do we Need Creativity and Innovation in Engineering? In summary, why is creativity in engineering education largely overlooked? (Corazza, Agnoli, & Martello, 2017; Cropley, 2015b; Lim, Lee, & Lee, 2014; Zhou, 2017). These reflections motivate us to know what happens with creativity in engineering education and raise the importance of fostering creativity in engineering curricula.

We must pay attention to the educational environment generated by teachers’ attitudes. Then, this includes the acceptance of ambiguity and risk-taking, viewing failure as an opportunity to learn, and the habit of searching for multiple answers beyond a correct one (Cropley, 2015b; Kazerounian & Foley, 2007). Thus, we observe that there are barriers to creativity in engineering education like i) lack of or poor conceptualization of creativity by students, ii) little attention to creativity by teachers, iii) lack of systematic efforts for building a creative learning culture in institutions, and iv) ‘insufficient time’ for activities aimed to develop problem-solving and creativity skills (Belski & Belski, 2015; Charyton, 2014; Valentine, Belski, & Hamilton, 2017). These aspects motivate us to connect creativity and the practice of engineering design.

We can consider three general and essential aspects of ICT, creativity, and engineering: a) ICT programs are fundamental to developing new products and innovations, especially in this digitization era. b) In engineering, creativity results in a critical issue in developing suitable technology for facing challenges of the context and generating new solutions to the problems that exist. And c) engineering has a crucial role in social and economic development. And from an educational point of view and curriculum design, we would have to consider i) Involving creativity as an essential part of engineering education to realize its full potential. ii) Fostering creativity in engineering must encourage students to develop skills to solve problems and execute projects. And iii) Creating or developing new approaches to strengthen creativity in engineering that deals with engineering design (Bourgeois-Bougrine, Buisine, Vandendriessche, Glaveanu,

& Lubart, 2017; Santos, Martins, Brito, & Ciampi, 2019; Wu & Wu, 2020; Zhou, 2012). In (Cropley, 2020), the author sumps up the need to foster creativity in engineering, referring mainly to the disconnection between creativity research and the practice of engineering design and the need to use cross-fertilization and mention that Without this cross-fertilization, engineering design will remain anchored in convergence and analysis.

The PBL approach is an essential way to foster creativity because PBL is a student-centred educational approach that uses problems or projects as a learning scenario. PBL bases on three main principles cognitive learning, collaborative learning, and contents (de Graaff & Kolmos, 2003). Cognitive learning means that learning is organized around problems and will be carried out in projects. The problem provides a starting point for the learning processes, places learning in context, and bases learning on the learner's experience. The content supports the relation between theory and practice and promotes exemplarity in learning activities. And the social or collaborative approach is team-based learning. The team learning aspect underpins the learning process as a social act, where learning takes place through dialogue and communication. These principles guarantee PBL effectiveness in engineering education. Regarding the relationship between PBL and creativity, some characteristics demonstrate the strengths of PBL for developing creativity like i) problem orientation and project work: the use of open and real-life problems, ii) group learning context: the process of group collaboration in searching for solutions, and iii) the shift from teaching to facilitation: the idea of facilitating student-directed learning rather than teaching (Zhou, Holgaard, Kolmos, & Nielsen, 2010).

This paper focuses on presenting characteristics that should be considered in the PBL approach when it is desired to incorporate the promotion of creativity in a course; we focus on considering the five Ps of creativity (process, person, product, press, and phases) and what are the main characteristics when considering the phases of the creative process in a course. The rest of the paper is organized as follows: section 2 presents concepts of creativity, engineering, creative process, five Ps of creativity, and problem-solving. Section 3 focuses on conceptualizing of Harmonizing and Integration of Creativity and Project-Based Learning alignment elements. Finally, the authors present some concluding remarks about encouraging creativity in engineering students. This paper has important significance for linking creativity, learning, and the PBL approach for future studies.

2 Creativity, Engineering, and Problem-solving

Engineering stresses creatively solving problems, Problems that concern daily and contextual needs, and the development or use of new technologies, where the terms 'creative way' relate to the generation of useful and novel solutions. According to (Belski, 2017), engineering creativity is the ability to generate novel solution ideas for open-ended problems, ideas that appear not obvious to experts in a particular discipline, and which can be considered by them as potentially useful, highlighting the importance of convergent and divergent thinking for obtaining a problem solution. In the same sense, (Perry, 2015) points out creativity is a type of learning process where "the teacher and the student is in the same individual." Thus, if solutions to new problems remain like past problems, they face a stagnation of development. Otherwise, if an obtained solution is new or novel, a creative solution, this certainly will drive technology or redirects the market pull (Cropley & Cropley, 2016).

In engineering, it is common to work with problems or projects; this idea is used and important to promote students' creativity, to encourage creative thinking. Rhodes (1961) defined problem-solving as the process of designing, evaluating, and implementing a strategy to answer an open-ended question or achieve a desired goal. In engineering education, this aspect is important because we can use projects to focus on the process, not just an end-product. Engineering creativity emanates from problems, and it seems natural for engineering students to gain creativity through the practice of problem-solving (Cropley & Cropley, 2005).

In Project-based learning, the problem is the starting point, and the project is the route to get a solution to the problem; this approach is strongly connected to the development of problem-solving skills, and of course, to the creative process (Zhou et al., 2010). The PBL approaches are integrated to allow participants to strengthen collaboration and interdisciplinary and intercultural work and also to lead participants to divergent thinking to solve problems. Usually, these approaches consider six factors to promote creativity: i) originality, ii) fluency, iii) flexibility, iv) elaboration, v) divergent thinking, and vi) convergent thinking. In engineering, the students and teachers need to be open-minded; they need to be fluent, look for alternatives, and not for the correct answer. Because when you think creatively, there's no single correct answer; there are many possible alternatives.

Historically, different definitions of creativity have been given from an anthropological, psychological, and philosophical view. We observed that most of the creativity definitions consider five elements, (I) product, (II) process, (III) social context, (IV) environment, and (V) qualities or conditions of being creative, and one of the most recent definitions consider the time. In line with the pragmatist requirements of overall experiential representativeness, educational efficacy, and time and context-dependent subjectivity, Corazza (2016) proposed the dynamic definition of creativity, in which creativity requires potential originality and effectiveness.

2.1 The Creative Process and Creative Thinking

The process aspect of creativity refers to the mental mechanisms that occur when a person is engaged in a creative activity. Major findings of this area include that creativity results from a combination of basic mental capabilities that involves everyday cognitive processes result from long periods of hard work that involves small insights and is always specific to a given domain (Sawyer, 2012). And the Products are the results of the creative process. Research in this area aims to quantify how creative products enable the objective evaluation of real-life creativity (J. C. Kaufman, Plucker, & Baer, 2008). creativity in engineering is concerned with solving problems, but the solution engineers devise does not emerge in a single step; engineers use a sequence of stages (Cropley, 2016).

One of the essential factors in creativity is the person. Creative thinking appears as an ability, a subcomponent of creativity, that concerns the ability to generate ideas and solutions that are novel. Some creativity researchers describe the creative-thinking process under the umbrella of creative problem solving mostly used in group settings (Hong, 2014). We can solve problems following the creative process model, which has two characteristics: convergent or divergent thinking (Guilford, 1959). These two kinds of thinking are associated with the ideation stage, divergent thinking, and the last stage, where a concrete solution is given for the problem, convergent thinking (Cropley, 2015a). Likewise, in engineering, creativity involves divergent thinking for generating multiple answers and convergent thinking for producing a specific answer (Charyton & Merrill, 2009).

Wallas (1926) synthesized the creative process in a four-phase model that considers i) preparation, ii) incubation, iii) illumination, and iv) verification. In the phase of preparation, an individual becomes familiar with a content area; in the incubation phase, he/she 'stews' over the information obtained in the previous phase (ideation); in the Illumination phase, a solution emerges; and finally, in verification phase, the individual tests the solution. In (Cropley, 2015a; Howard, Culley, & Dekoninck, 2008), the authors present an analysis and Comparison of different creative process models. For example, Cropley (2015a) proposes an extended phase model based on the model of Wallas that includes: i) preparation, ii) activation, iii) generation, iv) illumination, v) verification, vi) communication, and vii) validation.

2.2 The Five Ps of Creativity in Engineering

The most known creativity framework is the four P model. Rhodes (1961) proposes the Four Ps (4Ps) model, in which he provides an excellent framework for understanding who, what, when, and how of creativity. The model considers the Product, Person, Press, and Process. A wide consensus in creativity research is represented by the conceptualization and observation of creativity within the 4Ps framework. This model subdivides creativity into four Ps (facets): (i) creative Person, (ii) creative Process, (iii) creative Product and (iv) creative Press (conditions)—each of the 4Ps covers fundamentally different aspects that may influence creativity. Regarding the definition of creativity, the model is important because a lot of recent literature on creativity has been built upon 4Ps Model, showing as the definition may change on what exactly is being considered or evaluated (Valentine, 2018). Whereas early conceptualizations focused mainly on one of the four Ps and how the individual or intrapersonal features determinant creativity, recent theories emphasize the interaction among 4Ps, integrating all Ps, and involving even the group creativity (Kozbelt, Beghetto, & Runco, 2010).

The 4Ps model is a framework for understanding the relevant aspects of the creative process because it includes the mains considerations for promoting creativity. However, it is important to consider an extra 'P' (Phases) in engineering's creative process. Creativity is just one part of a more extensive innovation process, and design is how engineers solve problems and create innovation. Therefore, solving a problem follows a design process and consequently requires creativity. We can then observe a close relationship between the need for fostering creativity and the development of problem-solving skills in engineering students. Worth noting that the creative process phases are developed in stages; the researchers commonly use four to eight stages to be grouped into four big ones, namely, Analysis, Generation, evaluation, and Communication or Implementation. Table 1 shows six examples of the creative process models; one of these is the Design Thinking Model of IDEO (Brown, 2008).

In the creative process, we must consider different factors like originality (to evaluate if an idea is unique), fluidity (to have a lot of options), flexibility (to observe if options aim to diverse possibilities), elaboration (quality of ideas), divergent thinking (the capability to generate ideas) and convergent thinking (the ability to select a good idea), motivation, among others (Reisman, Keiser, & Otti, 2016). About how creative is a person, appears the Levels of creativity model consider six levels (Chemi & Zhou, 2016), from Little-c that relies on daily problem solving and creative expression (for example, a child when paint a landscape in the school) to Big-C, which is reserved for an individual who creates something great (e.g., Leonardo da Vinci, Van Gogh or Monet). We can note that models and theories share elements like motivation, domain knowledge and expertise, divergent and convergent thinking, and a set of personal characteristics such as openness to experience, tolerance to ambiguity, willingness to take risks, and a supportive environment.

Table 1: Examples of phases in the creative process.

Models	**Analysis phase**			**Generation phase**			**Evaluation phase**	**Communication / implementation phase**		
(Wallas, 1926)	Preparation			Incubation		Illumination	Verification		----	
(Amabile, 1983)	Problem or task presentation		Preparation		Response generation		Response Validation		Outcome	
(Isaksen, Dorval, & Treffinger, 1994)	Constructing opportunities	Exploring data	Generating ideas		Developing solutions		Developing solutions	Building acceptance	Appraising tasks	Designing process
(Brown, 2008)	Empathize		Define		Ideate		Prototype		Test and Reiterate	
(Sawyer, 2012)	Problem finding and formulation	Acquiring knowledge	Gathering information	Selecting the best	Externalizing	Combining ideas	Selecting the best		Externalizing	
(Cropley, 2015a)	Preparation		Activation	Generation		Illumination	Verification	Communication		Validation

3 Harmonizing and Integration of Creativity and Project-Based Learning Alignment Elements

PBL promotes aligned curricula, which involves different elements. This section presents how the creative process and research on creativity can be integrated into Project-Based Learning (PBL) approaches. Thus, it intends to relate the creative process, the five Ps model of creativity (Cropley, 2015a), and the aligned model proposed by (Kolmos et al., 2009) that considers seven elements: 1) objectives and knowledge; 2) types of problems, projects, and lectures; 3) progression, size and duration; 4) student learning; 5) academic staff and facilitation; 6) spaces and organization; 7) and evaluation and organization. In the students must encourage not only the knowledge and transversal skills, but it is also essential to promote creative thinking and, therefore, originality, fluidity, flexibility, elaboration, divergent thinking, convergent thinking, tolerance of ambiguity, resistance to premature closure, risk-taking, and intrinsic and extrinsic motivation. These aspects of a creative person must be considered in all aspects of design in PBL alignment elements and how to ensure that they are strengthened in the development of PBL courses.

Likewise, we observe an important link between creativity for problem-solving in a novel way and PBL as a learning approach for solving problems under the exemplarity principle. The analysis seeks to create a general framework to enhance creativity in engineering education when a PBL approach is considered. The goal is to show the distinctive characteristics of PBL that favour the creative process encouragement and how the PBL alignment model's elements correspond to crucial elements and factors of creativity, emphasizing the promotion of divergent and convergent thinking.

We observe a close relationship between the PBL alignment model elements and the creativity integration as explicitly part of a curriculum design, the interaction of five Ps, and the design of the different aspects of the integration. Where it must be considered that for the promotion of creativity in a PBL approach, not only the problem and the project must be taken as the axis, but also the concepts of creativity, the five Ps model (person, process, product, press, or environment that will generate it, and phases of the creative process), and consider the design and the different alignment elements of PBL approach. These are the steps involved in the generation of novel and useful engineering products.

The elements of curricular alignment are affected in a traditional PBL approach when it seeks to enhance creativity since divergent thinking needs to be strengthened, carried out in the creative process's different phases. Likewise, it is possible to see a strong connection between the elements of the PBL alignment model elements and the five Ps, where it is observed that each of these P affects each one of the elements. Still, it is seen that their interaction towards some elements is stronger; for example, we observe a close relationship between the elements (1) and (4) of the PBL alignment model and the creativity integration as explicitly part of a curriculum, the element (3) and creative process, the element (6) and environments for encouraging creative thinking, and the element (7) and creativity assessment, only for citing some matches. Likewise, we observe an important link between creativity for problem-solving in a novel way and PBL as a learning approach for solving problems under the exemplarity principle; hence the need to encourage the phases of the creative process in developing courses seeks to promote creativity.

We must consider that when developing a project following the phases of the creative process (assuming the four general stages Analysis, Generation, Evaluation, and Communication or Implementation), the teacher is the designer of the tools and spaces necessary to achieve harmonization in the phases of the creative process in the elements of the PBL alignment. Figure 1 shows the elements of the alignment, the phases of the creative process, and some characteristics of both the teacher and the student in the process's different phases. The concept of phase will also be strongly linked to the idea of engineering design as the mechanism by which products and systems are made. We must focus on students being able to follow these stages and promote divergent thinking, so we must consider:

i) In the analysis phase, we must consider that it will be a phase dedicated to recognizing that a problem exists; it is necessary both convergent and divergent thinking, where it seeks to define or redefine the problem. In this phase is essential to consider the real-world issues, and this must be open-ended and flexible. The nature of the real-world problem is that they are often without the types of boundaries or structures that define problem solutions.

ii) In the generation phase, we must consider that it will be a phase dedicated to producing possible solutions, where we start from divergent thinking, where we seek to recognize the possible best solutions. In this phase, it is necessary to apply different creative tools to strengthen the divergent thinking according to the previous phase's problems. The main role of teachers is as a facilitator. PBL scenarios are designed to give students the opportunity to become self-direct in their search for solutions.

iii) In the evaluation phase, we must consider that it will be a phase mainly of convergent thinking, focusing on evaluating that the solution is useful. The teacher's role is the expert, and in this phase, the teacher must advise the student to evaluate the different ideas to decide which is the best. The student evaluates the possible solutions, implications, and restrictions to determine which idea is more feasible. Constraints are the basis of the analysis that our divergent and convergent thinking follows.

iv) In the communication/implementation phase, we must consider that it will be a mixed phase (divergent and convergent), where we look for making the solution available to others and applying the solution in practice; this phase is commonly applied already in the innovation process because it is necessary at the end to validate the development. Usually, in engineering courses, the results are communicated, leaving the validation phase to be carried out external to it or in post-course processes.

v) The first phase of the process plays an essential role in helping with the third phase. When the problem is clearly identified, the limitations are often much accurate, but the more we limit the problem, the less freedom and novelty are possible. There is a delicate balance between too few limitations that make it impossible to choose between alternatives and too many restrictions that eliminate creativity. Suppose when reaching the evaluation phase, it is difficult to carry it out. In that case, it is necessary to return to the analysis phase or the ideation phase to redefine the problem or expand the possible solutions to be evaluated. Hence, the importance of clearly defining the problem and not just looking for the student to arrive at a 'correct answer' (the teacher's response).

In integrating creativity in the PBL approach, it is necessary to consider that the model encourages creativity by itself. Still, it is necessary to strengthen this training by including the five Ps in the development of the projects and, mainly, following the phases of the creative process, and in this way integrate the different P in the elements of the PBL alignment, and seeks to integrate or reflected in each of the seven elements. The theories of creativity and the principles of PBL share important aspects such as considering the person as the center, the environment that empowers it, and the process and the expected product as transversal axes to the final objective.

4 Concluding Remarks

The paper shows a general framework to enhance creativity in engineering education when a PBL approach is considered. The goal is to offer the distinctive characteristics of PBL that favor the encouragement of the creative process and how the PBL alignment model's elements correspond to crucial elements and factors of creativity, emphasizing divergent and convergent thinking. Creative thinking strengthens through considering the phases. In this way, it focuses on the solution to a specific problem or project and encourages the student to have a broader look at how he/she could develop a real project. In the end, we see that managing to integrate these five PS and creativity factors into the PBL is reflected in a greater propensity towards divergent thinking and the generation of new ways to solve engineering problems.

This work presents the interrelationship between fostering creativity and the PBL approach and shows the opportunity to strengthen the elements of alignment PBL to foster creativity. In curricular alignment, it is necessary to complement and enhance creativity to achieve that the Engineer can go beyond just disciplinary knowledge and develop innovation in different areas. The conceptual principles on creativity can be used to achieve to promote creativity in courses where PBL is applied. Thus, in the PBL approach, creativity can be encouraged from the exemplary nature of the creative process, for example, including the phases of the creative process in the development of the project. Likewise, it is possible to see that it is necessary to consider in each of the alignment elements some characteristics to enhance creativity, such as the environment and creative tools where it is focused so that the student enhances their divergent thinking skills. The need is seen to include promoting creativity in engineering curricula as a primordial need in engineering education that goes beyond just mentioning it in the syllabus. It is essential that future engineers think creatively, considering the challenges they will have. Thus, fostering creativity has become a significant challenge in curriculum design. The PBL constitutes a useful and widely disseminated approach that enhances creativity due to its principles, especially exemplarity.

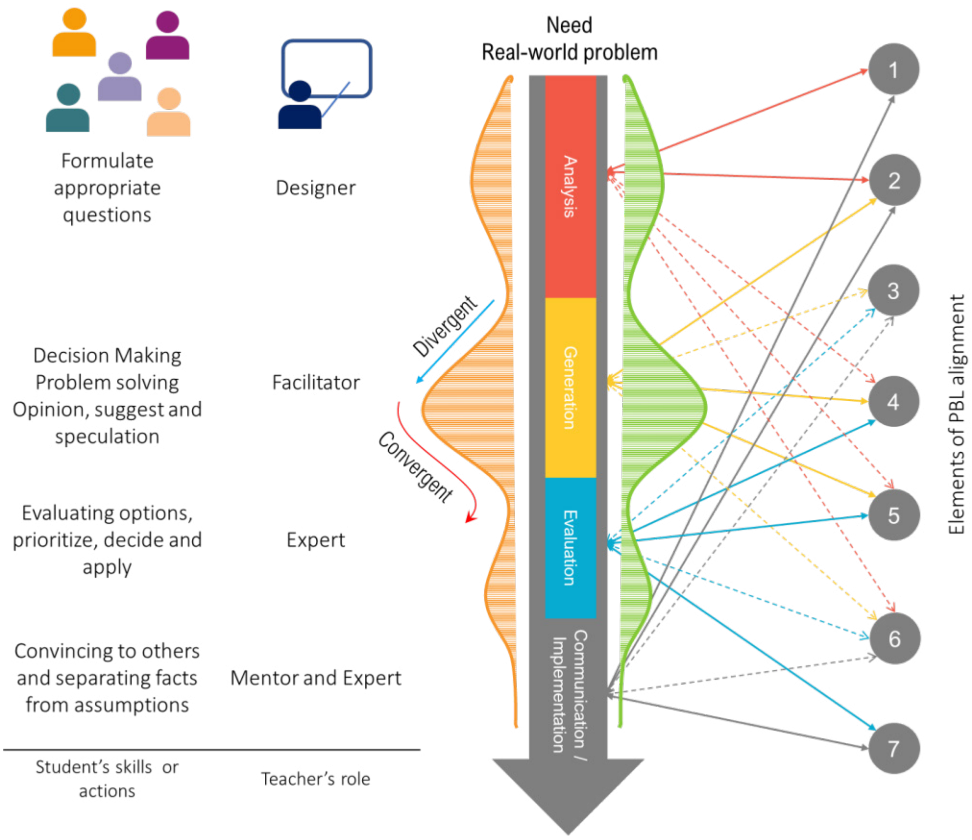

Figure 1: PBL alignment model and Creativity integration. Labels: 1) objectives and knowledge; 2) types of problems, projects, and lectures; 3) progression, size, and duration; 4) student learning; 5) academic staff and facilitation; 6) spaces and organization; 7) and evaluation and organization.

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Sustainability, Identity and Learning: Lessons from a two-year Investigation in a Problem-Based Setting

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Abstract

This paper conceptualises the findings of a two-year research project on sustainability, identity and learning in a problem-based setting in Denmark and the Netherlands. During two years of research, the author conducted a grounded theory *lite* investigation, an interpretive phenomenological analysis, a phenomenography and a longitudinal thematic analysis, investigating the relationships between students' class habitus, learning approaches (pedagogy, content, disciplinary culture), student identity transformations, and the impact of sustainability education in terms of student awareness, interest and engagement. Though these studies were conducted separately, this paper brings all of the empirical results together to propose a conceptual framework for the relationship between identity, learning, and sustainability outcomes in problem-based education. This paper suggests that the relationship between these elements is determined firstly by habitus, in particular working-class *versus* middle-class habitus, secondly by the influence of pedagogy (problem-based learning *versus* project work), and disciplinary culture on the learning experience, and thirdly by the reflective approach that students take to their own identity processes throughout the learning experience. A series of suggestions is put forward to address some of these issues: firstly, building a more explicit relationship between socio-economic class issues and sustainability through *exemplary learning*. Secondly, incorporating pedagogical elements of *environmental education*, including situated knowledges and environmental identity-building in problem-based learning. Thirdly, recognising the role that identity plays as a mediator for sustainability education outcomes. Universities would do well to recognise their role as arenas where student identities are shaped and reshaped around sustainability issues, by building reflective practices at every level of the institution. The findings of these studies will enable problem-based educators to build more effective and impactful pedagogies for sustainability.

Keywords: Problem-based learning, Project-work, Sustainability, Identity, Learning

Type of contribution: PBL conceptual paper

1 Introduction

In the light of the Coronavirus pandemic, its causes and aftermaths, the question of sustainability in its broadest sense is front and foremost in political discourse, economic forecasts, and projections of future crises. Higher education, being by nature dependent on lengthy decision-making processes and budgeting, and by custom subject to inertia in its practices and products, is not geared up for rapid, massive, global change. Yet change rapidly it must: the pandemic and the climate emergency have left us with no other option. The students who come out of our universities and into society, work and politics must, from today, be ready to take the helm in seriously choppy waters. Nothing short of systemic change is required to tackle to the interlocked crises of global heating, biodiversity loss, resource depletion and socio-economic inequality.

Is higher education up to this task? On paper, it would seem so. University programmes abound with promises of sustainability engagement, touting twenty-first century skills for flexible, socially active workers of tomorrow, while “societal impact” is on the mission statement of every self-respecting University Board. There is evidently a step to take between saying and doing in sustainability education. Too often, higher education institutions are happy to provide education *about* sustainability, neatly bounded by status-quo epistemic paradigms and thin-on-action pedagogies. By contrast, true examples of education *for* sustainability, or even paradigm-shifting *sustainable education* are harder to find (Blake, Sterling & Goodman, 2013; Filho, Raath, Vargas & Souza, 2018). But leaving aside, for the purposes of this paper, the gulf between discourse and action in sustainability education at large, the universities and their pedagogies are only one side of the equation. The success of any sustainable education programme will depend on the interest of students, their willingness to engage and take action at the individual, professional and politico-societal level.

This paper presents a reflection on the outcomes of a 2018-2019 qualitative education research project on sustainability, identity and learning, held at a problem-oriented, project-organised Danish University. During two years of research, the author conducted a grounded theory *lite* investigation, an interpretive phenomenological analysis, a phenomenography and a longitudinal theory-led thematic analysis. The studies investigated the relationships between students’ class habitus, learning approaches (pedagogy, content, disciplinary culture), student identity transformations, and the impact of sustainability education in terms of student awareness, interest and engagement. In this paper, a framework for understanding the relationship between sustainability, identity and learning in a problem-oriented context will be offered.

2 Background: four studies on sustainability, identity and learning.

The basis for discussion in this paper are four qualitative studies conducted in Denmark during a two-year period. These studies were designed to investigate various facets of the interrelationship between sustainability, identity and learning. Table 1 lists the studies, their method and summarizes the findings.

Table 1: studies in the sustainability, identity & learning research project.

	Title	Method	Summary
Study 1	Investigating the impact of problem-oriented sustainability education on students’ identity: A comparative study of planning and liberal arts students	Grounded Theory *Lite* (Boeije, 2010)	This study compared the impact of problem-based sustainability education in a liberal arts programme and problem-oriented project work programme in planning. It concluded that students who learning about sustainability

			experience "identity dissonance" but do not fundamentally change behaviours.
Study 2	'I started this, and I will end this': a phenomenological investigation of blue collar men undertaking engineering education as mature students	Interpretive Phenomenological Analysis (Smith, 2008)	This study gave an in-depth account of the lived experience of four working class men who undertook problem-based engineering education later in life. It showed that socio-economic class is a "silent" factor in determining identity positions vis-à-vis societal responsibility and sustainability issues.
Study 3	Student conceptions of PBL in engineering education: a phenomenographic investigation.	Phenomenography (Marton, 1986)	This study looked at the conceptions that engineering students hold of PBL in its project form. It concluded that while skills-based conceptions of PBL dominate, socially-oriented conceptions are scarce. Disciplinary and campus cultures and shortcomings in reflection practices were indicated as a potential source of this finding.
Study 4	Sustainability matters: the evolution of sustainability awareness, interest and engagement in PBL engineering students.	Theory-led longitudinal thematic analysis (Braun & Clarke, 2014)	This study followed 16 PBL engineering students over an 18-month period and looked at the evolution of their awareness, interest and engagement with sustainability issues. It concluded that problem-based sustainability education does increase awareness and interest, but modes of engagement are determined and limited by questions of disciplinary identity and campus culture.

All four studies were conducted with a light-constructivist epistemological stance: rather than looking for essential "truths", the studies investigated socially-constructed meanings that participants gave to their world. However, unlike approaches with a "strong" constructivist stance (e.g. discourse analysis, critical ethnography), the approach used here did not primarily look for the reflection of socio-economic and political structures in individual discourse. Different methodologies were used to explore different qualitative angles:

- The grounded theory used concepts emerging from 23 interviews to build a model of identity dissonance using Bourdieu's theory of *habitus* as an anchor. This study compared planning engineering education with liberal arts education.
- Interpretive phenomenological analysis focused on "thick" analytic work with a small sample size, giving an account of the lived experience of four mature male working-class students in a PBL engineering programme. This study focused exclusively on "classic" engineering education – mechanical and electronic engineering.
- The phenomenographic study sought to understand relational meaning-making around the concept of problem-oriented project work using 16 interviews. This study looked at four different engineering programmes: mechanical and electronic engineering, medialogy and planning.
- The theory-led thematic analysis built an analytical framework by assembling concepts from quantitative literature on sustainability awareness, interest and engagement, and investigating the nuances in their manifestation in a longitudinal qualitative data set of 48 interviews. This study also looked at four different engineering programmes: mechanical and electronic engineering, medialogy and planning.

For a more detailed description of each study's methodology, readers are invited to consult the reference list for links to the full papers (not included in this draft for the purpose of blind review). The purpose of this paper is to cross-reference the findings of all four and produce a framework for understanding the relationship between sustainability, identity and learning.

For the sake of clarity, since the acronym PBL in used in the literature to refer to two different pedagogies:

- Problem-based learning in this paper refers to the seven-step method pioneered by McMaster University, in which problems are written by content experts and tackled in seven steps over the course of one week (Moust, Bouhuijs & Schmidt, 2007).
- Problem-oriented project work in this paper refers to the project work method pioneered by Roskilde University and promoted in engineering education by Aalborg University, in which problems are formulated by students and tackled over the course of one semester (Kolmos, Fink & Krogh, 2004).

3 Class Habitus As Determinant of Sustainability Awareness, Engagement and Interest

The first key finding of these studies is that class, defined in the sociological sense of class-in-practice materialising in a shared *habitus* (rather than the economic sense of relations of production) (Bourdieu, 1991), is a key factor influencing a student's relationship with sustainability issues.

Among working-class students, meaning students whose parents came from low-education jobs or who themselves worked in low-education jobs prior to attending university, several attitudes towards sustainability questions were observed as they entered university:

- Indifference: often owing to their precarious financial situation, students were more worried about immediate and personal concerns than about global issues like climate change (Study 2, Study 4).
- Disenfranchisement: students were aware of sustainability issues, but felt powerless to do anything about them – they felt locked out of the political system, and unable to undertake individual changes for a greener lifestyle due to their economic disenfranchisement (Study 2, Study 4).

Among middle-class students, meaning students with a more affluent lifestyle in which international travel plays a big role, who often have at least one parent who went to university, and who have not worked a low-education job as their primary occupation, awareness and interest in sustainability questions was much higher at the start of their studies:

- Moral obligation: students considered it a "duty" to care about environmental issues and often framed sustainability choices in terms of right and wrong, altruism and selfishness, good and bad (Study 1).
- Individual choice: students mainly engaged with environmental questions at the level of individual lifestyle choices – eating vegetarian, buying second hand, cycling rather than driving… however, they were, without exception, unwilling to give up flying (Study 1, Study 4).

The response to sustainability education was also significantly different among working class and middle-class students:

- Working class students, particularly in engineering education, felt empowered to promote technical solutions to sustainability problems (Study 2, Study 4). They incorporated their new-found technical capability in an engineering-identity-in-the-making. However, they balked at the idea of social, economic and political engagement (Study 4).
- Middle class students experienced powerful identity dissonance between their moral identity as "good" stewards of the environment, and their own environmentally destructive lifestyles. They used several strategies to deflect moral responsibility for this dissonance: threat reduction (e.g. saying that they will be long dead before climate change becomes a problem), blame (e.g. blaming ineffectual politicians), bargaining (e.g. claiming that switching to a vegetarian diet compensates for CO_2 emissions from flying), fatalism (e.g. saying it's too late to do anything anyways, so one person's actions will make no difference), faith in salvation from external forces (e.g. saying that technology will fix it), postponing responsibility into future professional life (e.g. deferring action until they enter the job market), and limited engagement (e.g. being involved in a sustainability organisation, and therefore being absolved of further action) (Study 1). Within the field of engineering, many of these students also balked at the idea of social and political engagement (Study 1, Study 4). However, those students that did engage institutionally and politically were all from a middle class background.

4 Education Design, Identity Formation and Sustainability Learning Outcomes

The four studies considered the impact of three aspects of educational design of student identity formation and sustainability outcomes: content, pedagogy and disciplinary / campus "culture".

4.1 Content

Although the studies did not set out to explore the impact of the teaching contents of sustainability education, this emerged as a salient theme in several studies:

- Presenting sustainability issues from a critical, systemic, humanities-oriented perspective increased student's systemic awareness, and self-reflection on sustainability-related identity issues, as compared with presenting sustainability issues in a more disciplinary, more technical format. However, presented in a problem-based learning format, it also seemed to encourage feelings of despair and powerlessness (Study 1).
- Presenting sustainability issues in very specific, technical forms did raise students' interests in sustainability issues – even among students with no prior interest in sustainability. However, this fostered professional, rather than institutional or political forms of sustainability engagement, feeding techno-fix escapism and an uncanny admiration for Elon Musk into engineering identities-in-the-making (Study 2, Study 4).

4.2 Pedagogy

The studies considered the role of problem-based learning (Study 1), and problem-oriented project work (Studies 1, 2, 3 and 4) in student identity formation and sustainability learning outcomes.

- Problem-oriented project work had an advantage over problem-based learning in fostering action-oriented mindsets among students (Study 1).
- While problem-oriented project work was on the whole experienced as beneficial for engineering students' group-work skills, many students experienced emotional distress and individual stress in their project groups. It was suggested that the dominance of positive or negative affective experiences among students could foster collaborative or competitive engineering identities (Study 3). Interestingly, class did not seem to be a determinant of positive or negative social and affective experiences within project groups.
- The dominance of academic and affective issues also tended to obscure the social relevance of project work for students, at least in their first 18 months of study (Study 3).
- An increase in sustainability awareness, interest and engagement was noted across nearly all participants in a longitudinal study of engineering students learning with problem-oriented project work. However, the study was not able to draw an explicit causal link (Study 4).

4.3 Campus Culture

Studies on the formation of engineering identity in engineering education speak of the importance of "campus culture" in determining the kind of engineering identity that emerges. Studies 3 and 4 noted in particular the influence of campus culture on the relationship between identity and sustainability among engineering students:

- Engineering students, regardless of disciplines, tended to strongly favour professional engagement with sustainability questions. In particular, there was a strong preference for exclusively technical professional engagement, meaning that students exclusively bounded their engagement with sustainability to technical and technological expertise related to their future engineering professions (Study 1, Study 2, Study 4). The minority of students who preferred a more socio-economic professional and political engagement were at best dismissed, at worst vilified and ostracised by their technically-minded peers (Study 4). Study 4 suggested that this minority of politically engaged students was considered as a threat to the technical engineering identity-in-the-making of the majority. It was also suggested the particular history of this Danish institution instituted a campus culture, at least at the faculty of engineering, that is unfavourable to political engagement.
- The campus culture of this particular faculty of engineering was also considered a factor in the relatively small role of societal orientation in engineering students' conceptions of project work (Study 3). When social relevance was mentioned, it tended to be in relation to future engineering careers rather than broader socio-economic and political sustainability considerations.
- Liberal arts students were much more likely to favour institutional engagement, taking part in various sustainability committees and taking on political roles within the university. Such forms of engagement were strongly encouraged within that institution, further demonstrating the role campus culture in determining sustainability engagement (Study 1).

5 Mapping the interrelationship between sustainability, identity and learning

The conclusions draw from the cross-comparison of the four studies leads up to suggest an explanatory framework for the interrelationship between sustainability, identity and learning. We suggest that student class habitus has a strong influence on the mediating effect of education design in student identity formation. The emergent identity in turn has an effect on the impact of sustainability education, and the kinds of outcomes that one is likely to see in terms of student engagement. In particular, we can conclude that:

- Working class habitus, when mediated by technical contents, project-based pedagogy and a campus culture that does not favour political engagement, may yield technical engineering identities, and technical professional engagement with sustainability issues. The same holds true to middle class habitus under the same conditions, with the added difference that middle class students will also tend to engage individually.
- Middle class habitus, when mediated by systemic, interdisciplinary contents, problem-based pedagogy and a campus culture that favours political and institutional engagement, will likely feed moral identities in which environmental care is seen as a moral duty. It may spur individual and institutional engagement with sustainability issues.
- Political engagement, while necessary to foster systemic change, is still uncommon among students, and is sometimes met with such hostility that it may discourage other students from following suit. The rejection of political forms of engagement reflects a discourse of "apoliticisation" and "scientific neutrality" within universities, that discourages political activism on ideological grounds.

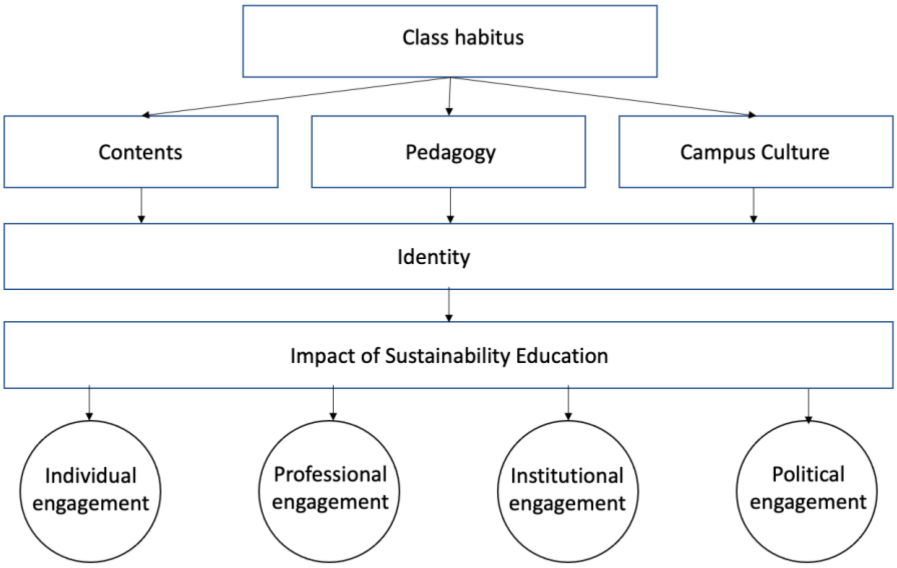

Figure 1: mapping the interrelationship between sustainability, identity and learning

Ideology notwithstanding, it is now widely accepted among climate scientists, political economists and other serious students of our current climate predicament that on climate alone, the kinds of changes necessary to stabilise the planet's atmosphere below 2 degrees Celsius of warming will require massive and urgent engagement at the individual, professional, institutional and political levels – the latter being absolutely *key* to making the required changes at the legislative, judiciary and executive levels of power. The political disenfranchisement of students, far from honouring an illusory principle of "neutrality", perpetuates a system that, left unchecked, promises the end of civilisation as we know it within their lifetime. It is therefore incumbent upon higher education, if it is to live up to its sustainability mission-on-paper, to foster the sustainability engagement of its students on all fronts.

6 Implications for practice: managing identity considerations in problem-based education for sustainability

Fostering engagement with sustainability issues on all fronts will require moving beyond dichotomies of technical-professional and moral-environmental identities. In the closing section of this paper, I would like to propose that problem-based learning and problem-oriented project work can be made to foster multidimensional engagement, if used in the right way. That is, I argue, if they are used following the principle of exemplarity, with content and context in view of promoting environmental identity, in regenerative campus cultures that make space for everybody's engagement.

6.1 Exemplarity

Exemplarity is an educational principle well known to those familiar with the history of problem-oriented project work (Servant-Miklos & Guerra, 2019). Inspired by Frankfurt School critical pedagogy and the world of American sociologist C. Wright Mills, exemplarity proposes to anchor the learning process in students' immediate experience of the world. Experience is used as a springboard to uncover and understand underlying systemic problems, making the personal both educational and political. There's just one problem with exemplarity: it's been tried and tested, at Roskilde University, for instance, but systematically falls short in connecting middle class students with problems that essentially affect poor people and people of colour first and hardest. This problem was already noted by critical pedagogue Eva Hultengren (1979) at the inception of problem-oriented project work in Denmark, and the studies of this project have done little to allay the fear that if one's every day experience is relatively privileged, then one will struggle to truly see climate change, biodiversity loss and socio-economic inequality as anything but an abstract, theoretical problem requiring, at best, limited individual and professional engagement. While this criticism is certainly valid, there's no need to throw the baby out with the pedagogical bathwater. Exemplarity can be revived in the context of sustainability education, if the day to day experience of students can be changed to make them feel deeply personally connected to the sustainability problem. This cannot be done with paper problems. But it can be done through engaged forms of environmental education.

6.2 Environmental Identity

In the discussion of Study 1, it was suggested that encouraging the formation of an *environmental* identity (Clayton, 2003), as opposed to a technical-professional or moral identity, would serve as a better conduit for multidimensional sustainability engagement. Environmental identity is a concept developed by Susan Clayton, describing an identity that is primarily defined by attachment to the natural world. Such an attachment is usually fostered by childhood experiences in nature. However, it was suggested to develop environmental education designs that push students outside of the stone walls and concrete floors of their university institutions and into the forests, meadows, coasts and other ecosystems of their region. Urban-dwelling students would gain first-hand knowledge of the impact of pesticides on insect populations, the intensity of air pollution around busy roads, the presence of climate-pests encouraged northwards by warming winters, and the resilience of life despite all of these threats. From a socio-economic perspective, volunteering in deprived communities, perhaps borrowing from service-learning pedagogies, may help middle-class students build a first-hand awareness that even within the same city, the university remains an alien world for many. Building on such first-hand experiences would make it much easier to embed exemplarity back into problem-oriented project work and problem-based learning.

6.3 Campus Culture

While individual teachers can try their best to innovate and inspire in individual courses under their control, no systemic change will be possible without a re-appraisal of campus cultures, in engineering education or otherwise. It is long past time for universities to give up dangerous both-side-ism when it comes to climate change, biodiversity loss and socio-economic inequality. Neoliberal economics is broken, and politics as usual doesn't work. Universities were once the birthing place of new visions for society. They need to embrace this role once more. However, a broken clock is right twice a day, and conservative educators are right to fear a monopoly on certain forms of engagement. It does nobody any good to substitute exclusive professional engagement for exclusive political engagement. The great promoters of democratic education that were John Stuart Mill (1848) and John Dewey (1916) proposed an ideal of tolerance that both respected individual difference while ensuring the right of each to a basic subsistence. What such a system would look like in practice is for the students of today (many of whom will be the thinkers of tomorrow, we hope) to determine.

7 Conclusion

We can conclude that although problem-based learning and problem-oriented project work hold great promise in their potential societal and sustainability impact, both fall short of fostering multidimensional engagement in practice. This shortcoming has been explained in terms of restrictive identity formation processes that favour certain types over engagement while discrediting others. The study of sustainability, identity and learning is still in its infancy – calling for further qualitative and quantitative studies to explore other aspects of the interrelationship that were not addressed in this project. New methods of inquiry, new research questions, there is a wide range of possibilities for education researchers in the years ahead. Given the urgency and scale of our sustainability problems, the payoff will be worth the investigation.

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Passion and Problem-Based Learning to Innovate and Close Inequality Gaps in the Fourth Industrial Revolution

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Abstract

This document presents a framework based on PPBL (Passion and problem based learning) developed by the Laboratory to Innovate in the Fourth Industrial Revolution of the National University of Colombia (UNLab 4.0), which has proven great potential to reduce inequality gaps by developing the 4C skills (critical thinking, communication, creativity, collaboration) in the context of the fourth industrial revolution. This framework has been successfully implemented within heterogeneous groups of persons with different age, ethnicities, religious beliefs, economic, cultural, political and social conditions. By this means, it has helped to break social inequalities by developing abilities to identify, manage and propose solutions to complex problems, such as the ones in the 17 Sustainable Development Goals (SDGs). This is all made from a perspective of a never-ending journey, an adventure, which begins by asking the participants about their inner passions; the process takes them through an exploration that allows them to discover challenges connected to problems and later with projects. The process is guided by mentors, which have a peer-to-peer interaction, living the whole process together with the participants and helping them to break prejudices and paradigms. This process results in a boost for potential innovations, which are expressed as artistic, technological, scientific, and cultural artifacts that the participants create as a response to the problems or challenges they choose to, explore and face.

Keywords:
Complex problems, artifacts, digital illiteracy, functional illiteracy and possible adjacent.

Type of contribution: PBL best practice

1. Introduction

Since 2016, according to the World Economic Forum (WEF), we have been in a fourth industrial revolution (4IR), a revolution that is changing the way we live, work and interact. The repercussions that this change brings will affect who we are, and how we approach the new needs that the environment presents us, from a humanitarian, academic and working perspective (Schwab, 2016: p. 7-8). According to WEF, this revolution will affect the job market and the future of work, which makes evident the need to transform the way in which the new generations are preparing for it.

In the future of employment there will be jobs that nowadays do not exist (Ibid., 2016), so it is necessary, not only to change the way in which people are educated, but also to prepare young people to generate knowledge by identifying and facing complex problems based on their passions. This allows the development of life skills through the four skills to innovate and their consolidation with the use of current technologies. The latter has the purpose of envisaging the revolution that has already started and for which the traditional model of education is hardly coping.

As expressed by the World Economic Forum in its report on education (New Vision for Education, 2016) the education transition from the 3Rs (reading, writing, mathematics) to the 4C, which are the development of critical thinking, creativity, collaborative work and communication skills. This is key to break the inequality gaps, since they enable the identification, confrontation and proposing of solutions to complex problems.

On the other hand, in Colombia there are more challenges due to its current post-conflict process. In times of great technological change, people, companies and institutions feel the depth of the revolution, but are often overwhelmed by its effects and it can trigger actions that affect communities. For this reason, it is essential that all the initiatives in the 4IR have an innovation component and the imperative of closing inequality gaps. It could allow the improvement of the population's living conditions and the creation and access to more and better opportunities (Hernández, 2019: p. 57).

That is why UNLab 4.0 proposes the Passion and Problem Based Learning (PPBL) focused on the development of skills to promote innovation in the context of 4IR, aimed to close the current inequality gaps. In addition, the PPBL seeks that young people acquire the skills to adapt to this revolution through the identification of problems, context reading and solution-seeking proposals. Adding the deep and consistent use of frontier technologies, which play a fundamental role in this transformation process.

2. History of UNLab 4.0 and its Impact in Colombia

UNLab 4.0 is the laboratory to innovate in the fourth industrial revolution of the National University of Colombia. This laboratory was created with the objective of developing skills to promote innovation in the context of the fourth industrial revolution via the breaking of paradigms. Today the lab is led mainly by undergraduate students from the National University of Colombia, as well as graduates from other universities. UNLab 4.0’s topology is divided into four fields of languages: 1.) Languages of the pluriverses: which focuses on the sciences and disciplines that seek to understand how the universes work; led by Carlos Galindo, an undergraduate student of electrical engineering. 2) Machine languages: it focuses on engineering and includes topics in programming algorithms, flow diagrams, internet of things, big data, blockchain, robotics, artificial intelligence; led by Daniel Buitrago, an undergraduate student of electrical engineering. 3) Human Languages: it focuses on the humanities, includes themes in the arts, history, international and economic relations; led by Camilo López, an undergraduate student of plastic arts. And 4) Worlds design languages: integrates the previous languages for the gestation of life-based possible worlds; led by Dayana Mahecha Rozo, specialist in promoting public policies for equality in Latin America and master's student in interdisciplinary development studies. The above is enhanced by national and international cooperation processes by Angie Hernández, a professional in International Relations with a master's degree in international cooperation and development project management, and Freddy Lopez, who is the methodological director, an economist, with master's degree in development and doctoral studies in territorial development.

Since the foundation of the laboratory in 2018, UNLab 4.0 has led from the National University of Colombia skills development processes to innovate in the 4IR at local and municipal levels in different regions of the country. Unlike other laboratories, UNLab 4.0 is financed by external parties, which generates a commitment not only from the largest and most important Public University in Colombia, but also from different actors who decide to finance impact processes with the PPBL in communities throughout the country.

The first approaches to this methodology date back to 2014 by the creator of the framework, Freddy López, who generated interdisciplinary work scenarios in district schools in which groups of students were invited to investigate and propose solutions for problems of their interest, regardless of their academic performance. Among these solutions provided by the participants, an atmospheric water condenser was proposed to attack the water problem in various regions of Colombia and with this project; they were invited to present the results to NASA, results that motivated them to continue working on its development.

In 2018, the National University of Colombia, motivated by the results, decided to promote the creation of the UNLab 4.0 laboratory and thus began a continuous design of the PPBL proposal. The first exercises consisted of spaces for innovation and co-creation open to all audiences where they worked from mathematical problems to problems of violence in communities. These spaces allowed progress towards a plurality and adaptation of the topology, developing powerful tools and forming allies which in turn allowed a robust implementation. UNLab 4.0 gave support to the component of innovation of the Laboratory of Innovation for Peace of the National University of Colombia. This project was aimed at the generation of innovative projects focused on peace building by victims of the armed conflict, social leaders and ex-combatants. This project was developed in Bogotá, Manizales, Arauca and Tumaco. It included participants aged from 9 years to 80. All the support of the innovation component of the laboratory was leveraged based on the PPBL.

Subsequently, in a project implemented for the International Organization for Migration. The focus was to make a process of skills development to innovate in the fourth industrial revolution with children and adolescents from the most vulnerable neighbourhoods of Bogotá, in the framework of the community strengthening model.

Recently in 2020, the Presidential Council for Youth of the Government of Colombia financed a project to impact 25,000 young- This project was implemented with the PPBL with an emphasis on functional and digital literacy and with the objective of triggering processes of critical capacity, self-confidence and social roots in young people in Colombia (Sacúdete, 2020).

In addition, UNLab 4.0 has implemented the topology in entire classes of electrical and electronic engineering subjects and has launched outreach programs to the community in skills development diplomas for children and teenagers. Finally, social projects have been carried out in Tumaco, an area affected by the armed conflict and drug traffic in Colombia, to avoid the recruitment of minors through scientific vacations where UNLab 4.0 methodology was integrated.

Currently, UNLab 4.0 continues to strengthen strategic alliances with public-private institutions, companies, NGOs and academia to bring the topology to the most vulnerable communities in Colombia, to generate spaces for reflection and to take the process to other places in Latin America and the world.

3. How does the PPBL Promote the Emergence of Innovation and Close Inequality Gaps in the Fourth Industrial Revolution?

First, it is necessary to answer what is innovation? From UNLab 4.0 it is seen as local processes that face problems in a better and quality way, different from what was done previously. Innovation is the best way to resolve problems (Maldonado, 2020). One way to generate innovation processes is by developing the skills of the 21st century, essentially those to solve complex problems, the 4'Cs (Hani, 2018: P. 440).

Innovation from and for life is a fundamental node of the UNLab 4.0 topology as it is the result of thinking about the most complex problem that exists and has ever existed: life. Innovation from and for life, moves away from the mercantile and efficiency vision of markets and proposes the creation of new paths, new forms, new feelings, new logics that do not focus on linearity or hierarchies, nor in the determinism of the modern western system that traditional education has gone through. For UNLab 4.0, the maximum reference of innovation is nature, specifically the innovations that promote the formation of complex life. One crucial example of this can be found in the serial endosymbiosis thesis of Lynn Margulis; this theory explains how prokaryotic cells develop a new form of communication and interaction which eventually lead to the formation of a much more complex organism, the eukaryotic cell. This new type of cell then became the basis for all complex life on earth (Margulis, 1995). This reference has allowed UNLab 4.0 to learn from life and take language as a fundamental fibre of the topology that allows the confrontation of complex problems and the breaking of paradigms in order to innovate.

This innovation arises from passions because for it to be radical, it has to come from irrational processes based on poiesis (where good ideas come from), in spaces where participants feel the freedom to make mistakes and develop the skills of the 21st century. The creation of this environment is intended to be open, a space where ideas flow through unregulated channels; Since it has been shown that in other environments with more control, those that restrict the natural movement of ideas, innovation processes are stifled (Johnson, 2010). From the PPBL these spaces are generated to promote innovation and complex problems resolution. In the context of the Fourth Industrial Revolution it allows to close the inequality gaps in the territories of the participants.

Considering the above, the question arises to how it is possible to close the inequality gaps through the PPBL, especially in Latin America, were inequality addresses the different gaps in income equality, education, nutrition, access to information technologies, to durable goods and gender (Cepal, 2016: P. 07), and configures the structural gaps of well-being, recognition, autonomy and exercise of the rights of indigenous, afro-descendant peoples and of women in relation to men (Ibid., 2016: P. 23).

The laboratory's aim is to generate an alternative to the development of promoting scenarios of innovation where the process is not focused on giving some competencies but to boosting the development of skills to solve complex problems. This process marks an important difference because it allows participants to break paradigms about their role in the resolution of complex problems and thus, increase their confidence and believe in their ideas; and it also allows an approach to technologies that represent qualitative leaps in facing problems.

Besides, the laboratory seeks to extend the recognition and analysis of the characteristics of social inequality to understand the structural gaps that mark Latin American societies, which is essential to advance on the path of sustainable development and meet the objectives defined in the 2030 Agenda. One of the ways in which it is carried out through the PPBL is integrating diverse work groups, regardless of academic background, age, gender, religion, ethnicity, political ideals, among others with an intersectional perspective.

On the other hand, scenarios with soft and hard technologies are designed to reduce functional and technological illiteracy, which allows the expansion of possible adjacent areas that can generate economic, educational and leisure opportunities; along with the commitment to develop technologies and processes within the framework of sovereignties that achieves autonomy weaving processes and the development of skills to innovate to enable design of worlds. For this reason, a detraining is provided in soft and hard technologies of the fourth industrial revolution, so that the population can innovate and break the cycles of inequality through projects that impact communities. It is necessary to point out that the most important thing in this revolution is knowledge; today, the capital is in the ideas and how we innovate to undertake and solve problems through passions.

From UNLab 4.0 much emphasis has been placed on the need to be able to adapt to the fourth industrial revolution, since in this revolution there is a possibility of either increasing inequality gaps or breaking them definitely. This revolution, unlike the previous ones, makes a much stronger use of innovation, a fundamental engine for new economies where it can support Industry 4.0 to be aligned with the SDGs and thus prevent social or climate problems. In the 4IR it is important that the population, through their knowledge, with the support of the government and companies, maximize digital and technological resources, innovate, generate entrepreneurship and promote the closing of inequality gaps (Hernandez, 2019: P. 15). Because of this, the laboratory seeks to link public institutions, companies and academic institutions to generate cooperation so that projects do not remain in urban areas, but also reach the most remote rural areas of the country.

4. UNLab 4.0 and its PPBL Adventure

The executed processes have allowed the creation of the topology described in the previous section. It has evolved as a consequence of the approach to complex problems projected to complex systems, complexity and the sciences of complexity in connection with the collective knowledge and the cosmovision of the territories. The creation of a topology allows the confrontation of complex problems and the closing of inequality gaps based on the best way to solve them: innovation (Maldonado, 2020).

The name of *topology* comes from understanding educational processes in a non-linear way, and with the purpose to have a dynamic, solid, and flexible structure. This topology can shrink, stretch, adapt to various scenarios, and retain its properties. The topological structure of UNLab 4.0 is based on graph theory and allows the emergence of non-classical logics and ways of thinking in terms of sets, synthesis, and networks. The territorial exercises carried out by the team has made it possible to see that beyond the projects, passion allows participants to discover new worlds and thus expand their possible adjacent, break paradigms and develop skills to innovate. From passions and the approach to different visions of technology and different technologies, the participants go through heuristic and metaheuristic processes that lead them to face complex problems.

This idea of topology bases on the topology of the Möbius strip, which has the quality of being one of those geometric objects (tangible or intangible) that do not vary when subjected to continuous transformations. In a never-ending process of constant feedback and self-knowledge, which is not governed by incremental linear logics but emergent iterative processes.

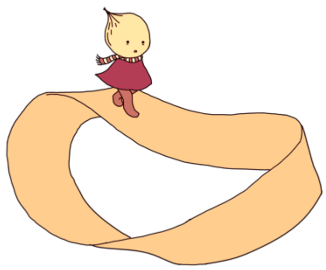

Figure 1. Möbius strip

The soft and hard technologies used throughout the process are meant to deepen, synthesize ideas, interpret and understand problems with an innovation approach from and for life as the best way to solve them. This logic leads to the emerged challenges where the participants themselves are guided by their passions enhancing the development of skills to innovate within the framework of the fourth industrial revolution. UNLab 4.0 calls this process poiesis based on passions, as it is a process that is not reduced to learning but rather implies and involves a process of creation.

Design enters in this process as a fundamental component in the process of poiesis based on passions and as a promoter of autonomous processes, since it unlocks the possibility of people to propose solutions to these problems. Design, as a transformer of realities, it provides the agency that people have lost due to the hierarchies imposed in traditional education and in academic scenarios (Escobar, 2019).

The beneficiaries go from learning as a one-way process to poietic experiences which are immersive and transformational for people involved. The process of approaching the PBL within the social projects of UNLab 4.0 involves different types of learning, where the relevance and need to identify, face and propose solutions to complex problems is required.

The PBL process begins through the stimulation in a forceful way from the creation -poiesis- and consequent learning that starts from passions. It is in this process where participants discover what motivates themselves and what they are passionate about. Next, based on these, they face challenges, problems and design projects in an iteration process. Unlike other approaches of PBL where the teacher selects and provides the students with a problem that he hopes will be of interest to them, in UNLab 4.0 process, it is the participants who decide completely freely and autonomously what they are passionate about and how they want to investigate, explore and design around a problem, while the mentor provides spaces for dialogue, soft and hard tools approach, connections with experts and everything that can enhance these processes. This starting point generates infinite possibilities among participants or teams, and takes them to work on impossible, imaginary, real and social problems, generating either a direct contribution to the SDGs, resolution of problems of their communities or a contribution to research on the worked topic.

Inside UNLab 4.0, the PBL seeks to be a disruptive process with no limitation on participants or teams, however for every 20 participants there is a mentor who guides the process. The number of participants, teams and mentors is defined by the budget that is assigned to each project. Mentors have training that ranges from baccalaureate to bachelor's master's and doctoral degrees. Participants arrive at UNLab 4.0 through a call that is carried out in alliance with educational institutions in the country, foundations, territorial institutions and NGOs who reach the target population of the assigned project. Mainly those who are not studying or working. It is intended that through this cooperation network a space of trust is generated in the different departments of the country so that more young people can participate and thus develop innovation processes and solution of complex problems in their territories. When participants register, contact begins with their assigned mentor, who will begin the process. During the experience, which can last from 5 weeks to a year, depending on the funding, the young people develop the skills to innovate and appropriate the soft and hard technologies of the 4IR, to generate a project or artifact that can work as a solution to the problem identified in the process.

A contribution that has been provided to the PBL from UNLab 4.0, and that has become a fundamental tool that has enhanced community work, has been **learning based on the passion**, described in the previous paragraphs, and that complements problem-based learning, since passion is an autopoietic exercise, where the autonomy of the subject is the focus of his convictions (Urbina, 2012: P. 318). Then, learning from passions is a continuous, recursive and introspective process that involves the initiative of the participants to leave the comfort zone and move to poiesis based on problems, challenges and projects (Garduño, 2018: P. 17). Therefore, within UNLab 4.0 you learn not by obligation or incentives but by passion, since in the act of learning the five senses converge, through a creative exercise (Urbina, 2016: P. 02).

5. Evaluation of the PPBL, a Fractal and Collaborative Proposal

Evaluations on traditional learning environments have been usually achieved by measuring how much a set of expectations (learning objectives) is fulfilled by the students. This set is initially established by the teacher and/or the educational institution. Their performance on the learning process is measured by their results with a standardized test. However, since the UNLab 4.0 framework is based on a free and personal discovery, exploration and creation from the passions and interests of each participant, a new approach is taken.

Generally the process, results and creations are completely different and dynamic from one participant to another, so in order to carry out an evaluation process with no exams or expectations imposed by an authority, these are instead set by each participant in its own terms. Which means that together with their mentor they continuously are building a plan and setting performance expectations, in this way each participant is motivated by their own goals and establishes how they want to explore and get there.

The evaluation of achievement is a conversation between the person's self-perception with the mentor and with the other participants. Due to this, the evaluation of the process from 2017 to 2019 was only of an appreciative nature based on comments and reports from participants like the following: *"The course is innovative, it is an education different from what is taught in college and university, I did things that I never thought I could do"* given by a 19-year-old young woman. In general, the testimonies showed that the experience of exploring passions in such a culturally diverse space of interaction had allowed them to expand their life perspectives, develop skills and trust more in their potential.

However, this type of appraisal lacked a numerical representation that would allow generating and studying statistical hypotheses about the impact of the practice. Therefore in 2020, during the execution of the project "Sacúdete con UNLab 4.0" in 2020, where 30,000 young people from all over the country were impacted through a "development of skills of the Fourth Industrial Revolution course" and workshops focused on food, cultural, energy and technological sovereignty, they had the opportunity to co-design with the population an assessment tool of the skills, which consists of a fractal rubric made of 3 artifacts. It manages to represent the results of each process phase: detraining, exploration and design.

The first artifact is the fractal, it is the basis of the processes of hetero-evaluation, co-evaluation and allows the exploration of new themes, expansion of possible adjacent and the breaking of paradigms; The second artifact is the tree of passions. it starts from the seed (starting point) and expands to branches and blooms as much as the participants wish and decide. The branches represent the paths followed. flowers and fruits represent the tangible or intangible artifacts designed by them; Finally, the last artifact is a video pitch where the participant tells his experience and work done. Two of these structures are shown below:

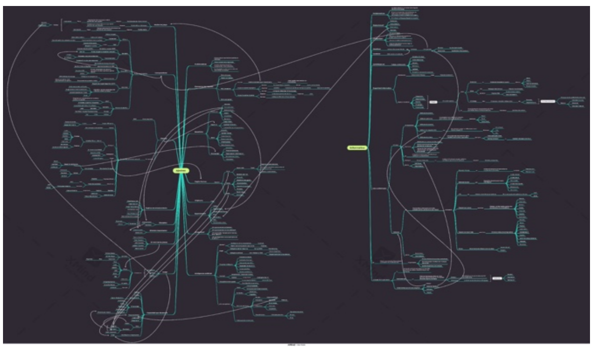

Figure 2. Fractal structure created by Víctor Manuel Ramírez Collantes, 17 years, during the execution of UNLab 4.0 project

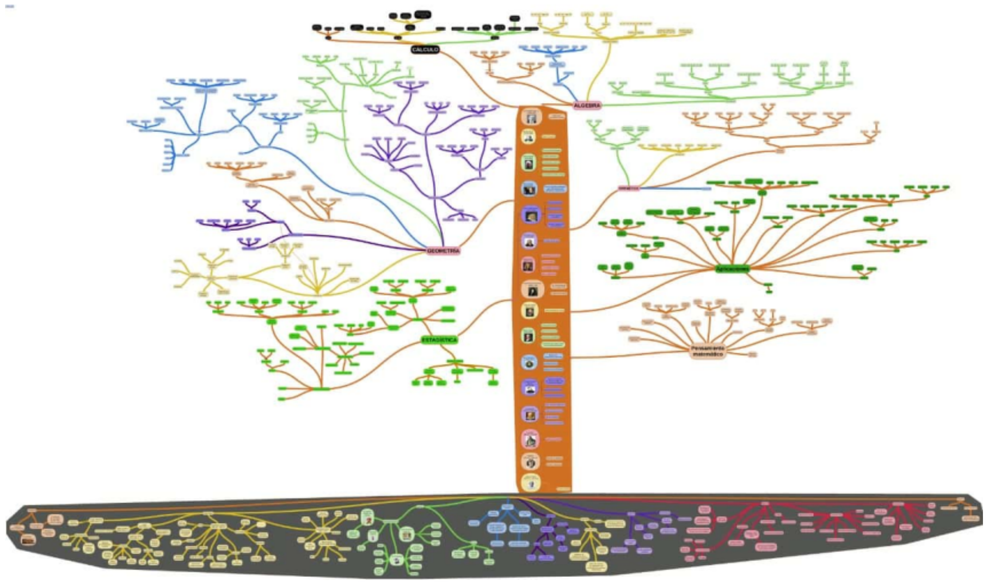

Figure 3. Structure created by Anderson Guaranguay, 17 years, to investigate Mathematics during the execution of the Sacúdete con UNLab 4.0 project

In 2017, the theoretical and scientific biologist of complexity, Stuart Kauffmann, and the mathematician of complex systems Vitorio Loreto developed the first mathematical model that correctly reproduces the patterns for innovation, it proposes that each innovation changes the landscape of future possibilities, that is, - the adjacent possible - is changing. This research shows that novelty generates novelty. In this sense, the artifacts shown above encourage the generation of novelty in the participants, from novelties in their thinking models to novelties in their way of acting or facing problems. For this reason fractal literacy and the tree of passions show a path travelled by the participants where they open up their possible adjacents, allowing to promote the emergence of innovation. (Loreto, Servedio, Strogatz & Tria, 2017).

The main artifacts collected in the process also allow to show the result of different processes and experiences that are carried out in the course with the aim of developing the four main skills to innovate in the fourth industrial revolution. This industrial revolution, as it was said before, has as its main characteristic the confrontation of new and complex problems (not disciplinary) before which, a revolution in the skills of professionals to face them is also necessary. In that sense, to obtain data regarding the development of skills of the participants it was applied the fractal rubric in 3 different moments of the process as evidenced in the following image:

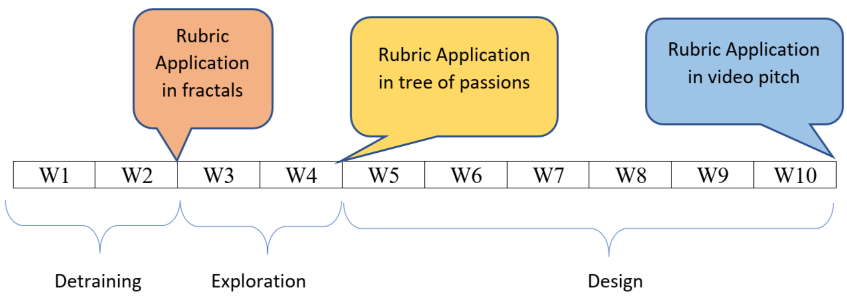

Figure 5. Development of Skills of the Fourth Industrial Revolution Course

From this evidence that allows an overview of progress, a comparative line was established to measure the changes around the 4C. For each skill two measurements were created to be used as evaluation criteria on the artifacts, in this manner each artifact allowed to estimate the 4C skills in terms of levels (levels ranges from 1 to 6 where 1 represented a difficult to evidence skill and 6 was an astounding development of it). The general results indicate that at the end of each of the 3 phases of the process the development of these skills increases by at least 20%, giving a 60% total increase according to the indicators of self and joint perception.

6. Main motivations, challenges and conclusions in the implementation of the PPBL in Colombia

The social impact process led by UNLab 4.0 in Colombia has been a challenge from its structure and the combination of methodologies in the implementation of projects. The integration of passion-based poiesis together with problem-based learning has made it possible to achieve an impact of more than 30,000 participants in Colombia and other countries of Latin America in three years.

However, although a positive impact has been seen, it is still necessary to face several challenges such as continuing working in the cooperation with other actors like State, private sector, academia and civil society in the adaptation and strengthen the UNLab 4.0 framework to close the social inequality gaps of the most vulnerable communities in Colombia, being the axis the participants, so that they become multipliers of the methodology in their communities and in such a way, dependency is not generated, but instead, an installed capacity is, so they can build their own topologies and projects in their environments with the support of soft and hard technologies from the fourth industrial revolution. Much emphasis is placed on cooperation, since innovation can arise from a cumulative process, based on small discoveries brought about by cooperation and information networks between different types of knowledge (Mora, 2011: P.240). Besides, to improve people's quality of life by focusing innovation and projects to solve local and complex problems.

Finally, the PPBL can close the inequality gaps and can generate innovation processes in the participants, in addition to acquiring knowledge and the necessary tools to create inside of the fourth industrial revolution. However, to achieve a positive long-term impact it is necessary that the PPBL is not anchored only to academia, it is necessary to link public institutions, companies, government and society, so that it generates a process of sustainability and enhances the skills of the people to become agents of change that can generate processes of food, energy, technological and cultural sovereignty to generate economic autonomy and thus close the inequality gaps in any territory where the methodology can be implemented.

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PBL Implementation - PBL for Professional Competence Development

Impact of Project Based Learning Approach on Higher Education in Teaching Communication Skills: A Case in Vietnam

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Abstract

This study investigates the impact of PBL technique on higher education in teaching communication skills at Duy Tan University, a large private university in the center of Vietnam. The influences of the PBL method are explored via a case study approach involving semi-structured interviews and LIWC (linguistic inquiry word count) analysis with two lecturers of English who have taught speaking and writing skills for over three years and sixty-one non-English-majored freshmen. The study's results suggest that PBL technique really makes students' communication skills much better. We consider the impact of PBL approach contributes significantly to enhancing the university's quality of teaching and learning communication skills. It is hoped that the new viewpoint on teaching communication skills through PBL activities will be applied widely in higher education in Vietnam.

Key words: impact; communication skills; project based learning; higher education.
Type of contribution: PBL research

1. Introduction

Nowadays in the era of scientific and technological development and the increasing global competition, there have been great challenges for young generation, the modern workforce. At the end of 20th century, a question was raised by a lot of educators "What skills do we need to provide our young generations to have a better life in the modern age with many technological and scientific changes?". Since the beginning of the 21st century, according to BIE (2016) a reference frame of crucial skills given has been considered as common core state standards in educational systems of a lot of countries in the world with some skills called 4C: Communication, Collaboration, Critical Thinking, Creativity. Certainly, the education with above mentioned 4 concepts will meet the requirements of modern life. In reality, the traditional teaching and learning method cannot adapt to the present situation of education, therefore PBL approach, a dynamic method which is quite different from traditional one gathers important factors satisfying the standard criteria in a new type of education. The use of PBL approach in teaching and learning often brings many benefits to learners, especially communication skills such as speaking and writing. However, in higher education in Vietnam PBL activities have not been paid much attention at universities. Maybe the usefulness of PBL approach has not been shown clearly and the traditional teaching and learning method has still been applied in teaching communication skills. Therefore, students after graduation hardly ever meet the needs of modern society connected with crucial skills: Communication, Critical thinking, Collaboration, Creativity. As a result, most graduates seem to be difficult to get jobs without 4C. Especially, to Vietnamese students the most important skill is communication and how we can help them get it is a hot issue. Consequently, it is necessary to conduct this research to find out how important PBL on teaching communication skills in high education in Viet Nam is and whether students' results are better after employing PBL or not. Duy Tan University, one of the leading private universities in the center of Viet Nam has employed PBL approach in teaching and learning since 2014 and initial results have been reported in recent researches such as (Nguyen et al., 2018) discussing on the importance of PBL in higher education, especially in teaching International Business with imported textbooks, (Tran, 2020) upgrading students' graduation theses through PBL approach. The current study was conducted at Duy Tan University with two lecturers of English and 61 first year non-English-majored students to give the different results between with and without using PBL in teaching and learning. It is hoped that the study will help lecturers of English at universities in Viet Nam get the knowledge of the importance of PBL and use it effectively in teaching communication skills.

This study is intended to achieve the following objectives:

To show the positive impact of PBL approach on higher education in teaching and learning communication skills.

To show advantages and disadvantages in using PBL approach in teaching and learning communication skills.

To suggest possible solutions to obstacles of using PBL approach to improve students' communication skills.

The research questions are formed as follows:

What is the impact of PBL on the quality of students' communication skills?

What are advantages and disadvantages of the implementation of PBL approach in teaching and learning communication skills?

What are possible solutions to obstacles of using PBL to improve the quality of students' communication skills?

2. Literature review

2.1. Overview on previous related studies

According to 21st century learning foundation, one of the most important theories which discusses learning process is constructivism (Steffe & Gale, 1995). The theory expresses the great impact of reflection on practice towards learners' learning quality (Weld & Funk, 2005). The roles of the teacher and the student are quite different from theirs in traditional method (Weegar & Pacis, 2012). Like a creator, the student will show his/her own thoughts and beliefs on new knowledge based on his/her experiences, whereas the teacher, as a facilitator should encourage students to develop their problem-solving skills by giving collaborative work and practical tasks (Ndon, 2011). As a matter of fact, constructivism mainly focuses on learners' learning activities and help them achieve both essential qualification and necessary skills in the modern age of science and technology.

In the early time, John Dewey (1897) believes, "*The school is primarily a social institution. Education being a social process, and the school must represent present life.*" (1897, P.7). Consequently, the educational strategy must focus on learners' role. Based on the principles of constructivism, one of the most useful methods is Project –Based Learning (PBL). PBL is considered as a learninng strategy organized with many various projects (Thomas, 2000), (Larmer, Markam, & Ravitz, 2003), (Bell, 2010). In reality, through PBL activities students can express their own ideas, adapt new knowledge in various real situations, reflect and give their assessment on their own learning strategy by working in collaborative teams with authentic tasks and learn how to solve problems on real life (Westwood, 2008). Blumenfeld, et al., (1998) claims that if the implementation of PBL in classrooms is successful, students will be motivated highly and fully engaged to the classroom activities.

The integrated learning, in fact, means that there is a great transition from receiving information to mastering and creating knowledge. In fact, there is a big distinction between traditional method and new method called PBL (project-based learning). While in traditional teaching teachers give planned projects at the end of learning procedure and then evaluate students' learning results, PBL allows students to integrate knowing and doing (Markham 2011). PBL is considered as a dynamic approach to teaching and learning (J. Stivers 2010) because PBL helps students explore real-life problems and challenges, concurrently develop crucial 21st century skills (4C) through working in small collaborative groups (Bell, 2010). At present, Project-based learning or problem-based learning (PBL) is being regularly employed in countries with advanced education such as The U.S, Singapore, and Finland. In Viet Nam, PBL has been used widely in teaching, especially in higher education since the beginning of the 21st century and it plays an important role in education because the new educational method can help students get the potential of critical thinking, creativity, solving problems.

Furthermore, if PBL is implemented flexibly, students can develop both their academic ability and their necessary soft skills such as communication and collaboration. Inspite of the appearance of PBL at the beginning of the 21st century and so many researches on PBL such as the crucial impact of PBL in high education in Viet Nam (Thien et al., 2018) in Viet Nam, challenges and solutions in the implementing PBL in English courses at a private central University (Bui, 2017), until now there are no researches on the impact of PBL on communication in universities in Viet Nam.

One of the main factors which will determine the result of learning process in 21st century is communication (Greenhill, 2010). Oral and written communication skills are really necessary and extremely useful for learners to get so that they can prepare themselves to overcome their obstacles in their real life more easily (Jerald, 2009), therefore it is said that successful language learners can employ their communicative skills in many various situations effectively. Through PBL activities, learners are always encouraged to express their own thoughts by being given opportunities to produce proper oral or written utterances. Clark & Clark (1997) considers that what a person produces by saying something will affect another one's point of view or thought, whereas, Harmer (1991) states that writing skill is the only language skill that we can touch and read. Anyhow, both of them become key components of 21st century education.

Until now there have been a lot of previous researches in the world on the influence of PBL on learners' language skills. Firstly, Imtiaz & Asif (2012) shows the importance of PBL in improving learners' language skills and motivating their autonomous learning in Pakistan. Secondly, Vicheanpant and Ruenglertpanyakul (2012) discusses that PBL creates a great impact on increasing Thai students' communication skill as well as brings positive attitude in learning process. Thirdly, in Iraqi Nassir (2014) demonstrates the essential difference on learners' English results before and after using PBL in classroom activities. Next, Rochmahwati (2016) also finds out positive influence of PBL on Indonesian learners' English speaking skill based on the results before and afer using PBL in teaching and the motivation on students' language learning. Moreover, Di Yang and Nattaya (2016) investigates effects of PBL on speakingabilities of non-English major Chinese. Furthermore, Ni, Luh, & Putu (2017) presents the results on the effect of PBL on students' English productive skills and how PBL activities make an influence on teaching and learning process in an Indonesian public Junior high school.

So far, there have been a lot of recent studies on the impact of PBL in higher education at PBL international conferences such as Nguyen Van Khanh (2015) suggests the improvement of ESP teaching and learning in Vietnam's higher education institutions by using PBL in ESP classes (English for specific purposes). Next, the research on Vietnamese students' awareness towards project-based learning was conducted by Anna et.al. (2016). Besides, the research by Diana et. al (2017) finds out the effect of PBL to oral production in English as a foreign language in a higher educational institution in Colombia. In conclusions, although oral and written skills have been playing an important part in learning process in 21st century, until now there have been no researches exploring the impact of PBL on communication skills in English at higher education institutions in Viet Nam. Consequently, it is necessary to conduct this study so that its findings will help Vietnamese learners of English enhance their communication skills more easily and lecturers of English implement PBL activities more often in teaching English in higher educational institutions. The innovation in teaching English contributes something useful to the increase of quality in higher education and produces skillful labour forces meeting the requirements of modern life.

2.2. Theoretical background

2.2.1. Definition of PBL

Since the beginning 21st century, Project or Problem-Based Learning has been considered as the most useful method in teaching, especially teaching foreign languages because PBL is one of the student-centered approaches implemented by a large number of higher educational institutions around the world as the most pedagogical method since it mainly aims at helping students enhance their self-directed learning process, show their own new knowledge based on the foundation of their experiences. The best thing is that PBL can give students good opportunities to develop crucial cognitive skills such as communication, collaboration, critical thinking, creativity, problem solving (Major, 2001). As a matter of fact, through PBL activities students can do independently their self-directed learning process and improve their acquired knowledge. Consequently, PBL can be thought of as the most successful small group teaching method which facilitates both the learning of knowledge and some other main skills including team work, problem solving, exchanging information, highly independent responsibility for learning, respect for others, and especially communication skills called key components in learning strategy in 21st century. In addition to PBL activities, modified PBL techniques should be provided for learners as the stimulant for learning.

2.2.2. The procedure of PBL implementation

In the procedure of Project-Based Learning implementation, sets of steps should be conducted (Moss & Van Duzer, 1998; Korkmaz & Kaptan, 2001) as follows

Firstly, learners choose and determine their topic of the project and show the way of solving the problem based on the teacher's guidance and suggestions.

Secondly, learners make a design of the project by inquiring information and acquired knowledge related to the content and objective of the project.

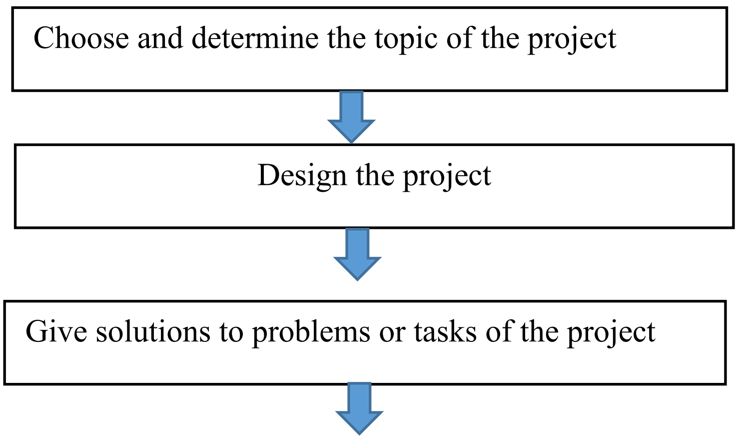
Thirdly, learners gather data analyzed and organized and apply their knowledge acquiring through the process of inquiring to give solutions to problems or tasks of the project.

Fourthly, learners mark out the important points of the project and make a plan of the presentation method.

Fifthly, learners design their presentation by discussing and pointing out essential information of the project and then present their project by employing their communication skills (oral and written).

Finally, learners give their comments on their work and receive the assessment from the teacher and other students.

Those above steps can be demonstrated in the following chart



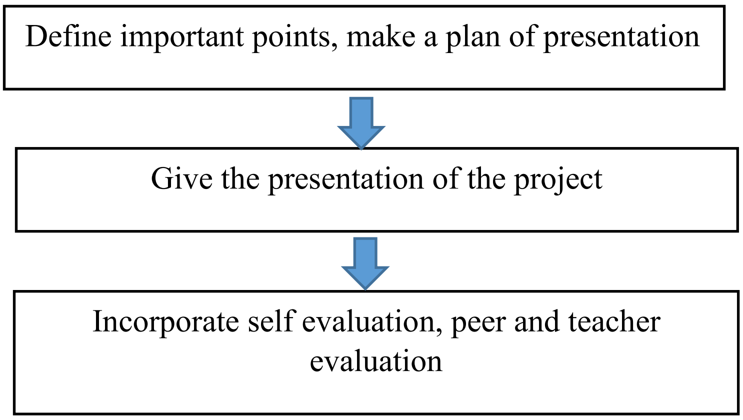


Figure 1: Procedure of Project –Based Learning implementation

Through above steps, students are trained to get used to working collaboratively and becoming an active creator with critical thinking, independent decision, problem solving.

2.2.3. Characteristics of PBL based on McClelland's three needs theory

In the 1960s, David MacClelland proposed his need theory based on Murray's work (1938) on the effects of human needs in a work environment. In his need theory, he proves that most people are constantly motivated by one of three basic needs: the need for affiliation, achievement, or power. Especially, students in PBL activities are certainly influenced by his three basic desires.

First of all, working in a small group, students' need for power is often shown in two different types: the need for socialized power and the need for personal power. In the former, students make descriptions of plans, self-doubts, mixed outcomes, and mutual concern, whereas in the latter, students try their best to look for power even must oppose others to get it. Working in a team, the best student with high power will dominate his/ her team like a leader of their team and become more argumentative, more assertive in a group discussion, therefore the teacher should encourage the need for socialized power in team work to avoid student's domination. Secondly, David considers the need for achievement as the attemp to overcome obstacles. It is very important because achievement is the last goal for students and a motive to strive for success. Thirdly, the need for affiliation is believed to be a feature that is very strong in most members in a team, especially in stressful circumstances. Two minds are better than one. It means that people will feel less stressed thanks to others' presence. Consequently, this trait is really neccessary in working collaboratively.

As a matter of fact, PBL methodology is an effective teaching-learning strategy to develop both students' socio-emotional skills and their academic knowledge. In educational context, they can confront issues in their daily life, looking for solutions to these issues by working collaboratively (Masson et. al, 2012). According to Stivers (2010) the most interesting feature of PBL is that PBL implementation varies from classroom to classroom, but it is characterized by the following common attributes

- Students make a design of their process for solving problem without a predetermined solution.
- Apart from important requirements such as critical thinking, problem solving, collaboration, PBL also demands the need of crucial content and various forms of communication skills.
- PBL gives students good opportunities to show their regular reflection on their task and learn to work independently and take responsilility for their task
- Assessment method on students' final product is quite different because scores are not good enough to evaluate the quality.
- The teacher becomes a facilitator rather than a leader.

Teachers should master characteristics of PBL approach to deal with obstacles occurring in implementation of PBL. Like any other teaching methods, PBL can be used effectively or ineffectively; however, at present it seems to be a dynamic approach which starts learning through experience, creates real-world context for a powerful learning community, has self-mastery and contribution to society.

3. Methodology

3.1. Case description

3.1.1. Research participants

At first, in our plan the study was conducted with 73 non-English majored students from 2 first year classes (one for speaking skill and the other for writing at Duy Tan university, Viet Nam, but latter because of other different reasons there were 61 students participating in the research. Among them are male: 11.48% and female: 88.52% in the school year 2019-2020. They all are first-year students whose age ranged from nineteen to twenty. Most of them are nineteen (98.36%), very few of them are twenty (1.64%) (see Table 1 below). Most of them spend all their time on English to develop their English communication skills because they specialize in English for hospitality and tourism. Besides, two lecturers of English who have ever used PBL in their teaching were invited to take part in focus group interviews.

Table 1: Freshmen's age and gender in two first-year non-English-majored classes

Class	Female	Male	Age 19	Age 20	Total number of students
ENG 229 JIS	29	3	31	1	32
ENG 229 LIS	25	4	29	0	29
Total	54	7	60	1	61
Percentage	88.52	11.48	98.36	1.64	100

3.1.2. Research instruments and contents of the questionnaire and the interview

Three research instruments which were in use to collect data are a questionnaire, focus group interviews, and the LIWC2015 software

The questionnaire for students consists of two parts: the background and the content (see Appendix B). The former proposes questions about students' background information including gender, age. The latter comprises the questions on their interest in PBL approach and the impact of PBL on their communication skills. Since 12 students were absent with different reasons, the questionnaire was distributed to 61 students at the same time to garner the clear data on general information and their interest in PBL approach.

Regarding the focus group interviews, two main interview questions and follow-up questions (see Appendix A) were used to collect lecturers' in-depth information about advantages and disadvantages encountered by their students and themselves when they used PBL approach in their teaching communication skills.

The LIWC 2015 software was really helpful in assessing the students' quality in communication skills. Among detailed variables the LIWC gives are four summary ones that reflect a 100-point scale ranging from 0 to 100. The variables include analytical thinking, clout, authentic, and emotional tone.

- Analytical thinking with high numbers shows formal, logical, and hierarchical thinking, whereas lower numbers reflect more informal, personal, here-and-now, and narrative thinking.
- Clout with high numbers demonstrates that the author is speaking from the perspective of high expertise and is confident, but lower numbers display a more tentative, humble, even anxious style.
- Authentic with high numbers suggests a more honest, personal and disclosing text, yet low numbers give a more guarded, distanced form of discourse.
- Emotional tone with high numbers is related to a more positive, upbeat style, vice versa low numbers are associated with greater anxiety, sadness, or hostility, especially a number around 50 shows either a lack of emotionality or different levels of ambivalence.

3.2. Data collection procedures

Sixty-one copies of the questionnaire were delivered to non-English-majored students in two classes, and all participants had fifteen minutes to give their answers to the questionnaires, and then sixty-one questionnaires were gathered.

At class, students in both classes were asked to take part in activities practicing speaking and writing skills given by their lecturers. At first, the lecturers were asked to give students speaking and writing activities before and after the implementation of PBL method in their classes. All students' tasks were recorded (in speaking class) and gathered (in writing class) by their lecturers. Later students' recorded speaking tasks were rewritten in the text files so that the LIWC could work with the data more easily. Especially in the writing class students had to complete their tasks in text files and then send to their lecturers.

Two lecturers of English using PBL in their teaching were invited to participate in focus group interviews carried out in Vietnamese and recorded for later analysis.

3.3. Data analysis

The results on advantages and disadvantages of PBL implementation collected from the focus group interviews of two lecturers of English at Faculty of English, Linguistics Institute, Duy Tan University were recorded and analyzed so that the most common ideas were chosen to show in the section of results and discussion.

The results of two surveys on students' interest in PBL approach and helpfulness of PBL to their communication skills were collected to show how interesting and helpful PBL approach is to non-English-majored students so that the study could give the impact of PBL approach on students' communication skills. In addition, possible solutions to obstacles of using PBL were suggested to improve students' communication skills.

3.4. Research methods

The main aim of the study is to find out the advantages and disadvantages encountered by non-English-majored students and lecturers of English at Duy Tan University and give some possible solutions to these problems; therefore, a mixed-method study was conducted with both qualitative and quantitative analysis. The surveys by means of using a questionnaire and focus group interviews were implemented with 61 first-year non English-majored students and two lecturers of English using PBL in their teaching. More importantly, the collection, analysis and presentation of the data were conducted thanks to the descriptive method to show the possible solutions to upgrade the quality of first year students' communication skills.

4. Results and discussion

4.1. Results of two lecturers' focus group interviews on PBL

After participating in focus group interviews, 2 lecturers of English at Faculty of English, Duy Tan University provided their own ideas on advantages and disadvantages of using PBL in teaching to upgrade the quality of students' communication skills. The following are their excerpts during the interviews

L1: *Well, to me PBL is really a good way to improve students' communication skills because they can have good opportunities to employ the language they have just learned before in real situations.*

L2: *It seems to me that PBL plays an important part in developing communication skills, since it helps students feel self-confident in expressing their own ideas and giving their critical thinkings.*

L1: *Through PBL, I think that students have to learn how to work both collaboratively and individually. Thanks to PBL activities, students will have to do their self-directed learning process; however, it takes lecturers a lot of time to control students' activities and give a suitable assessment.*

L2: *In fact, assessment by giving scores is not appropriate for students' final products. It is better for lecturers to use other assessment.*

L1: *One of my worries is whether lecturers are well trained in implementing PBL in teaching because it is very difficult for them to control all groups' activities at the same time. In fact, lecturers are considered as facilitators not leaders*

4.2. Results of students' survey on their interest in PBL and its impact on their communication skills

Followings are the surveys of English-majored students' interest in PBL and their remarks on the helpfulness of PBL approach.

Table 2: The survey of non English-majored students' interest in PBL

Students' interest in PBL	No	%
Yes	48	78.69
No	2	3.28
A little	11	18.03
Total	61	100

Through the survey, it can be seen that most of the students are interested in PBL approach (78.69%), some of them like it a little (18.03%), and a few of them do not like it (3.28%). As a matter of fact, PBL always attracts a lot of students thanks to its positive aspect, especially it helps more student participate in activities at class.

In order to find out how helpful PBL approach is to students, the results in the table 3 through the survey can show its helpfulness in learning.

Table 3: The survey on the helpfulness of PBL to non-English majored students

Levels of the helpfulness	No	%
High	45	73.77

Medium	13	21.31
Low	3	4.92
Total	61	100

With high level of helpfulness 73.77%, PBL is really helpful to students; however, a few of them do not find PBL helpful at all (4.92%) because of different reasons. Maybe they cannot be self-confident in expressing their ideas, or they cannot work collaboratively.

4.3. The impact of PBL on students' communication skills by using the LIWC software

The following results from two classes: ENG 229 JIS (speaking class) and ENG 227 LIS (writing class) have shown the remarkable improvement in using PBL in teaching and learning these two skills

Table 4: Results from ENG 229 JIS (speaking class) before using PBL

Filename	Segment	WC	Analytic	Clout	Authentic	Tone
1. txt.docx	1	100	73.88	54.00	96.63	99.00
2. txt.docx	1	96	53.31	55.20	55.79	92.40
3. txt.docx	1	82	81.23	31.29	97.62	96.29
4. txt.docx	1	132	72.53	50.00	95.30	89.31
5. txt.docx	1	255	77.88	52.65	17.08	86.75
6. txt.docx	1	208	80.05	46.15	63.54	97.65
7. txt.docx	1	67	77.34	38.25	92.99	80.01
8. txt.docx	1	222	84.47	69.00	25.87	98.82
9. txt.docx	1	82	55.57	40.36	77.89	48.39
10.txt.docx	1	150	39.52	51.92	30.86	91.14
11. txt.docx	1	147	79.28	27.03	98.42	91.78
12. txt.docx	1	57	73.21	29.92	96.09	97.58
13. txt.docx	1	167	42.69	67.90	24.01	97.95
14. txt.docx	1	73	73.09	20.56	90.21	99.00
15. txt.docx	1	154	57.19	71.35	44.24	97.38
16. txt.docx	1	115	42.82	43.08	71.17	25.77
17.txt.docx	1	79	85.19	55.02	94.09	49.32
18.txt.docx	1	88	57.84	36.66	89.14	99.00
19.txt.docx	1	160	60.61	63.30	35.37	72.57
20.txt.docx	1	223	52.20	44.89	94.30	50.91
21.txt.docx	1	86	89.37	24.26	98.24	95.29
22. txt.docx	1	88	70.88	58.97	85.21	85.42
23.txt.docx	1	130	73.14	67.77	72.65	89.84
24.txt.docx	1	111	35.57	86.02	25.87	42.09
25.txt.docx	1	100	53.26	50.00	96.63	96.76
26.txt.docx	1	134	64.54	35.44	88.99	99.00
27.txt.docx	1	92	73.26	68.04	40.55	93.61
28.txt.docx	1	91	53.34	66.98	99.00	93.91
29.txt.docx	1	140	51.04	69.14	66.59	78.19
30.txt.docx	1	113	85.41	46.46	93.49	86.87
31.txt.docx	1	70	48.58	61.26	99.00	93.21
32.txt.docx	1	61	81.89	31.15	99.00	56.75

Table 5: Results from ENG 229 JIS (speaking) after using PBL

Filename	Segment	WC	Analytic	Clout	Authentic	Tone
1.text.docx	1	203	95.59	67.12	58.37	99.00
2. text.docx	1	116	82.70	72.68	44.51	93.37
3.text.docx	1	360	71.36	75.64	70.08	84.54
4. text.doc	1	123	80.43	65.80	57.73	99.00
5. text.docx	1	429	53.25	70.42	67.66	56.59
6.text.docx	1	189	83.33	60.44	92.17	95.81
7.text.docx	1	232	74.71	81.87	62.09	58.39
8.text.doc	1	257	59.71	73.32	75.01	72.45
9.text.docx	1	241	92.87	91.93	87.33	57.15
10.text.docx	1	161	72.87	57.40	78.08	10.20
11.text.docx	1	182	84.75	77.92	83.15	96.55
12.text.docx	1	80	75.24	75.37	74.76	82.89
13.text.docx	1	161	51.29	79.04	75.49	93.61
14.text.docx	1	243	65.88	84.46	94.56	78.54
15.text.docx	1	167	95.21	64.05	57.46	92.57
16.text.docx	1	101	69.37	72.37	66.45	99.00
17.text.docx	1	311	55.61	86.21	57.23	62.36
18.text.docx	1	238	82.68	64.75	58.16	84.87
19.text.docx	1	126	85.16	56.31	58.07	82.57
20.text.docx	1	254	61.35	86.49	81.51	82.25
21.text.docx	1	152	53.47	52.63	71.57	50.32
22.text.docx	1	173	88.50	92.31	60.16	47.12
23.text.docx	1	181	80.64	86.54	91.56	99.00
24.text.docx	1	266	81.75	64.66	68.02	68.35
25.text.docx	1	256	70.82	77.10	50.62	90.36
26.text.docx	1	150	79.66	57.92	56.63	95.36
27.text.docx	1	185	71.72	99.00	93.05	75.85
28.text.doc	1	172	95.56	77.51	80.19	98.75
29.text.docx	1	157	62.32	79.61	66.91	89.62
30.text.docx	1	228	52.21	95.36	58.82	19.24
31.text.docx	1	365	73.75	62.88	86.66	87.10
32. text.docx	1	260	45.06	85.93	78.39	81.28

First of all, we can see the word count before using PBL (Table 4) is very different from WC after using PBL (Table 5) in the speaking class. For example, the highest number of words in table 4 is 223 and there are 14 students' speeches under 100 words, whereas in table 5 the highest is 429 and most of them are over 100. It is clear that after PBL is implemented the number of words spoken is increasing remarkably. In addition, in analytical thinking most numbers after using PBL are much higher than those before using PBL (the highest and the lowest: 89.37-35.57 and 95.59-45.06). It means that PBL really helps students get formal, logical and hierarchical thinking. Besides, in table 5 most numbers in Clout are higher than those in table 4 (the highest and the lowest: 86.02-20.56 and 99.00-52.63), which means that most of the students are speaking from the perspective of high expertise and they are quite self-confident. Moreover, high Authentic numbers in table 5 show that speakers presented their speech with a more honest, personal and disclosing thoughts. Last but not least, the results in emotional tone express more positive and upbeat style. The results in below tables also show the positive changes in writing skill.

Table 6: Results from ENG 227 LIS (writing) before using PBL

Filename	Segment	WC	Analytic	Clout	Authentic	Tone
1.txt.docx	1	100	49.86	72.57	25.24	25.77
2.txt.docx	1	216	63.27	66.17	9.03	92.40
3. txt.docx	1	130	84.19	80.12	4.43	99.00
4.txt.docx	1	204	47.41	53.92	31.67	71.75
5.txt.docx	1	126	66.26	50.00	4.97	95.81
6. txt.docx	1	307	85.42	31.26	15.79	68.79
7.txt.docx	1	170	19.60	70.21	22.52	99.00
8.txt.docx	1	158	54.12	71.55	36.87	25.77
9. txt.docx	1	232	77.56	36.51	45.09	74.00
10. txt.docx	1	106	68.63	80.20	54.63	77.79
11. txt.docx	1	164	74.84	47.56	8.61	96.29
12.txt.docx	1	104	62.88	42.37	13.65	89.84
13.txt.docx	1	305	81.89	44.79	6.97	79.54
14. txt.docx	1	103	40.63	68.62	27.85	25.77
15. txt.docx	1	153	66.38	60.32	66.34	50.14
16. txt.docx	1	95	77.17	58.33	24.41	65.65
17.txt.docx	1	168	60.75	70.40	23.51	95.81
18. txt.docx	1	105	76.13	42.44	21.13	95.81
19. txt.docx	1	123	63.11	40.36	25.63	99.00
20. txt.docx	1	235	57.74	77.82	6.52	95.43
21. txt.docx	1	19	35.06	14.62	96.09	97.58
22. txt.docx	1	212	67.00	33.55	33.22	77.79
23. txt.docx	1	200	49.33	59.88	4.01	91.14
24. txt.docx	1	336	63.63	62.20	28.32	65.25
25. txt.docx	1	114	50.45	46.49	28.23	99.00
26. txt.docx	1	208	74.94	76.46	7.84	43.27
27. txt.docx	1	169	74.26	66.08	15.04	86.98
28.txt.docx	1	163	89.12	70.97	10.57	93.27
29.txt.docx	1	122	73.17	57.44	14.89	91.91

Table 7: Results from ENG 227 LIS (writing) after using PBL

Filename	Segment	WC	Analytic	Clout	Authentic	Tone
1.docx	1	260	65.06	85.93	38.39	81.28
2.docx	1	212	79.46	76.05	44.56	18.79
3.docx	1	246	54.10	64.29	66.63	56.48
4.docx	1	238	68.29	64.75	67.20	10.03
5.docx	1	315	67.48	72.67	78.21	67.75
6.docx	1	253	66.74	80.77	49.27	55.58
7.docx	1	254	90.85	74.85	89.20	63.09
8.docx	1	204	87.41	53.92	61.67	71.75
9.docx	1	361	84.19	68.10	72.54	62.54
10.docx	1	406	81.55	71.45	33.67	71.95
11.docx	1	336	84.83	69.36	35.37	65.25
12.docx	1	338	94.76	70.29	15.04	53.59
13.docx	1	210	60.73	51.90	31.42	52.57
14.docx	1	289	93.57	71.02	41.58	44.80
15.docx	1	243	46.37	50.00	55.36	92.04
16.docx	1	236	49.32	63.27	22.80	19.45
17.docx	1	259	40.48	78.01	36.43	32.39
18.docx	1	410	58.87	77.52	34.05	53.27
19.docx	1	170	57.69	86.82	19.70	86.75
20.docx	1	226	80.62	76.06	59.92	67.58
21.docx	1	198	83.93	54.04	41.42	18.34
22.docx	1	296	68.53	70.57	47.39	20.64
23.docx	1	285	80.77	74.76	65.55	31.77
24.docx	1	550	81.22	77.75	60.18	73.32
25.docx	1	184	53.96	45.67	51.30	66.89
26.docx	1	267	85.13	71.29	76.48	32.19
27.docx	1	228	68.93	73.03	44.54	41.64
28.docx	1	175	75.04	99.00	98.53	85.64

When the research was conducted at the class ENG 227 LIS, at first 29 essays were collected (before using PBL), but later there was an absentee (after using PBL), however the results analyzed by LIWC software are accepted because of their reasonableness. As be seen in table 6, the number of words in students' essays is quite low even some of them have under 100 words, whereas in table 7 the number of words increases rapidly (the least is 170 words), which shows that students have a lot of ideas to express their opinions after PBL is used. Especially, lower Analytic numbers in table 6 (19.60-89.12) also reflect more informal, personal, here-and-now, and narrative thinking, while high Analytic numbers in table 7 (40.48-94.76) confirm that most of the students achieve logical and hierarchical thinking. In addition, low Clout numbers in table 6 (14.62-80.20) suggest a more tentative, humble, even anxious style, on the other hand high Clout numbers in table 7 (45.67-99.00) show that writers are always self-confident with high expertise. Moreover, lower Authentic numbers in table 6 display a more guarded, distanced form of discourse; however, higher Authentic numbers in table 7 are associated with more honest, personal, and disclosing text. There is a big difference between numbers in emotional tone in table 6 and table 7. Maybe PBL employed in class could have made most of the students anxious, even they are worried about their work.

4.4. Advantages and disadvantages of using PBL approach

According to above results 4.1, 4.2, and 4.3, we can see the important role of PBL technique in improving students' communication skills remarkably. It helps students feel more self-confident in expressing their opinions and know how to work both collaboratively and individually, especially working in groups will empower students to design their work effectively, which stimulates their creativity. However, it seems to be difficult for teachers to assess students' work by giving scores as usual. Scores may not be exact because what students need is their teacher's evaluations or comments so that they can recognize their good or weak points to get their self-directed learning process. In addition, it takes a lot of time to apply PBL approach in teaching and learning process, especially controlling all groups at the same time is not easy, so it is necessary to have a professional teaching staff trained well in using PBL.

4.5. Possible solutions to obstacles of using PBL to improve communication skills

First of all, instead of assessing students' final products by giving scores lecturers can use levels A, + A, - A, B, + B, - B… and give their comments on students' work. By this way, students will feel more comfortable and easier to improve their weak points exactly. Secondly, the teaching staff should be trained well in using PBL and they often participate in PBL workshops to update new techniques in employing PBL. Sometimes they should have opportunities to exchange their ideas on PBL approach, which is a good way to improve their teaching. Last but not least, in order to avoid taking time, lecturers should make their own plans before class. They also have ability to give flexible solutions to obstacles at once, especially lecturers must understand their students' requirements.

5. Conclusion

PBL approach has already contributed a lot to education in general and in teaching and learning a foreign language in particular since its first appearance in the 21st century. The implementation of PBL approach has brought a lot of remarkable improvements in students' communication skills such as encouraging students to work collaboratively, helping them feel more self-confident in expressing their own ideas, and enhancing students' self-directed learning process. However, there are some problems in using PBL in teaching and learning communication skills including teachers take a lot of time to prepare lessons before the class, it is difficult for them to control all groups at the same time, and assessment by giving scores is not appropriate. In order to solve problems, some possible solutions are giving comments or evaluations by using levels A, B, C…, holding workshops on PBL to help teachers exchange their ideas in using PBL so that they can know how to control all groups at the same time effectively, and especially all teaching staff should be trained well on PBL approach. It is hoped that readers will find out some useful information on PBL in developing students' communication skills to meet the social requirements in the 21st century with crucial skills: Communication, Critical thinking, Collaboration, Creativity.

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Appendixes

A. Questions **used in the focus group interview for two lecturers of English**

1. What are advantages and disadvantages of using PBL in teaching to upgrade the quality of students' communication skills?

2. What are possible solutions to obstacles of using PBL approach to upgrade the quality of students' communication skills?

B. Questions for students' survey questionnaire

1. What is your age?

- ☐ 19
- ☐ 20
- ☐ Over 20

2. What is your sex?

- ☐ Male
- ☐ Female

3. Are you interested in PBL approach?

- ☐ No
- ☐ A little
- ☐ Yes

4. How helpful is PBL to your communication skills?

- ☐ High
- ☐ Medium
- ☐ Low

Teachers' decision-making implications for the development of students' autonomy in the transition to PO-PBL model

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Abstract

Different processes at the Faculty of Engineering of the Universidad de Los Andes identified that to develop skills and competencies necessary in this century, it was essential to create courses with PO-PBL curricula in all programs. Since 2018, the Faculty has implemented the Multidisciplinary Engineering Design Project course as a space for curricular innovation to explore project-oriented courses. According to the literature, the teacher's role in PO-PBL is diversified considerably and includes five dimensions: facilitator, advisor, designer, model, and resource provider (Kolmos et al. 2004, Hernandez et al. 2015, Dahms et al. 2017). This diversification implies a profound epistemological change reflected (or not) in the teacher's daily pedagogical practice and affects curricular reform. This study explores: what has been the process of adoption and adaptation of teachers to the PO-PBL principle of development of autonomy in students? Using a qualitative approach, information was collected on four semesters through class observations, teachers' interviews, and document analysis, and they were analysed by triangulating. The results show 1. The course's design proposes a considerable space for the students' autonomous work; the teachers in practice end up taking a good part of that space for the magistrality or the projects' frequent supervision; 2. Teachers consider autonomy essential, but they do not believe that their students are prepared to work autonomously and do not provide the spaces or tools to develop this competence effectively; 3. Some teachers created an autonomous supervised workspace where students work on projects in the teacher's presence, who quickly address concerns and corrects processes to avoid mistakes. These results imply that to implement the proposed curricular reform, it is necessary not only teachers' participation in the course but also to generate spaces for reflection and analysis of the model that allow them to transform their pedagogical practice.

Keywords: Teachers' role, Decision-making, Students´ autonomy, Curriculum change, Teachers' learning process

Type of contribution: PBL research

1 Introduction

Since 2016, the University of los Andes in Colombia has been developing a curriculum reform process to better respond to local society's demands with the graduates of its educational programs. In particular, the Faculty of Engineering has considered its accreditation results and recommendations with ABET as one of the elements for reflection in its programs' reform. Hence the need to generate explicit curricular spaces for the development of competencies what has been called project-oriented courses, which curricular model is the PO-PBL (Kolmos, Flemming, & Lone, 2004; Hernández, Ravn, & Valero, 2015; Dahms, Sliid, & Dalsgaard, 2017).

Six basic principles characterize PO-PBL: 1. the problem is the basis of learning; 2. the project is the framework that organizes learning; 3. the courses support the work on the project; 4. cooperation is the basis of project work; 5. cooperation work must be exemplified; 6. students are responsible for their own learning achievements. Although these principles guide the curricular design of a PO-PBL course, it is not a prescriptive model in the detail of its implementation since it can be carried out in very different ways and still maintain these six fundamental principles (Dahms, Sliid, & Dalsgaard, 2017).

These principles involve considerable complexity in both the role of the teacher and the student. In a traditional curriculum, the teacher is mainly in charge of selecting, organizing, and presenting the discipline's relevant information, and verifying an adequate reproduction of the student's said information. For their part, the student is primarily responsible for receiving such information, memorizing it, and demonstrating that they can reproduce it correctly (Posner, 1992). In a PO-PBL curriculum, in addition to providing relevant information on the discipline, the teacher is a model of performance in the profession, feedback of student performance, a facilitator of self-evaluation of the practice, a stimulator of dialogue between peers, a promoter of self-esteem and motivation in the student, among other elements that complicate their work. For their part, in addition to being a receiver and reproducer of disciplinary information, the student is an administrator of learning resources, a decision-maker, a manager of their use of time, an interdependent co-operator, among other elements that make them a highly active participant in the learning process (Dahms, Sliid, & Dalsgaard, 2017).

These principles and roles, implemented continuously and consistently during training, lead student to develop greater autonomy in managing their own learning process. That is to say that, over time, the student displays an intrinsic motivation to learn, an initiative to deepen the knowledge of their environment, and, consequently, they can design and execute their own social and metacognitive processes to achieve their learning objectives.

According to Wenger (2001), the development of skills and competencies happens through the continuous and prolonged participation of the learner in the scenarios where that skill is practiced, together with the guidance of an expert, so that the learner becomes more and more skilled in practice and, therefore, they improve their performance by having increasingly competent participation that progressively leads them to be an expert themselves. This way, participating in a PO-PBL course not only leads the student to develop skills for teamwork and critical reasoning, but also to the acquisition of organizational habits and control of their own behaviour through planning, monitoring, and evaluating their own activities (Gutiérrez, de la Puente, Martínez, & Piña, 2012).

In 2018, the dean of the engineering department promoted the creation of the Multidisciplinary Engineering Design Project - MEDP course as an experiential reference for teachers in the discussion about the design and implementation of PO-PBL in the diverse programs offered by the department. Between 2018 and 2019, the department invited students from the last three semesters of various engineering programs to participate in MEDP every semester, also professors from different engineering fields to participate in the accompaniment and supervision of work teams, and as well as corporations / communities to participate as a context for the development of projects. This study aims to analyse the way teachers of the MEDP course adopted and adapted the curriculum characteristics of the course that promote the development of autonomy in students. The systematization and analysis of teachers' decisions in their practice can determine the students' experience in the course.

2 Context

Inspired by the PO-PBL model, MEDP seeks to ensure this curricular model's principles and roles through a specific curricular design. The course begins with the formation of work teams between students of various engineering fields. Each team selects an available context for the development of the project, identifies a problem, and proposes a solution that contributes to improving the situation. In the process, students are accompanied and supervised by a group of teachers from diverse engineering fields, who guide students in developing the project. Table 1 shows the variation in teachers' participation during the two years of implementation, and it is being taken in this article as a source of empirical data. The total number of teachers who participated in MEDP at least once during the two years was 24, representing 20% of the department's teachers.

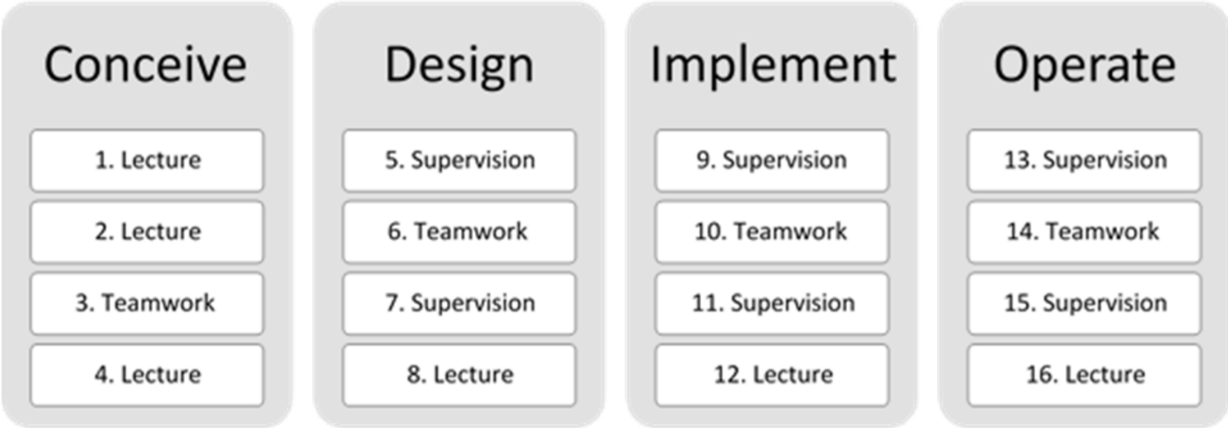
Table 1: Semiannual variation in the participation of teachers in MEDP.

Period	Total teachers	New at MEDP	Ancient at MEDP	Total MEDP	% teachers at MEDP
2018-1	123	16	0	16	13%
2018-2	123	6	13	19	15%
2019-1	123	2	9	11	9%
2019-2	123	0	8	8	6%

In its curricular design, MEDP is a course of 16 weeks and three academic credits where students' estimated dedication is expected to be 144 hours in total. One academic credit, in Colombian regulations, is equivalent to 48 total hours of student work (Ministerio de Educación Nacional , 2020). In the course syllabus, these hours are distributed in synchronous activities with the teachers and asynchronous activities without them. Synchronous activities are of two types: lecture sessions and supervision sessions. In lecture sessions, all students attend the classroom to receive general instructions on developing projects, orientations for developing teamwork skills, and carrying out formative evaluation activities. In the supervision sessions, each work team meets with their teacher-advisors to present progress, make decisions about the project and receive specific guidance. On the other hand, asynchronous activities correspond to the time allocated to teamwork, where students meet autonomously in their teams to develop the tasks associated with their projects' advancement.

The course is divided into four stages that reflect the CDIO (Conceive - Design - Implement - Operate) methodology of engineering design (Dym, Little, & Orwin, 2014), four weeks each. Of the 144 estimated hours of student dedication, 18 (13%) are for class activities, 6 (4%) for supervision, and the remaining 120 (83%) are for autonomous work related to the progress of the projects. Illustration 1 shows the distribution of these activities throughout the semester.

Illustration 1. MEDP session planning



Compared to the general model of a traditional 3-credit course, of the 144 estimated hours of student dedication, 48 (34%) are for lectures, 32 (22%) for laboratory activities, and 64 The remaining (44%) are for individual work activities determined by the teacher. Table 2 shows a comparison of the student's expected dedication in the course activities according to the curricular design.

Table 2: Students' activities and dedication per curricular model.

MEDP			**Traditional course**		
Activity	**Hours**	**Dedication**	**Activity**	**Hours**	**Dedication**
Lecture	18	13%	Lecture	48	34%
Supervision	6	4%	Laboratory	32	22%
Autonomous work	120	83%	Independent work	64	44%

There are several significant differences between the two models. The first is a considerable reduction in the lectures' time, which reduces teachers' opportunities to intervene and control the students' learning process. The second is independent work means that students spend this time (44%) on activities predetermined by the teacher, such as previous readings or assigned exercises, opposite to MEDP where autonomous work is doubled (83%) than a traditional course and implies not only time without the teacher's intervention but space for students to take charge of generating routes for their learning. Students spend part of this time in the laboratory in many cases, but not developing predetermined practices but experiments or measurements that contribute to their projects' concrete development. This distribution of time is the main characteristic of the MEDP curricular design for students' autonomy development. In this study, we are specifically interested in knowing: **what has been the process of adoption and adaptation of teachers to the PO-PBL principle of autonomy development in students**?

3 Methodology

To answer this question, we use a qualitative research approach that seeks to know and understand the participants' experience in the situation or phenomenon of interest. The methods used in this research were based on the following ethical considerations:

- We maintain the anonymity of the participants.
- We sign informed consent for the use of the information.
- We guarantee that said information would not have repercussions on the participants' administrative and teaching tasks within the institution.

To record and systematize the information, we used the semi-structured interview with teachers, the observation of sessions, and the documents' content analysis. The interview is a conversation whose purpose is to know and understand the interviewee's perspective through the meanings of their experiences related to the phenomenon of interest (Álvarez-Gayou, 2003). The interview's objective was to find out the experience and perspectives of the teachers who participated in MEDP as advisers to the work teams regarding the distribution of activities proposed in the curriculum design of the course. All interviews were conducted in person and individually at the interviewee's office within the faculty facilities and were audio-recorded.

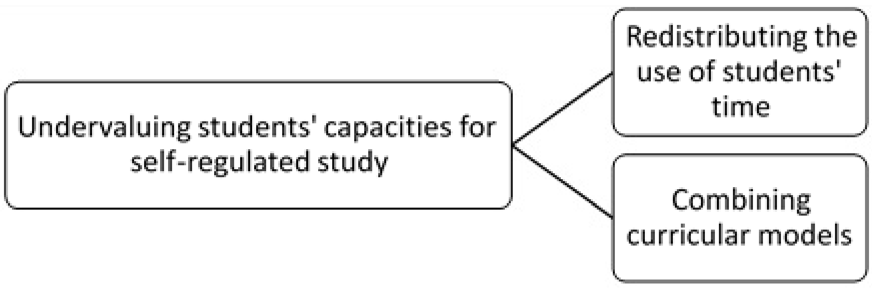
On the other hand, observation is a qualitative technique that consists of active or passive participation in the scenario of interest and is registered through notetaking of what the observer considers relevant to consider for his research. The observation objective of different MEDP sessions was to know and classify the activities carried out by teachers and students, and they were registered by taking handwritten and digital notes. Finally, content analysis is a technique that allows studying documents as a form of human communication that contains the interests, ideas, and values of the human groups that produced them. (Akkus, Nur-Sari, & Uner, 2012). The primary analysis document in this study is the PMDI syllabus, which contains the course syllabus. This document's analysis's objective was to know the characteristics of the course related to the development of autonomy in students.

The information analysis was carried out through triangulation to promote quality in the data interpretation process. Triangulation is a contrasting strategy between various sources of information that, when put together, allows a better understanding of the experience and the phenomenon. Additionally, triangulation does not have a specific moment of the investigation dedicated to data analysis, but rather it is a process carried out in parallel to the generation of information (Flick, 2007).

4 Results and discussion

The making of three specific decisions characterizes the process of adoption and adaptation of MEDP teachers to the PO-PBL principle of development reflected in the course's curricular design through a specific distribution of activities. These decisions had critical implications in how this design came to be embodied in the students' experience throughout the course: undervaluing students' capacities for self-regulated study, redistributing the use of students' time, and combining curricular models. The order in which we present the decisions is not due to a timeline in which the teachers would have made them, but to an analytical subordination that simplifies this process's complexity (see Illustration 2).

Illustration 1. Decision-making subordination



4.1 Undervaluing students' capacities for self-regulated study

Unanimously, the interviewed teachers consider essential the development of autonomy in students: "*for an engineer, autonomy is critical because in a job you cannot go around asking permission to do what you know how to do: an engineer creates, designs, and solves, and you can't do any of that if you are not an* *autonomous professional*". However, at the same time, they consider that their final semester students are not prepared for this type of work: "*Today's students are not interested in deepening their knowledge. In my time, you had to dive into studying without the teacher asking. Today, not even by leaving the task, they do It".*

These excerpts from the interviews show the perception that teachers have about their students' attitudes and skills. They also reflect a lack of knowledge about how to stimulate and guide the development of a learner's skill that, according to Wenger (2001), happens through the student's constant participation in the scenarios where the skill is practiced and with the guidance of an expert. Under this ignorance, teachers assume that MEDP, far from promoting the development of autonomy in the student, presupposes said ability as a requirement to have a good performance in the course: "*To think that* (students) *are going to work autonomously from one moment to another it is challenging, it will not happen*". That autonomy is a requirement for students in the last three semesters seems reasonable, but there are no other courses of this type in current programs where this process occurs; therefore, the curricular tension is evident in this process.

Further, some teachers consider that the time students are given for autonomous work in MEDP (83%) is a space in which they work disorderly since they do not receive the pertinent indications to advance in developing a solution. According to a teacher: "*exposing them* (the students) *in this way to spaces where they do not receive relevant orientation would not be responsible. You have to be there for them, showing them, guiding them, motivating them"*. This position reflects a strong root in teachers of the provider of relevant information of the discipline (Posner, 1992), typical of the traditional curricular model. It also shows resistance to adopt the character of the promoter of student self-esteem and motivation, the stimulator of dialogue between peers, facilitator of self-evaluation of practice, among other attributes of teacher's role in the PBL-OP model.

Similarly, this resistance (to some extent unconscious) limits the student's possibilities to manage their own time, manage their learning resources, collaborate with their peers, among other characteristics of the student's role in PO-PBL. Consequently, maintains them in the role of receiver and reproducer of the information that teachers provide in the curricular model of a traditional course: "*You cannot abandon them* (the students)*, and even less in a project with external organizations where the name and prestige of the university are at stake. That is practically condemning the project* "*.*

Additionally, teachers conceive MEDP spaces for teamwork (which, remember, are 4 out of 16 weeks) as a free time that leads to the failure of projects and, consequently, can harm future job opportunities for students: "*Leaving so much free time (to the students) not only disorients them and gives them a false feeling that the project is easy (…), but it can leave them in a bad way in front of the companies. Furthermore, we, as teachers, are there precisely so that this does not happen. On the contrary, if they are hired for their work on these projects, it would be great*". This stance shows teachers' deep-rooted emphasis on the quality of product and carelessness or neglect of the process. This idea generates pressure on the student to demonstrate good performance immediately. This condition automatically removes them from the active role and administrator of their own learning and makes them a staunch demanding of the adequate information that the teacher can provide for the development of the project. With this, both actors return to their traditional roles.

The strong tension between teachers' conception of autonomy as a prerequisite of the course and the reality of programs where there is no pedagogical space for its development has consequences for teachers. First, it reinforces their position of undervaluation of the students' capacities for autonomous work; second, it is challenging to understand MEDP as a scenario for developing said ability; third, they were to make one or the other of the following two determinations.

4.2 Redistributing the use of students' time and combining curricular models

From the role of provider of relevant information of the discipline, some teachers chose to reorganize the students' use of the time: "*I did ask (the students) to meet weekly so that they are more focused and do not wear out in unfeasible solutions, or that just don't come together. As a teacher, you already know what the problem is and what solution is needed. (…) Four weeks lost in a 16-year project; it is something that shows in the final product*". This decision resulted in a sequence of different activities from the one proposed in the course design, which replaces teamwork sessions with supervision sessions and increases the number of sessions per week (see Illustration 3).

Illustration 1. MEDP adjustment in practice

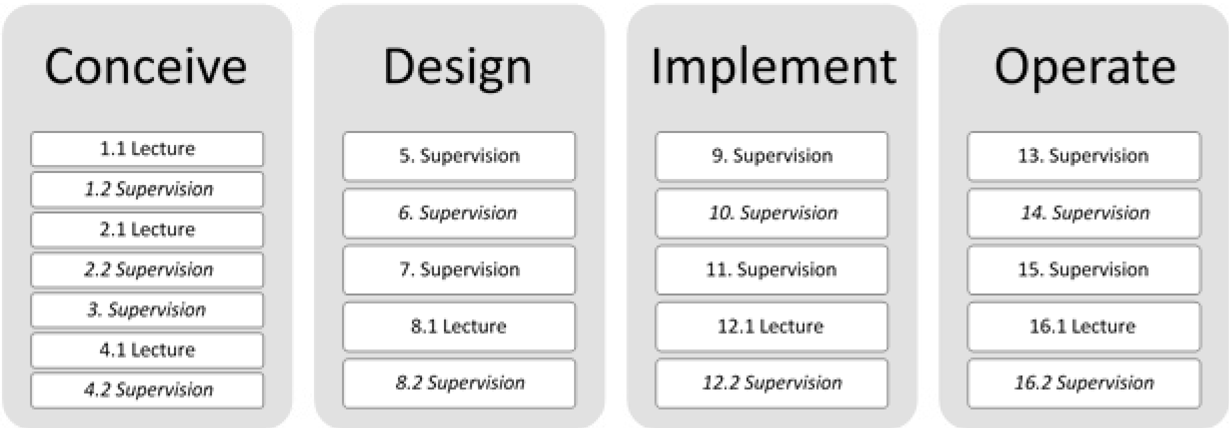


Illustration 3 shows in italics that, in addition to the regular class sessions with the entire course, the students had weekly supervision sessions with the advisor teacher of approximately two hours due to the diverse needs that the teacher had to satisfy with the team. This change is consistent with the interviews where the teachers expressed that "T*he meetings with the teams take a long time because we have to level them on issues that not everyone has seen because as they come from different careers, and sometimes the challenges are from a specific area, so we have to teach them that (...) We do not delay an hour in that; it takes about two*". This redistribution of the use of students' time modifies the distribution of their activities in the course concerning the curriculum design. It ends up relocating them in the passive role of receiver and reproducer of the information provided by the teacher with 18 hours of lecture (13%), 32 hours of supervision (22%), and 94 hours of independent work (65%).

Generating a weekly meeting with students gives teachers a sense of security regarding the project's appropriate progress, as it allows them to determine further the activities that students carry out week by week by assigning specific commitments. In this way, it is the teacher who decides whom to meet, where, what to do, and for how long: "*You* (the teacher) *are like the manager of that project, I cannot just wait for them to look for me and they self-regulate, they do not know how to do that, also because it doesn't depend on them. It is my responsibility to coordinate them so that they can work as a team so that they can move forward*". Thus, the students' weekly activities lose the character of autonomous work and become independent work where they are dedicated to carrying out the teacher's tasks.

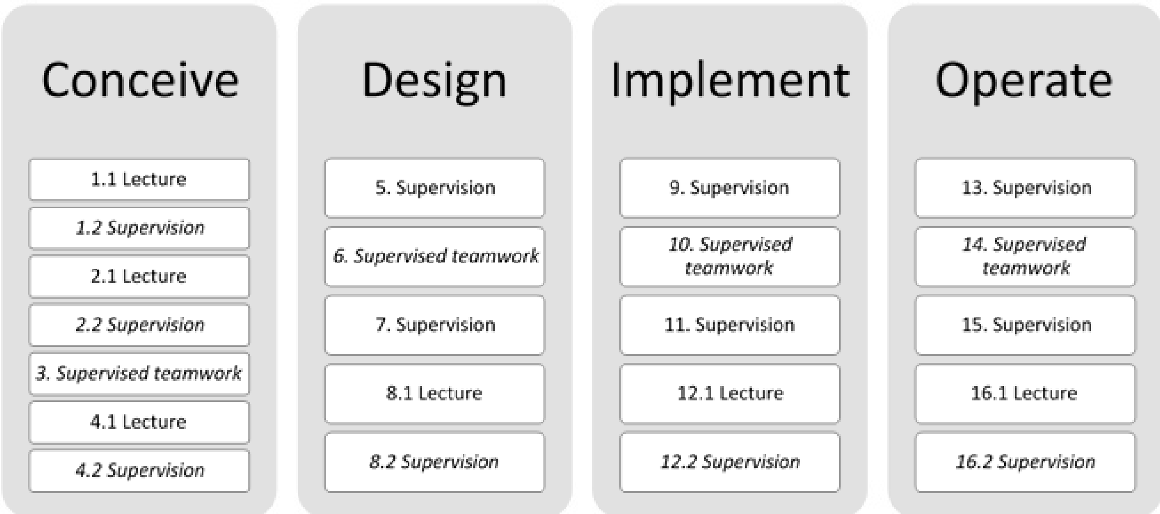
4.3 Combining curricular models

As well from the role of provider of relevant information of the discipline, although interested in testing the performance of the students in the teamwork spaces proposed in the MEDP curriculum design, some teachers decided to allow these spaces and, also, to participate so that the work team could be at their fingertips in case a quick intervention is necessary. This decision resulted in a space we call supervised teamwork.

According to the observations made, supervised teamwork is an adjustment in the practice of some MEDP teachers that consists of asking students to hold their teamwork meeting of the week in the classroom and at regular course hours so that the teacher can be present in the room to intervene in the team meeting when he considers it pertinent and / or when the students request it. According to one of the teachers who opted for this adjustment: "*logistically it is easier to accompany them* (the students) *like this in those meetings because I can make sure they are actually meeting to work, I can observe them, and if questions arise, I am there to solve them, because sometimes a simple question can be delayed while you respond and meanwhile the project remains quiet* ". This adjustment in practice shows how the teacher, as a provider of relevant information, corrects the course design in practice so that the student can play their role as receiver and reproducer of information. With this, the teacher prevents the student from making decisions, managing their resources, and cooperating interdependently with their peers, since they are the ones who quickly address the concerns of the team, correct their discussions, and avoid errors that could delay the development of the project.

These teacher interventions in teamwork can be classified into two types. On the one hand, there are disciplinary interventions where the teacher explains to the team engineering concepts necessary for the project's development. On the other hand, the teacher makes logistics interventions that give the team ideas for the relationship with the company or context; and the planning and division of work associated with the project. Thus, instead of the four sessions of teamwork proposed in the design of MEDP, this decision led to carry out four sessions of supervised teamwork (see Illustration 4).

Illustration 1. Second MEDP adjustment in practice



Like the results of decision number two, where work without the teacher loses the character of autonomous work and becomes independent work determined by the teacher, with this decision to supervise the students' teamwork, the PO-PBL principle of autonomy development is also compromised. Table 3 describes a cumulative comparison of students' time use that shows how with this decision, which attempts to negotiate and integrate elements of PO-PBL and a traditional course curriculum, students end up being supervised even more than in the scenario of the second decision since the supervised teamwork sessions lasted approximately three hours.

Table 3: Student's use of time in different curricular models.

Traditional course			MEDP Design		
Activity	**Hours**	**Dedication**	**Activity**	**Hours**	**Dedication**
Lecture	48	34%	Lecture	18	13%
Laboratory	32	22%	Supervision	6	4%
Independent work	64	44%	Teamwork	120	83%
MEDP in practice			**MEDP in practice II**		
Activity	**Hours**	**Dedication**	**Activity**	**Hours**	**Dedication**
Lecture	18	13%	Lecture	18	13%
Supervision	32	22%	Supervision	32	22%
Independent work	94	65%	Supervised teamwork	12	8%
-	-	-	Independent work	82	57%

According to the teacher who designee the MEDP curriculum, the purpose of the distribution of activities with a significant dedication to autonomous work is to provoke and allow students to manage their own progress in the project and to experience what for some is disorientation and for others it is freedom: "*the temporary distancing from the figure of the teacher leads to the students having to communicate and work collaboratively to advance the project and, in this way, present progress (or delays) to the teacher in the next supervision session*". When this scenario does not occur, that is, when the teacher is far from assuming the more complex roles of the PO-PBL and the students have little or no stimulus to reflect on the consequences of their actions, their idea of needing the teacher to define their learning routes and, consequently, the dependency relationship between both actors is perpetuated.

5 Conclusions

The purpose of this article was to analyze the process of adoption and adaptation of teachers to the PO-PBL principle of development of autonomy in students and is part of a broader investigation. Our analysis shows that the teaches' adaptation process at the beginning of the development of autonomy in students, typical of the PO-PBL curricular model, was characterized by three decisions that determined in various ways the experience of the students in the course. On the one hand, teachers decided to believe and maintain that their students are not autonomous. On the other hand, this position led them to modify the course proposal concerning this principle, and, consequently, it was blurred in the teachers' practice. The scope of this document does not explore students' perspectives on these aspects but is addressed in the entire research.

The time gained with these decisions is occupied with activities where the teacher can direct the project's development to a greater extent through direct interaction with the students (supervisions), which reinforces the teacher's role as organizer and exhibitor of the relevant information of the discipline. Finally, the emergence of supervised teamwork increases the teacher's intervention in the project, achieving the opposite effect of the student taking over the project. In this way, less time for autonomous work and more time for teacher intervention indicates that for the teachers, the experience of students working without them is less relevant in the learning process.

Although teachers explicitly state the importance of strengthening autonomy, their decisions in practice limit the deployment of the PO-PBL curricular model's tools related to this purpose and reduce the student's opportunities to take charge of their learning. Therefore, this principle of the PBL-OP was compromised in the experience of the students.

This scenario describes a vicious circle in which the teacher must provide the student with relevant information because they consider them incapable of being autonomous; simultaneously, the teacher considers that the student is incapable of being autonomous because they must continuously supply with relevant information. This dynamic is nurtured by the same vicious circle in the student's role: the student receives relevant information from the teacher because they are unable to manage their learning, and students are unable to manage their learning because they continuously receive relevant information from the teacher. In this way, both the student's lack of autonomy and the teachers' control over the learning process are reinforced and perpetuated indefinitely, regardless of whether they are beginning or at the end of their career.

This case shows how living the experience of participating in the implementation of MEDP as a project-oriented course is not enough to mobilize the transformations of teachers' pedagogical practices and, ultimately, of the curriculum. In addition to the experience, teachers must participate in formal reflection spaces in parallel to their participation in the course so that individual and unconscious assumptions that reinforce beliefs and generate vicious circles are replaced by formal and collective reflections. This way believes can be removed and virtuous circles can be generated to provoke the authentic transformation of the curriculum. Hence adoption and adaptation of teachers’’ to PO-PBL needs to be supported institutionally by formally providing these collective reflection spaces.

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Adaptability to Problem-based Learning at Aalborg University: Experience from four first-year Chinese engineering graduate students

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Abstract

The current trends in engineering education require new competencies that go beyond students' technical expertise. Among these skills, adaptability is regarded as one of the important skills as it indicates how engineering students approach changing circumstances. In general, this means to what extent engineering students are able to adjust to new learning methods and different social and academic environments. The transition into any university is generally known to create some difficulties for students. Problem-based and project-based learning (PBL) has been part of curricula over the past four decades at Aalborg University (AAU), and also here the transition process into the university can be challenging. Students usually transit into the university on two occasions, as undergraduates or as graduate. This paper focuses on the challenges encountered when adapting to PBL for international graduate students without prior knowledge and experience in PBL. In addition, these challenges are even larger for students from China due to the differences in culture, language, learning behaviours, conceptions of learning, and so on. From these perspectives, it is necessary to broaden our understanding of Chinese students' transition from lecture-based traditional learning and adaptation into a new problem-based and collaborative learning. Therefore, as an exploratory study, this paper aims at investigating what challenges first-year graduate Chinese students experienced when entering AAU and discussing the strategies they used in the adaptation process. Four first-year master Chinese students from different engineering departments participated in the semi-structured interviews and answered open-ended questions. The result showed that Chinese students face challenges in heavy academic workload, collaboration, communication and different assessment. However, making more efforts on study, clear groupwork division, good project management, inclusive and balanced team and effective communication we anticipate that this will help Chinese students to become better at adapting the Danish PBL context at AAU.

Keywords: PBL, Chinese engineering students, first-year graduate, adaptability

Type of contribution: PBL research

1 Introduction

Problem-based and project-based learning (PBL) is a promising and innovative education approach that has been widely implemented and remains the practice of engineering education at Aalborg University (AAU) in Denmark during the past four decades. This learning model not only focuses on students applying theory and knowledge in their work with a complex and real-life problem (Marra et al., 2014), but also specifies the principles of self-directed group work, student-centered learning, teacher as a facilitator, active-based learning, exemplary practice and collaboration with peers or external partners (De Graaff & Kolmos, 2003; Kolmos et al., 2009). At AAU, this model is usually structured with a 15 ECTS project and three compulsory courses of each 5 ECTS. Within this frame, engineering students are required to formulate and analyze ill-defined problems, construct their own learning experience and interests, and collaboratively work in small groups on the common project (Kolmos et al., 2004). Furthermore, this model also provides students with the tools to independently acquire knowledge, skills and competencies in problem-solving, project management, cooperation, leadership, dealing with complexity and intercultural relation and being able to transfer across different disciplines. (Kolmos & De Graaff, 2015).

However, transiting from traditional lecture-based approaches to PBL methods may cause some challenges for international students, especially for Chinese learners as they possess different perceptions of teacher-student relations and understandings of learning. Influenced by the Confucian cultural heritage, Chinese learners are often described as passively accepting the knowledge and seldom challenging the teachers' authority and the validity of what they learn (Wang & Moore, 2007). In addition, according to various prior studies, some predominant views in Chinese learning can be summarized as being in favor of mechanical rote learning, teacher-directed and lecture-based learning, a belief that deep knowledge is acquired by memorization and repetition and the preference for individual learning (Gram et al., 2013; Huang, 2005; Wang & Moore, 2007). Under these circumstances, Chinese learning behaviors portrayed above are incompatible with the notions of PBL emphasizing project, active learning, student-centered and teamwork. When further exploring what differences and difficulties Chinese learners experience from the perspective of cross-cultural transition, research shows that some Chinese students from AAU are confronted with cultural differences in education for instance the direct teacher-student interaction in PBL at AAU (Du & Hansen, 2005). For the purpose of adapting to a new cultural environment, they also need to deal with more challenges than native students including language barriers, lack of interpersonal relations with team members, academic marginalization and social alienation (Gram et al., 2013). Psychologically, problems such as a sense of loss, rejection and confusion, stress, anxiety and even depression are adverse to the learning experience and the mental health of some international students in an unfamiliar educational setting (Brunette et al., 2011). After the completion of the three-year bachelor program at AAU, some native students continue their PBL studies at one of the master programs and regard their master in the first semester as the "7th semester". Compared to their Danish peers with prior PBL experience, the entry-level PBL Chinese learners may confront more first-year issues. Previous research has indicated that in the process of negotiation and integration to a new academic and social environment, some first-year ethnic minority students find it hard to build a sense of belonging, form students' identity and become a part of the community (Ulriksen et al., 2017).

Therefore, due to these difficulties, it is necessary to broaden our understandings on adaptability to a PBL model for first-year Chinese graduate engineering students. "Adaptability", also termed "adaptation", is defined as the ability for an individual to fit into a new environment by adjusting their thoughts, emotions and actions (Sirotiak & Sharma, 2019). In the context of PBL, it refers to engineering students being able to transfer their knowledge, theory and method from previously constructed areas to the new PBL educational setting and psychologically or socio-culturally integrate to the new society. As an exploratory research, this paper focuses on addressing the following research questions: During their first semester at AAU, what challenges do first-year Chinese graduate students face when they attempt to fit into the Danish PBL context? How - if at all - do they change their behaviors to be more appropriate?

2 Theoretical Framework

In an effort to answer the research questions outlined above, this study investigates first-year graduate Chinese students' adaptation processes by employing Berry's acculturation conceptual framework (2016). Initially, the concept of "acculturation" proposed at the group level refers to the cultural changes caused by interactions among two or more different cultural systems (see the left part of Figure 1). Furthermore, the individual level is widely accepted to explain the psychological adjustment in an individual being affected by both the external culture(s) and the changing original culture(s) (see the right side of Figure 1).

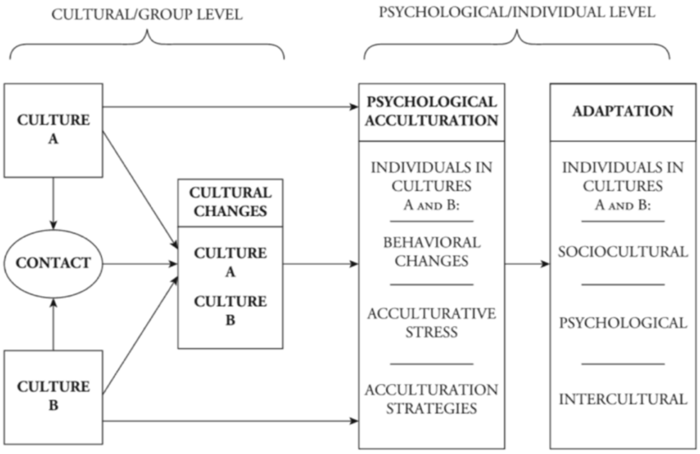

Figure 1 A general framework of acculturation process (Berry, 2016, p. 16)

In order to understand the acculturation at the cultural level, elements are presented to illustrate the acculturation process including culture A (heritage culture(s)), culture B (host culture(s)), the nature of the intercultural contact and the dynamic cultural changes between these distinct cultures. Although this framework uses the word “culture” at all levels, this study primarily concerns students’ adaptation to the culture in education. Specifically, in PBL, our research explores the experiences (contact) of students from previous learning culture in China (culture A) utilizing the PBL in the Danish context (culture B).

The dynamic interaction among all these components is taken to construct the starting point for and affect acculturation at the psychological level. Three acculturative outcomes, “behavioral shifts”, “acculturative stress” and “acculturative strategies” have been outlined under the psychological acculturation. The first term means that individuals change their behaviors to fit into new cultures. According to Berry (2016), these adjustments are achieved with minimal difficulties or problems. “Acculturative stress” refers to the psychological stress reaction in response to an incongruence of values, beliefs and cultural norms between an individual’s original culture(s) and host culture(s). During this process, individuals experience deeper changes to the extent of cultural conflicts. With reference to “acculturative strategies”, it means the multiple ways of acculturation among different groups of people. Four strategies to analyse individual acculturation are identified as integration (one wishes to maintain the original cultural identity and absorbs into the dominant culture(s)), assimilation (the individual fully participates in the new society and rejects their own culture identity), separation (one adheres to the heritage culture(s) but one does not integrate to the host culture(s)) and marginalization (one relinquishes both home and host cultures).

Resulting from the attempts to deal with the changes in psychological acculturation, three types of longer-term outcomes “psychological adaptations”, “socio-cultural adaptations” and “intercultural adaptations” are also presented in this structure. The first outcome is defined as “feelings of wellbeing and satisfaction during the intercultural adaptation” whereas the second means “the ability to fit in or to have an effective interaction with members of the host culture” (Zhang & Goodson, 2011). “Intercultural adaptation”, which is a notion that has come forth in recent years, refers to building practical relationships across cultural boundaries. In short, these three forms of adaptation have also been described as “feeling well”, “doing well” and “relating well” (Berry, 2016).

In conclusion, as an explorative research, the acculturation theory is utilized to explore the adaptive process of Chinese graduate students in the engineering field. Moreover, taking this structure into consideration, this study could contribute to understand Chinese international students’ adaptation to the PBL model. In the next parts, we will further look at the applications of these frameworks in a real setting and investigate how these frames conceptualize PBL learning experience of first-year Chinese graduate engineering students at Aalborg University.

3 The research methodology

This research took the qualitative approach with the guidance of Berry's acculturation. Four Chinese engineering master students who were enrolled in the fall of 2020 at AAU participated in semi-structured interviews consisting of several open-ended questions. Three students came from different majors in the same engineering department while the last one came from another department (see Table 1). They did not get prior PBL experience from their bachelor. In table 1, all names are pseudonyms due to confidentiality of the participants.

Table 1: Description of the participants

Name	Gender	Department
Steven	Male	Electronics and IT
Ben	Male	Electronics and IT
Yvonne	Female	Electronics and IT
Joe	Male	Energy and technology

During the interviewing process, three students engaged in physical individual interviews whereas one student, Steven, used Wechat, a Chinese social media, to describe his experience. The participants were interviewed during the first half of their first semester, with each interview lasting approximately one hour. They were asked to narrate their expectations and the learning activities in PBL, the benefits and challenges they experienced in a new academic environment, approaches to overcome the difficulties and their evaluation of the learning outcomes. The first author conducted the interviews in Chinese because using participants' native language allowed them to fully express their own opinions. Then the descriptions from the participants were transcribed verbatim and translated into English.

Following the process of the thematic analytic approach (Braun & Clarke 2012), the transcripts were first read carefully and iteratively in order to familiarize the data. Based on the elements from Berry's acculturation theory, a set of temporary initial codes were generated where the experience of these students could be linked to adaptation. After the preliminary coding process was finished, the coded sequences were continuously revised until the overarching themes related to adaptive issues appeared. The themes were then analyzed and reviewed to see if themes and theoretical framework are related to the data. Finally, the analysis of data represented by the finalized themes were written up as a report.

4 Findings

The results from qualitative data reflected some major components of Berry's acculturation theory (2016).

4.1 Perceptions of prior learning experience in China (culture A)

The qualitative data revealed that all students mainly obtained knowledge through lectures and self-study. From their statement of prior learning experience, the lecturers highlighted the key topics that students need to learn and also transmitted a great amount of new information during the courses. Students kept listening to their lecturers, taking notes and memorizing the main concepts for their final written test but had little opportunity to apply the theoretical knowledge into practice. As Yvonne explained, in order to reflect on the knowledge that has been presented, she had to spend more time on self-study after the lectures.

> "During my study for my bachelor's degree, I took the courses, made notes of what lecturers taught, finished my homework and had a cram session for the final exams. However, at that time, I felt taking

> lectures was still not enough for me to understand what I learned. Therefore, I spent a lot of time on self-study." (Yvonne)

In addition to taking lectures and studying on their own, the students also worked in small groups. However, they built a group in a very short period for some purposes such as discussing close-ended questions in the lectures or participating in some voluntary competitions which required to work in a team for submitting a program report within one or two months. According to Joe, the team was loosely-structured.

> "When I was a bachelor student, there were some project competitions organized by the school and our teachers. Those projects required students to work in a group. However, they were not mandatory which meant students could drop out from these projects at any time." (Joe)

4.2 Challenges of adapting to PBL (contact)

Although the students were enrolled in different master programs, we also find out some similar adaptive challenges consisting of heavy academic workload, challenges related to teamwork, language barriers, communication issues and pressure from assessment. Each of these challenges is elaborated below.

Heavy academic workload

In contrast to the academic workload in their bachelor, these new master students claimed to make more pre-course preparations within limited time. Joe mentioned that preview before a lecture benefited him to understand the lectures. But due to lack of time to read piles of literature, he normally took notes in the course first and tried to delve into more details after that. Under these circumstances, he spent longer time to figure out questions on homework but spent less time to do pre-course reading. Similar to Joe, in Yvonne's case, due to change of the research direction in her master, she took more software lectures and was exposed to a lot of new knowledge. However, even though she spent extra time to prepare the course, it was still insufficient to go through and get familiar with all recommended literature, which gave rise to incomprehension to learning content and less participation in the group exercise.

> "It seemed like a vicious circle that if I do not have enough time to read all references at the beginning, I need to spend more time to understand the learning content and finish my homework after the course. It further leads to a lack of time to look through references for the next courses." (Joe)

> "Due to time constraints, I was unable to read all the recommended literature before the course. During the lecture, I could only follow and understand the part that I already read. Then I stared into space for the rest of the lecture and occasionally caught one or two key words." (Yvonne)

Another issue derived from the difficulty of exercise. Ben held a negative attitude towards the exercise which were mandatory but had no relation to the final assessment. He was reluctant to spend his spare time in completing those difficult exercise which would not be examined at the end of semester.

> "I need to finish exercises for each course. That is to say, after every lecture, I would spend a lot of my spare time finishing those difficult exercises which actually caused a lot of study pressure on me. Now I feel more stressed than studying in China." (Ben)

Challenges pertaining to teamwork

With more chances to collaborate with other students for the projects, these Chinese PBL beginners described that they faced a great deal of frustration in the process of teamwork. Because of distinct cultures, they experienced differences from their group mates in ways of thinking and views towards PBL. In Ben's case, he participated in a group with five Danish students who had prior PBL experience. Ben regarded PBL as a flexible learning method to gain knowledge whereas he felt his groupmates had a narrow-minded interpretation of what PBL is and treated it as a rigid framework. As a result, he found it hard to integrate in his group by accepting his groupmates' ways of doing the project. Furthermore, because his group members had similar style of behaviors and team roles, he felt a lot of pressure to balance and coordinate his team.

> "What my members understand of PBL is totally different from what I think. For me, I feel PBL is a method or a means of learning while they think PBL should follow what they did before, because this is what they learnt from PBL. Actually, I suffer a lot from this rigidity and have to strictly follow the procedures." … "Right now, we have six people in our group but five of them want to become a leader. It makes me feel more stressed to accomplish the project because I need to coordinate different ideas from different members." (Ben)

In addition, three students reported that poor project management, inadequate time management and lack of common goals have negative impacts on group collaboration. These elements gave rise to inefficiency in PBL learning. Joe worked with two other PBL-beginner level students in the first graduate semester. Being unfamiliar with PBL and lacking project management experience, his group distributed tasks but finished them individually without knowing each other's project schedule. Consequently, they found it took longer time to keep the same pace together. Ben pointed out that his group wasted time to roam around and chat for several hours in the group discussion, which increased procrastination and unproductivity to finish the final projects. Yvonne also stated that at the start of the semester, her team got lost in doing the project with no common goals and schedules.

> "The poor project management makes our group lack information transparency. It means that, due to opaque workflows, our group members were unable to know what work and how much work that the others did at the beginning. Actually, it affected the overall productivity of our project." (Joe)

> "The group meeting lasted about two hours, but we only took half an hour to talk about some useful and effective information. Then, the other one and a half hours were spent on chatting." (Ben)

> "Without a schedule, one of my group mates often messed around and watched Youtube videos during our group work." (Yvonne)

Language barriers and communication issues

All four students claimed that low English proficiency became one of the largest challenges in their learning process. Steven explained that due to unfamiliarity with the terminology in English, he took longer time to comprehend some basic professional knowledge in his field and give response to the others.

> "The challenges and difficulties come from my English level because a lot of terminology I used before was taught in Chinese. Some things I want to say but I do not know how to express them in English. Meanwhile, I do not understand what the others say." (Steven)

In terms of building relations with team members, Joe mentioned that owing to different languages and cultural backgrounds, it is much harder to find common topics and have deep conversation with native students compared to other international students from European countries. Moreover, his shyness interfered with asking for help from other native students even though he faced difficulties in adjusting to PBL.

> "However, because of different language and cultural heritage, it is difficult for Chinese people to talk about gossip or anecdotes with Europeans. Even though we watch the same American TV series, we focus on different perspectives." … "Sometimes I asked questions to my classmates who had prior PBL experience but I felt too shy to ask all my questions or too many details together at one time. Therefore, I explored PBL by asking them only one question first and contemplating or searching for information on my own." (Joe)

Pressure from different assessment

Three students reported that they were very anxious about the oral project exam. According to Ben, due to unfamiliarity with the exam and insecurity about the language proficiency, he felt stressed on his final exam.

> "In fact, I am worried about my final exam, especially the oral exam. It seems horrible for Chinese students because doing a presentation within five or six minutes in English is a big challenge. In addition, the exam becomes uncertain if I do not understand the questions from the examiners." (Ben)

4.3 Psychological reactions to PBL (Acculturative stress)

Based on what these Chinese students stated, the main mental challenges are centered on loneliness, isolation and lack of intrinsic motivation whereas the students benefit from developing a sense of belonging.

Loneliness and isolation

Since Chinese students studying abroad are without the company of their family, they often feel lonely and isolated living in a new environment. Due to the homesickness, even though they stay close to their friends and roommates, this does not necessarily solve the problem (Henze & Zhu, 2012). Yvonne said that a sense of loneliness resulted in a negative impact on her academic and social life in her first two months at AAU.

> "Sometimes staying alone makes me feel bored and unhappy. This bad mood caused a large negative influence on my work. Hence, I had to adapt to the boredom and loneliness here." (Yvonne)

Lack of intrinsic motivation

Another significant aspect of acculturative stress is lack of intrinsic motivation, which means that students lose their inherent enjoyment in PBL activities if they focus a lot on external rewards and requirements (Taylor et al., 2014). In Joe's case, he evaluated himself to be result-oriented where his learning motivation derived from submitting the project in time, passing the tests and getting academic credits rather than from his natural interest in PBL.

> "I found that I lack an intrinsic passion towards my project. Because I am more result-oriented, the only motivation I have towards my study at present comes from finishing my project work on time and getting enough credits to graduate. I feel I am obliged to do so." (Joe)

Improved sense of belonging

In spite of feeling pressure from resolving some conflicts in teamwork, Yvonne reported that she gradually became cheerful to be accepted by her group. The inclusive and open-minded working environment encouraged her to ask more questions and express her own opinions freely.

> "Our group looks like a family and every member is really nice. It made me feel accepted when they told me that if I had any questions, I could ask them and that there is no need to feel sorry to them when asking questions." (Yvonne)

4.4 Behavioral shift to PBL

Despite the fact that the students pointed out the challenges mentioned above, they took different ways to deal with them. These ways assisted them better integrate to a new PBL environment. For example, when encountering pressure from heavy workload, they tended to work harder to endure hardship and cultivated their desire to learn. As what Steven stated, he became more self-directed and actively engaged with the knowledge he learned through putting more effort to studying.

> "Compared to my bachelor studies, the self-study time is longer and I take more initiative to study. I spend more time on independently searching for useful resources related to my field and actively taking some relevant online courses." (Steven)

When a problem was too large to deal with alone, these students chose to communicate with their groupmates and asked for their help. Good and effective communication will benefit them to deepen their understanding of new knowledge, resolve group conflicts, increase engagement to PBL and improve productivity of project work (Awang & Daud, 2015). Yvonne mentioned that asking questions to her groupmates helped her better understand the lectures and group exercise. Furthermore, from Joe's description, we learn that effective face-to-face talk enhanced the team cohesion and effectiveness of teamwork.

> "If I constantly asked my groupmates some questions, I could catch up with the course and discuss with my team members as well." (Yvonne)

> "After a group meeting on Friday, I decided to talk with my groupmates about the problems such as our slow project progress and lack of information transparency. I also pointed out our isolated group atmosphere and our self-centeredness. I told them we need a common goal instead of working individually and asking questions to the supervisor alone. That talk worked because our group atmosphere got much better than before, at least we discussed some problems together in our group." (Joe)

With reference to team collaboration issues, the ways to break down the barriers from these Chinese students can be summarized as creating balanced teams with different team roles, formulating clear work division and using effective management tools. Joe shared his experience about managing the project.

> "We first made a schedule for our project and divided the work in our group. Afterwards, using some management tools, we strictly followed the schedule and also sent it to our supervisor who would help us revise our schedule. The feedback given by our supervisor assisted us to ensure weekly work and plans. Additionally, the schedule also allowed us to have enough time to finish the group project before the deadline." (Joe)

5 Discussion: Preferences of acculturation strategies

From the analysis of which acculturation strategy that these students choose, it should be noted that two students Joe and Yvonne selected the integration acculturation strategy where they actively engaged with PBL activities and meanwhile integrated experiences to the past. For example, in order to enhance the team cohesion, Joe used the coordinating strategies he learned from previous learning and working experience to cooperate with groupmates who were all PBL beginners. In addition, he improved his generic skills from PBL, which includes communication skills, collaboration skills, problem-solving skills and project management skills. These abilities will enhance his confidence to deal with teamwork problems in a real workplace. In Yvonne's case, a sense of responsibility got improved during the integration process. It means that she not only focused on her own learning process but also gave feedbacks on team's project schedules. Although PBL increased her willingness to make contributions in her teams, she was looking forward to taking more ownership by getting more respect from her groupmates. Steven's positive attitude towards PBL and relatively negative attitude towards traditional teacher-centered learning demonstrated that he primarily tended to adopt the assimilation acculturation strategy. On the one hand, learning through listening to teachers was not suited for his learning style and also failed to provide him intrinsic learning motivation. On the other hand, through in-depth investigation of authentic problems, PBL allowed him to apply acquired knowledge into practice, which improved his learning efficiency. In opposition to Steven, Ben leaned towards the separation acculturation strategy. He valued the style of collaboration in his bachelor with clear group work divisions and balanced team roles. Moreover, he was reluctant to build personal interaction with his groupmates and gained knowledge mainly through individual learning instead of group discussion.

6 Conclusion

Building on Berry's acculturation theory, this study investigated how first-year Chinese graduate students in engineering field adapt to PBL at AAU and the challenges they experienced during the adaptation process. The empirical data from the interviews reveal that rather than beginning with taking PBL methods in their undergraduate education, these students brought with them the traditional lecture-based and teacher-centered learning approach which they felt were at odds with the ways of thinking and acting in the PBL context. Although PBL radically shifted and expanded engineering students' understanding of education, students encountered some challenges and a sense of insecurity when trying to fit into the new PBL environment (Prosser & Sze, 2014). This study shows that during the adaptation process, first-year Chinese graduate students faced difficulties including heavy academic workload, language barriers, different ways of assessment, loneliness and isolation, reduced interpersonal communication with their team members and native students, which confirm some of the findings from previous research (Du et al., 2019; Gram et al., 2013; Henze & Zhu, 2012). In addition, it yields new findings of challenges related to teamwork and collaboration such as unbalanced team roles, poor project management and inappropriate time management, and lack of common goals which further leads to a decreased effectiveness of these Chinese students' learning through PBL. Psychologically, students' intrinsic motivation normally influences their internal satisfaction with learning (Taylor et al., 2014), but because of low intrinsic motivation, some participants in this study are reported to have less passion and interest towards their project work than their classmates from other European countries. In order to resolve these problems, this article demonstrates that the four first-year Chinese graduate students adopted integration, separation and assimilation acculturation strategies. None of these students exhibited marginalized attitudes and behaviors, which is in accordance with other studies in this field (Chen et al., 2008; Yu & Wang, 2011). According to the experience of behavioral shifts from these entry-level PBL learners, this research also suggests that making more efforts to study, clear groupwork division, good project management, inclusive group atmosphere, balanced team roles and effective communication help first-year Chinese graduate students transiting to the Danish PBL context at AAU. Finally, it should also be emphasized that PBL in turn serves as a driving factor to enhance students' communication, collaboration and problem-solving skills and develop them a sense of belonging and responsibility.

However, the results are subject to certain limitations. Firstly, because not many Chinese master students were enrolled at AAU in the fall of 2020, only four Chinese engineering students participated the interviews. Consequently, the small sample may not be sufficiently representative of overall Chinese first-year graduate students. Secondly, this study requires more rounds of interviews. Adaptation is a changing process that occurs over time and keeping track of the same students for a longer period of time would contribute greatly to deeper understand this process. Hence, it is recommended to include a larger sample and longitudinal data for future work. In terms of new research, it may be worthwhile to pay more attention to the changes of students' acculturation strategy selection during the adaption process and the adaptation experience of more international students.

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The Entrepreneurial University and the PBL

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Abstract

This article shows in the first instance the key aspects of the entrepreneurial university, the education in entrepreneurship that creates an entrepreneurial and innovative culture, the networking that involves the university-industry-government. The innovaTE Program of Entrepreneurship of the Faculty of Engineering of the National University of Colombia has made efforts to form the entrepreneurial character of the University through event organization and participation, the creation of networks inside and outside the institution, and following the strategic guidelines of the University to support entrepreneurship as a key action that allows transferring their knowledge and applying their abilities to solve problems through the creation of technology-based companies. The innovaTE Program has developed a methodology for the maturation of technology-based projects, which was implemented since last April 2020 when a great need arose in the country to develop mechanical ventilators due to the pandemic. As a result of the above, there it is the articulation of the institutions (triple helix), that supported medical and veterinary projects development with a working methodology for entrepreneurship based on problems. The Group for the Development of Mechanical Ventilators was created, and it supported seven projects, and later this group became into the Supporting Table for Innovation and Entrepreneurship of Medical Solutions, to develop, not only ventilator projects, but also other medical and veterinary ventures.

Keywords: Entrepreneurial university, triple helix, entrepreneurial method with PBL

Type of contribution: PBL best practice

1 Introduction

One of the main characteristics of the entrepreneurial university is that it is involved in public and private networks and associations, and this is one of the growth inducers of the innovation system (Guerrero & Urbano, 2012). These alliances produce interactions and collaborations, which in turn allow the generation of many other different interactions (Inzelt, 2004).

Authors such as Guerrero (2008), Guerrero et al. (2011), Guerrero and Urbano (2011a) and Kirby et al. (2011) mention that the entrepreneurial university is defined as an adaptable organization to competitive environments, with a common strategy aimed to being the best in all its activities (for example, having good finances, selecting good students and professors, producing high-quality research). In this way, you try to be more productive and creative in establishing links between education and research.

In this order, Barnett (2000) argues that an entrepreneurial university, in addition to being a promoter of entrepreneurship, develops administrative techniques and associated strategies to promote and enrich the entrepreneurial culture (Kirby et al., 2011). In the words of Inzelt (2004) "the entrepreneurial university implements several strategies to work together with the government and the industry in order to achieve a common goal: the generation and exploitation of entrepreneurial activities".

This interaction and collaboration must be supported by entrepreneurship education and PBL; In this regard, Rossano et al., (2016) show it by stating "Entrepreneurship programs, including those that use PBL as a learning approach, structure their problems in order to giving the students greater freedom to self-direct your knowledge development process. Similarly, the problems are authentic, intensifying student's inspiration to search for knowledge gaps. The students are thus in close contact with companies and their problems."

In this sense, the National University of Colombia during the months of April to September 2020, in the middle of the COVID pandemic, coordinated the mechanical ventilators support with university-industry-government strategy and through PBL methodologies for technological project development.

The experience brought together five groups of entrepreneurs, and entities such as the National University of Colombia: Faculties of Medicine, Veterinary Medicine, Sciences, Engineering and the National University Hospital; on the part of the industry: INDUMIL Military Industry, the Association of Aeronautical Parts ACOPAER and the Colombian Air Force FAC. This relationship was led by the innovaTE Program of Entrepreneurship of the Faculty of Engineering, in charge of promoting the entrepreneurial culture and the development of technology-based entrepreneurship.

As a result of the experience, the Entrepreneurial Route of InnovaTE Program was validated, this is the tool with which the culture of entrepreneurship is promoted and PBL methods are applied. This article is an entrepreneurship approach to learning collaborative innovation competences based on real problems.

2 Networks, associations and the entrepreneurial university

It is necessary to develop an entrepreneurial orientation in the university to influence innovation, knowledge generation and economic growth processes, as the third university mission seeks.

The idea of an engagement between universities and society has been growing more than ever when the third mission has been recognised as a powerful driver of innovation within economic development. University third mission is focused on academic knowledge activities aimed to reinforce social, economic and cultural development (della Volpe, 2017).

The cooperation between academia and industries can be efficient only if all actors positively perceive, develop and drive their respective areas of responsibility and parts (Davey et al., 2011). According to Etzkowitz (2013), adopting a more entrepreneurial approach by university should be considered as a conduit of innovation and economic spillover on territorial growth.

There are many actors playing different roles in the achievement of the third mission. It is not possible to consider, as representative, just activities referred to startups, scientific parks, incubators, offices of technological transfer and other structures, which promote innovation and knowledge at an economic level (della Volpe, 2017), there are other actors and factors to consider.

Methodologies are also required to energize the actors and factors, and generate among them the necessary incentives to mature the solutions to the problems. In the experience of the innovaTE Program, the PBL practices and the PBL learning scenarios are value inducers for the maturation of these solutions. PBL practices contribute to consolidate the entrepreneurial university and to the achievement of the third mission, PBL is relevant for entrepreneurship education programs, it creates a learning environment that allows students to tackle real entrepreneurship problems (Wee, 2004).

In this perspective, university should play a mediation role but it needs a new mandate and more incentives: only in this way, it is possible to build on a collaborative research with all stakeholders for underpinning policies, practices and professional growth. Universities should open the barriers and link with companies, institutions and organizations, so creating a new way to communicate with them. To reach this goal university have to redesign the model, starting from teaching (della Volpe, 2017).

A contribution in the cultural and social dimension by university implies the involvement of numerous social and economic actors: to facilitate the interaction among them, it is necessary to carry out multiple activities supported by useful tools. The network approach is made up of subjects or organizations that can influence the institution performances, directly or indirectly. In the current social, political and economic scenario, no partaker can do without interacting with all the others. Actually, all organizations are embedded in a system characterized by the presence of relationships based on collaboration and also competition. It needs aggregations: organizations are, more than even, interdependent, and their success, or sometimes even their simple survival, depends heavily on the actions of the other players. (Daft, 2004).

3 Strategies in the entrepreneurial university to work with the triple helix

University may be experiencing a resistance to interact and collaborate with other actors, which implies difficulties in the achievement of the third mission. The achievement of the third mission is often seen as a threat to teaching and research. In the European Union, it has been found that it is identified as commercialization of research, with less interest in education (della Volpe, 2018). All of this creates a strong resistance to change. A balance could be found by developing different business activities, such as consulting, industry training courses, co-research, supporting a unified culture in all institutions. (Philpott et al., 2011). This is one of the strategies that, as highlighted by Clark (1996; 1998), is the transition from the traditional culture of the university based on the creation of knowledge and scientific work, to the entrepreneurial culture.

The evolution process of universities has gained significant attention in recent literature that emphasizes the role of universities in capitalizing knowledge, organizing new entities, and managing risk. (Etzkowitz, 2013). In fact, the university acts as a provider of knowledge, supporting the transfer of researcher's discoveries to the business world through valuable products and services (Mian, 1996). This allows the knowledge produced within the university to be translated into economic and social utility (Etzkowitz, 2003). This approach to entrepreneurship and external collaboration gives access to external sources of funding (Kirby et al., 2011), and provides "entrepreneurial capital" (Audretsch, 2012).

Engaging all stakeholders (higher education institutions, academics, students, businesses, intermediaries and governmental organisations) involved in University-Business Cooperation (UBC) generates value, improves understanding of this cooperation, new solutions, new practises, common culture (della Volpe, 2018). Therefore, the aim for universities is to understand the importance of acting in synergy with other organizations, for development and innovation, and to increase performance. Particularly successful cooperation could be realised through relationships with governments and businesses (Triple Helix), recognising that the interaction is the ideal driver of knowledge-based economies (Etzkowitz & Leydesdorff, 1995).

Regarding cooperative relationships, they should lead to a creating opportunity for people to meet and develop interesting relationships, in the right time and space; mutual trust and commitment; managing expectations when a collaboration begins; communicating with transparency and clearness; creating win-win negotiation; engaging academics through incentives; choosing which are the strategic partners according to one’s own aims. The performance of university-business cooperation is closely related to the development of an attitude or a mindset. Results are often leaded by intrinsic and psychological elements rather than predefined rules and schemes. In order to highlight the role of cooperation in the academic sphere, it is necessary to create a positive environment to communicate advantages, to prefer better practices, to define the role of intermediaries and to establish a number of appropriate incentives (della Volpe, 2017).

Finally, as summarized by Della Volpe (2018), in the case of the European Union, universities need to select forms of entrepreneurial activity that can optimize the impact of university on economic development (Philpott et al., 2011), it includes partnerships with industry (Etzkowitz, 2003; Kirby et al., 2011) and the creation of new ventures (Jacob et al., 2003; Etzkowitz, 2003; 2013). One important factor is the development of new spin-offs which are company based on university research (Shane, 2004; Lockett et al., 2005). They represent a socioeconomic contribution to the region (Guerrero et al., 2015; 2016).

Universities could greatly increase their emphasis on technology transfer activities through science parks and business incubators (O'Shea et al., 2005; Grimaldi et al., 2011). Additionally, universities often include industrial liaison offices and technology transfer offices (TTOs), which perform university formal functions in managing the interface between academia and various industries, governments, and other research organizations (Fassin, 2000; Perkmann et al., 2013). Other important sources for the university contributions to the economic growth are knowledge networks industries and training courses, which can include executive education (Huggins & Kitagawa, 2012; Guerrero et al., 2015). Moreover, Cohen et al. (2002) show the relevance of softer channels through which universities can transfer their knowledge to industry, such as publications, contract research with industry and consulting. The latter refers to the selling of academic expertise to external organizations to solve practical problems (Philpott et al., 2011).

4 Entrepreneurial activities: Supporting Table for Innovation and Entrepreneurship of Medical Solutions

4.1 Mechanical Ventilators Development Group

The Group for the Development of Mechanical Ventilators was formed in April 2020, with the participation of university, industry and government triad, to support seven projects of mechanical ventilators responding to the needs imposed by the pandemic. The seven projects are made up of: three projects from the National University of Colombia in cooperation with other universities in Bogotá, one from the public company INDUMIL, another from the Colombian Air Force, one from a private company named ESSI, and finally an initiative from an entrepreneur.

Mentoring sessions are key to meeting the triple helix around entrepreneurship projects. There are face-to-face or virtual moments in which the entrepreneurial team presents its project in an agile way through a pitch in which it shows its strengths, opportunities and also its specific needs, and after its entrepreneurs receive from the mentors: opinions, recommendations and key information to help to advance projects and to give the entrepreneur a broader vision. We encourage entrepreneurs to develop a clear and agile pitch where they show, in the most detailed way possible, the problem, the technology and its challenges; and the mentors, who are all experts from the triple helix, are invited to inquire, ask, advise, suggest and recommend the entrepreneurs improvement for their devices and projects. In total, 10 mentoring sessions and 14 work meetings were held. All the meetings were virtual, and two 2 hours long.

By the university they participated: the National University Hospital of Colombia, the Faculties of Medicine, Veterinary Medicine, Sciences and Engineering, the Mentor Acceleration Program, the Knowledge Transfer Team, the Electromagnetic Compatibility Research Group, the innovaTE Program, from the Los Andes University the Department of Electrical and Electronic Engineering; The following participated by the Industry: ACOPAER, D'MARCO AÉREO, Equitrónica, ETS Ingeniería, SOMEC Cooperative and Marly Clinic; For the Government participated: the Colombian Aeronautical Industry Corporation CIAC, INDUMIL and Tecnoparque SENA. Additionally, some undergraduate and graduate students were involved in the development of some mechanical ventilator projects.

Each project was developed by applying the mentoring methodology, it is a working based on projects methodology, participants are encouraged to solve the problem from the different perspectives of advisory specialists: the medical, the technical and technological aspect, the intellectual property and business model. The permanent reflection of this interdisciplinary work, not only built and contributed to the solution of the problem, but it also allows to advance in the entrepreneurship development methodology.

4.2 Supporting Table for Innovation and Entrepreneurship of Medical Solutions

This Group for the Development of Mechanical Ventilators was transformed in September 2020 into the Supporting Table for Innovation and Entrepreneurship of Medical Solutions, this due to the great opportunity to integrate not only ventilator projects, but other types of innovations and ventures of medical and veterinary nature, this proposal was welcomed by the triple helix players and today more types of medical entrepreneurship projects are benefiting.

Seven additional medical entrepreneurship projects have been supported, 16 mentoring sessions and 25 work meetings have been held to date.

This year 2021, more entities of the triple helix will be added: by the Industry: Compensar Caja de Compensación Familiar, Oracle Academy, by the National University of Colombia: UN Innova, Inmednova the Innovation Unit of the Faculty of Medicine, Ingnova the Innovation Units of the Faculty of Engineering, LIAT-ER the Laboratory of Innovation in High Voltage and Renewable Energies, and the Research Group in Nursing Care to the Chronic Patient of the Faculty of Nursing.

4.3 innovaTE Rout, Technology-Based Entrepreneurship Methodology

This methodology is based on problem-based learning, it has been developed by the InnovaTE Technology-Based Entrepreneurship Program and the innovaTE-UN Research Group, both from the Faculty of Engineering of the National University, and was applied to medical projects aforementioned. It has designed to develop scientific and technological-based ventures, it has phases and dimensions of the venture development, and always starts from the problem identification to be solved and in this way the work for entrepreneurs is organized. This methodology, plus the accompaniment of entrepreneurship mentors, guide entrepreneurs in the creation and strengthening of their business projects.

This Route is made up of a succession of phases which describes what are the entrepreneurship projects characteristics should have, and each of these phases can be studied by the following project dimensions: the technological development dimension, dimension of production, industry dimension, business model dimension and intellectual property dimension.

To measure the progress of the venture, project maturity levels are used, four maturity levels or readiness levels are used, they are: the Technology Readiness Level TRL to measure the maturity of the technological solution, the Manufacturing Readiness Level MRL to measure the maturity of the manufacturing and production environment, the Supply Chain Readiness Level SCRL to measure the maturation of supply chain and industry knowledge, and the Commercial Readiness Level CRL to measure the maturity of the business model and the business enlistment.

The characteristics for each phase, the dimensions and the levels of maturity of the project, show to the entrepreneurial team the desirable status of the project at all times, and in this way, they are pointed out the actions they must take to move forward and be closer to the creation of a company with a scientific and technological base.

5 Discussion and Conclusions

The health emergency caused by the pandemic at the beginning of 2020, brought together many public and private institutions, and companies to join forces and work with a single purpose. This dynamic makes all these organizations get to know each other and learn about the capacities they had, and this exercise left many lessons learned for inter-institutional collaborative work.

In terms of work organization, this dynamic generated interest and needs to learn open innovation practices and entrepreneurship methodologies, in addition it highlight all the instances that technological development and business creation requires, such as access to laboratories, resources for prototyping and validation, knowledge about intellectual property, relationships with the industry to manage supply and distribution chains, relationships to find human talent and collaboration to push forward projects, as well as manufacturing prototyping and its scaling and its relationships, as well as the deep knowledge of the prototyping and validation of medical technologies, which require mastery of international standards that guide the certification processes. At the organizational level, companies and public and private institutions noticed how important is the full and determined commitment of senior management for the achievement of development purposes. As shown in this paragraph, the areas, actors and factors that were activated are diverse, and this entire process could be successfully organized in work packages, thanks to the innovaTE Entrepreneurship Route that works with PBL organizing work in phases, dimensions and maturation levels.

Aspects to highlight:

The application of methodologies based on the PBL, entails a high efficiency of the solution alternatives to the problems identified.

Triple helix relationships represent a constitutive element of organizational structures, their objective is to manage complexity and turn it into opportunities for growth and innovation.

Entrepreneurship and innovation arise with free interaction and mutual positive influences.

The university and companies must work together to unleash innovation and growth, and they need to learn how to cooperate, share interests, capacities, resources and achieve synergies.

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Project-Based Learning and Design Thinking to Develop Skills and Competences in High School Students

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Abstract

Design Thinking (DT) is an approach adopted to help solve problems in a creative, collaborative and humanistic way. The main objective of this work is to describe how the DT strategies were used with high school students enrolled at STEAM (Science, Technology, Engineering, Arts and Mathematics) curriculum to guide a project. This work consists of a qualitative descriptive experience sampling that arises from retrospective documental sources of the process and personal impressions of the authors. Five hundred (n=500) senior high school students and 14 tutoring teachers from a private school in Brazil participated, the theme projects were based on Sustainable Development Goals (SDGs) established by the United Nations Organization. The students were able to study and discuss some SDGs goals, choose one and develop a project so as to experience the phases of DT (Empathy, Definition, Idealization, Prototyping). At the end of the course, the students were capable of developing and delivering a prototype (digital or physical) and presenting their work. This report showed that DT can be a good strategy for implementing the Project-Based Learning with STEAM approach helping students to integrate inter, trans and multidisciplinary content and develop competences and skills such as: teamwork/collaborative actions; argumentation/negotiation/communication skills; reflective thinking and logical reasoning; creativity; time management in a project; resilience and tolerance when the group had to face some frustrations (projects that did not go as expected, lack of material/time/planning or disagreement between teammates), as well as development of the ability to use different resources to create their prototypes (like scrap materials, metal tools, or some technological resources to create digital prototypes). It is the author's hope that this article contributes to the development of curricular activities using DT, Project-Based Learning and the STEAM approach, and also that it can be used as a guideline.

Keywords: STEAM Education, Sustainable Development Goals (SDGs), Teamwork, Student-centred, Active Methodologies

Type of contribution: PBL best practice

1 Introduction

The term “Design Thinking” (DT) started to be popularized in the 2000s by some companies in Silicon Valley (United States) and it is generally defined as an analytical and creative process that involves a group of people in a process in which they must discuss ideas, experiment, collaborate, empathize, create and prototype models, collect feedback and redesign (Brown, 2010; Razzouk & Schute, 2012). DT consists of a new way of thinking and treating problems or, to put it another way, DT can be considered a model of thinking or “a new way of thought” in which people are allocated at the centre of the process to find the solution to a problem or difficulties (Gonsales, 2017).

More recently, an effort is being made to make the learning process less based on content and more focused on human development, as, apparently, what future demands is people capable of making wise decisions, leading teams, resolving conflicts and using the knowledge acquired throughout the school or academic process (Larmer et al., 2015; Cascardo, 2021). According to the current rules of the Brazilian National Curriculum Base (Brasil, 2018), throughout basic education, students must develop skills, abilities and competences to prepare them for life, work and citizenship in the 21st century. In order to reach those characteristics, they must acquire, in addition to curricular content, general skills and competences such as: scientific, critical and creative thinking; cultural repertoire; communication; digital culture; work and life project; argumentation; self-knowledge and self-care; empathy and cooperation; responsibility and citizenship.

According to McDonald (2017), children enter the educational system with a natural ability to be creative and innovative, but they are losing that ability as years go by. The author believes that the current education system of most schools in the world puts an end to the natural creativity and curiosity of children and adolescents, forcing them to fit within a traditional academic standard. This model may even work very well for some people, however, for a large majority and for the skills and competencies required by this XXI century, the current educational system can destroy many of these skills (McDonald, 2017). In order not to lose this capacity, activities involving DT with adolescents seem to supply this need a little. According to Owen (2006), among the concepts of innovation, DT is of great importance because it is equivalent to other forms of thought, such as scientific thinking. However, DT has a more focused approach to solving problems and finding opportunities that can be directed towards innovation.

DT can be used through project-based learning as a framework in STEAM (Science, Technology, Engineering, Arts and Mathematics) curriculum which is as a possibility for orientation and organization of the science educational content, which proposes the integration of Natural Sciences with Technologies, Engineering, Arts, Design and Mathematics (Yakman, 2008; Gonsales, 2017).

The DT process has become very popular in recent years in different fields, especially in the university environment (DT4T, 2016). Lately, several university students have already got access to subjects involving DT in their curricula. However, not many high school students have ever heard of DT and seem not to have many options, opportunities or resources to contact them for the first time.

Although DT is still considered a novelty in the basic education field, there are already some case reports applied in various parts of the world and even in Brazil (de Oliveira, 2014). An example is the case of the Howard County Public School System in Maryland (DT4T, 2016), which, with the idea of moving towards personalized, student-centred instruction, is using DT to address the new generation of curriculum that incorporates 21st century skills. In Brazil, some examples of activities involving DT have minimally been reported, there are some examples in elementary school (Gonsales, 2017), but detailed data and reports of experiences of activities involving DT is still scarce, especially in high school with a high number of students for a long period of time.

Therefore, this work has as main objective to report the experience of implementing Project-Based Learning [ProjBL/PBL] at STEAM classes using DT to search for solutions to some problems related to

Sustainable Development Goals (SDGs) with senior high school students at a private school in São Paulo, Brazil.

2 Material and Methods

In this paper, the authors report and analyse their experiences in activities using DT, ProjBL and the STEAM approach in high school students. This work consists of a descriptive experience sampling, with basic qualitative approach, that arises from retrospective documental sources of the process and personal impressions from the authors. In this text, the authors write about the experience of using Project-Based Learning and Design Thinking as an educational approach for senior high school students in order to develop Science projects at STEAM curriculum using Sustainable Development Goals from ONU as their theme.

The data survey was obtained by qualitative way through crossing documental sources such as minutes of the meetings and other documents (STEAM Discipline's Syllabus and class scripts for the teachers) were used to write this paper. Additionally, some data was obtained by informal conversations with the team of teachers, coordinators, directors and, mainly, through the personal impressions of the authors, who are part of the teacher's team and participated in the whole process.

3 Results and Discussion

3.1 Course Description

The first stage of this course was showing the students some problems related to the SDGs. SDGs, also known as Global Goals, are a universal call for action against poverty, protection of the Earth planet and a call for peace and prosperity for people. In 2015, realizing that the economic, social and environmental scenarios were pessimistic about the future, the UN (United Nations) suggested that member countries sign the 2030 Agenda, which is an agreement composed of 17 objectives (SDGs) and 169 goals for these countries to reach the sustainable development in all areas by 2030 (Nações Unidas no Brasil, 2015). The themes chosen to be worked with students were only some of those SDGs. Considering that this STEAM course is allocated to the Science curriculum, the group of teachers decided to choose eight SDGs that were more focused on the area of Natural Sciences and Technology and, thus, the teacher group would be more comfortable to guide the projects. The SDGs were: SDG 2, Zero Hunger and Sustainable Agriculture; SDG 3, Health and Well-being; SDG 6, Drinking Water and Sanitation; SDG 7, Clean and Accessible Energy; SDG 11, Sustainable Cities and Communities; SDG13, Action Against Global Climate Change; SDG 14, Life in Water and SDG 15, Terrestrial Life.

In general, the DT process consists of the following steps: Defining the Problem, Searching and Synthesis of Needs, Designing, Prototyping and Testing (Brown, 2010). When adapting the DT to the field of Education, Cavalcanti and Filantro (2017) suggest the use of four steps: a) understanding the problems, in which students must listen, observe and comprehend; b) designing solutions, creating, defining and idealizing; c) implementing the best option, delivering ideas, and d) prototyping and testing. The process used in this report started with the presentation of the problem and proceeded to the funnelling of the best ideas, choice of a project theme, study of the target audience, data collection of this audience, review of the project viability to end the cycle by prototyping. In some cases, the students totally changed the theme previously chosen and started dealing with a new choice. The students could go back and forth but they always needed to accomplish a task and pay attention to the calendar. Although DT seems to have a linear process, this is not entirely true. Kumar (2013) explains that many projects use the steps in a non-linear way. For example, a project can start with intense brainstorming (Exploring concepts) and then proceed with further research and analysis of the theme to validate and improve the idea. Sometimes, the project can start with the prototype and then other DT steps can follow. Still, according to the same author (Kumar, 2013), the process must be iterative, that is, requiring several cycles and even repetitions of the steps, and teachers need to be prepared to understand that some students will ask to return to some steps back.

The concept of sustainable development and what the SDGs mean was presented to students and then they chose one of the SDGs that the group was most comfortable working with. The attempt with these activities was to create an immersion in the theme “SDGs”, exploring different aspects and, also, to know the pre-existing projects in the area. In the following classes, students participated in dynamics and filled out what was called the “Master Plan”, in which they listed three problems of a SDG, four goals, four short-, medium- and long-term proposals and signed the document as if they were adults in important posts. Subsequently, the students presented the master plan to the class through an integrated panel. The use of the SDG theme to be worked on in basic education is highly encouraged by the UN. According to the Manitoba Council for International Cooperation (2018) manual, educators have a great ability to guide students' positive energy to effective change. Teachers can fuel students' curiosity and provide them with the tools and resources to investigate, understand, engage and communicate the importance of sustainability. When students are empowered with knowledge, critical tools for reflection and media literacy, they will be better prepared to act and make changes for themselves and for others around the world (Heyler, 2015). This understanding enables individuals and collective actions at a local, national and international level (Manitoba Council for International Cooperation, 2018).

After understanding the problems through face-to-face classes and home activities, the concept of “divergent and convergent thinking” can be applied and developed. Divergent and convergent thinking is defined as the conflict between creating choices and making choices (Brown, 2010; Cavalcanti & Filantro, 2017). Divergent thinking works on creativity and develops the ability to imagine future scenarios (Cavalcanti & Filantro, 2017), whereas convergent thinking is the practical way to decide between the existing alternatives (Browm, 2017). The moment of “Divergent thinking: creating options'' can be seen at this point in the course. It is possible to inform, understand and refine the problem, locate the main points related to each objective and, thus, provoke discussions between students and teachers, inside and outside the classroom.

According to the authors Brown (2010) and Cavalcanti and Filantro (2017), there should always be a moment to converge ideas in order to choose the best idea to direct each group's project (Convergent thinking: making choices). To paraphrase Linus Pauling (1901 -1994), an American scientist, winner of the 1954 Nobel Prize in Chemistry and the 1962 Nobel Peace Prize, this moment reflects his sentence very well: “The best way to have a good idea is to have lots of ideas." This was the moment when the students were provided with notepads of different colours, cardboard sheets, A3 sheets and coloured pens and experienced the famous “Brainstorming” moment. The brainstorming session creates a collection of ideas that must be shared, categorized and evaluated (Cavalcanti & Filantro, 2017). Teachers asked students to list their ideas in the following way: 1) desire - what makes the most sense for them and for people (community that suffers the chosen problem); 2) practicality - what is more practical to be solved, taking into account the available material; 3) feasibility - what problems can be solved in a viable way, taking into account the students who are involved in the process and their knowledge and the contact they may have with the target audience and, finally; 4) consideration of the deadline available to produce the prototype of the idea. The categorization of ideas in these four aspects followed the guidance of the “HCD Toolkit” (IDEO, 2009). At this stage, some students raised very generic problems that needed to be refined according to the criteria of the teacher and, even, of other colleagues. It is important for the teacher to listen to students' ideas carefully and idealize with them the possibilities of carrying out the project.

When DT is proposed as a teaching-learning framework for project development, the teacher assumes the role of project leader (Cavalcanti & Filantro, 2017). The teacher will have a position of tutor during the classes, being responsible for coordinating the groups of students and guiding them in relation to the best way of thinking about the DT process and strategies. Still thinking about the role of project leader, the teacher must engage the participants, direct and guide the project and, thus, respond to the demand to leave the student at the centre of learning.

3.2 Project-Based Learning and Design Thinking Course Design

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After completing the step of deepening the SDGs and choosing the project's theme, students can move on to another stage of the DT: the stage known as “empathise”. Then, in this phase they begin to survey the possible characteristics of the target audience. It is at this moment that the students should be led to see the problems and pains from the perspective of the other and, thus, imagine their desires, needs, losses and gains. This allows the students to understand the intrinsic meaning of the experiences lived with the objective of obtaining more insights into the problem to be worked on (Cavalcanti & Filantro, 2017). DT, which is a process that places the human being at the centre, enabling a detailed look at the human being, inspiring those involved in the process and making it clear that the solutions created are from people to people and with people (Bacich & Moran, 2018).

In these “empathy” classes, as one of the proposed activities, students developed an Empathy Map on A3 sheet. The empathy map is a document which describes what your user does, says, thinks, and feels. Once your user's information is gathered, it will be much easier to guide the project and to improve your final product (Cavalcanti & Filantro, 2017). Through the map empathy classes, students should raise possible questions directed to the project's target audience. After understanding the activity, the information gathered by the groups helped to outline, delimit and refine their projects. For Freire (1996), empathy contributes to the exercise of active listening, and it is only possible to understand someone when we learn to listen to that person.

In addition to the map, they created a persona digital profile. Personas are fictional characters which the designers create based upon their research (Brown, 2010). The students received a digital template simulating a profile of a social media network (Facebook®). They filled out this social media profile by imagining a person who could be in the target audience, in order to put themselves in this person's shoes and try to understand their problems and needs. In this profile, students should think about information such as birthday, age, sex, marital status, hobbies, profession, city, neighbourhood, movie preferences, food, team, sport, religion, thinking of the day, sharing posts, interviews, personal photos and other information to make a persona as real as possible. The students also wrote an emblematic sentence that represented this “persona”. For McDonagh and Thomas (2010), it is highly recommended to use empathic strategies as early as possible in the educational curriculum in order to improve awareness of others. Activities like the ones presented here seem to help fill these gaps in basic education.

At the end of this bimester, students had the task of developing a presentation of the proposal established by the group in order to communicate to their colleagues what had been done so far and the future perspectives. The goal in this part of the process was to develop challenging skills such as orality in a precise, rehearsed and objective way. For McDonald and Derby (2015), since the development of public speaking and business skills are not usually developed in the traditional class, it is important to motivate this kind of activity.

In order to better understand the target audience and collect more specific information, students were encouraged to work with questionnaires. Students learned how to formulate questionnaires through MicrosoftForms® and then they received tips on how to elaborate questions and to analyse their collected data, they also learnt how to use the PivotTable tool from Microsoft Excel®. At this time the students realized how important it is to learn how to use this type of tool. The first version of the questionnaire was considered a pilot version and before being sent to the target audience, students underwent an activity in which they should share these questionnaires with their classmates. In this collaborative moment, they had already started receiving feedback and were able to improve many issues that had not been very clear before. The teachers also participated in the corrections and at the end of this stage, it was possible to notice that many questions were not compatible with the theme or it would be difficult to analyse the target audience or even the project theme. After the feedback, students were able to readapt the questionnaire and to send it to the largest number of people.

After resuming empathy exercises and analysing the responses to the questionnaires, some groups realized that the proposed ideas were difficult or even unfeasible to work with. Many groups decided to change some of the objectives initially proposed and some groups changed the theme radically. In these cases, it is very worthwhile for the teacher to use this for reflection. It is an opportunity for students to reflect on the whole process and to deal with the frustration that a possible failure might bring. It is advisable to show them that this is a real process, real life, that "designer thinkers" often need to resume the whole process and rethink the ideas. This is a moment in which the DT concept as an iterative process is reinforced, that is, repetitive cycles of the steps are often required until the ideal model is reached. Since they had only two classes to plan it, there was not much time for this iteration process to happen repeatedly and those groups that had to go through this situation needed to find new solutions and ideas quickly. For Kumar (2013), the DT can demand many cycles throughout the process which means that the repetition of cycles within cycles often happens. A project can start with an intention, a dream, and with little contextual research passing quickly through the user's analysis. The number of repetitions and cycles in any innovation project will depend a lot on the budget, time and scope of the project. In some cases, several cycles may be necessary. In others, the process may take place on a direct sequential impulse, and in other cases, it may prove to be totally unfeasible. Doing more iterations generally leads to higher value and more successful innovations - although it should be borne in mind that it is not advisable to pursue them for a long time (Kumar, 2013).

After establishing the themes, the objectives and the target audience, an important practice was presented to the students for the organisation and planning of the project: the schedule. The project schedule is the tool that communicates what work needs to be done, when this work needs to be done and even who is responsible for certain tasks. The project schedule should reflect all the work associated with delivering the project on time. Without an organised and complete schedule, the team will not be able to communicate the complete effort, in terms of cost and resources, necessary to deliver the project in due time (Newton, 2015). The idea of this activity was to explain what a timetable is, how important it is for any kind of project and its importance within the context of the students' project. The development of the prototype was expected to take place over 5 weeks in the third bimester and, therefore, the division of tasks and good planning would be essential for the success of the group. Teachers were instructed to ask students to plan a Gantt Chart. The delivery of the Gantt chart constitutes a part of the group's assessment and students should indicate the activities required for the accomplishment of the project, indicating all the dates and who was responsible for each task. The Gantt Chart is a useful tool for the presentation of time information concerning plans (Maylor, 2001).

To close the two-month period, students were instructed to present to their colleagues one more time what was being done by the group, the data collected and the next stages of the project through a quick presentation. They could learn the meaning of the term “pitch”, which is a very quick presentation with the intention of “selling" a product, an idea or a business, to viewers, investors, customers or partners. It is a very popular term in the universe of "startups" (SBCoaching, 2018). Once again, the ability to speak in public was reinforced with this kind of activity.

In the third bimester, the students basically had hands-on activities while working with their prototyping. In the first class of this bimester, the students were presented with the concept and the different types of prototyping (digital, physical, social/service). According to Cavalcanti and Filantro (2018), prototyping visually represents the solutions proposed by design thinkers, which help them to achieve their solutions. For Carroll et al. (2010), the prototype can be a process, a service, a product and even a draft. The students were requested to choose one type of prototype (digital, physical and social/service) and hand in to the teacher a detailed drafting as the first activity of this third bimester.

The next task to be performed by the group was a three-dimensional template made of different materials, scraps, dough, mock-up, an application, a website, storyboards, among others. After four classes working on the prototype itself (models, apps, website, service), there was the final presentation of the prototype. The last class was organized as a science fair and all the works were exhibited. The students had to participate actively, and they had to evaluate some colleagues' prototypes and give them some feedback. They also received feedback from peers and teachers.

The students were supposed to describe the entire process of creating the prototype. They should always document the date, the name of the students who were present, what was done on that day and the possible reflections and findings or even difficulties faced during the process in a notebook. In addition to documenting, students were asked to take several photos throughout the process. The organisation and the content of the notebook were considered one of the components of the group's grade. For Ruiz et al. (2004), the idea of using the logbook as an assessment tool in the classroom is not new. There is a consensus that notebook entries allow teachers to assess students' conceptual and procedural understanding and provide feedback on what students need to improve in their performance. It was also at this moment that the teachers could better understand how the process was evolving and to discuss the various stages of the process with the members of each group.

The main goal of the fourth and the final bimester was to promote the student's project outside the classroom. As a final task they had to make short videos about their work. The students should choose one of the following videos: dissemination of the product/prototype, dissemination of a concept, a tutorial or a documentary of the process. They wrote a detailed video script showing consistency in terms of format, requested time and narrative; details of the scenes described; clear presence of the SDG worked on in the narrative, and description of the resources and tools used to record the video. In the following weeks, the groups got together to shoot their video and accomplished the whole process just like capturing old and new images and editing soundtrack, audio and video quality. All the videos were presented at a big event at the school gymnasium, in which all the teachers and all the students were present, closing the cycle as a great gathering.

3.3 Development of skills

Throughout this year, after some conversations with the teachers team, they could observe that students were able to develop skills such as constructing questions, making hypotheses, making predictions and estimates, employing measuring instruments and representing and interpreting explanatory models, data and/or experimental results to build, evaluate and justify conclusions when facing problem situations from a scientific perspective.

Working with ProjBL and DT combined in a STEAM approach using SDG as a theme, allowed the students to look at some current theoretical and practical problems in Science, in Health, in Environmentalism or in Technology/Engineering. They could discuss them and also search and propose for solutions or new ideas. The development of these skills and competences by schools is highly encouraged in those official documents at the Brazilian Curriculum (Brasil, 2018). According to Drummer et al. (2011) stages worked through ProjBL helped to improve logical thinking, widely enhance creative abilities, and encourage students to undertake scientific research work. Corroborating the Drummer et al. (2011) work, Project-based learning may be applied as a pedagogical approach implying not only knowledge integration but also the application of knowledge and development of soft skills. For Mills and August (2003), this kind of process requires high levels of student initiative, reinforcing the idea that students need to develop motivation, organisation and other skills.

This process was not evaluated in this work but the group has received some emails from some ex-students telling the school how they feel different when they compare themselves in some aspects with their colleagues at college. For example, they realized that they are well prepared to organise and lead a project. Although this is not scientific data yet and it has not even passed through any critical analyses, the authors believe that the students are already reaping the rewards of the process.

3.4 Difficulties faced

One of the great difficulties faced throughout the process is the criticism of this "new" approach in our school. The critics came from some of the participating students, parents and even our teachers from other school departments. These people think that this approach has little content but what they cannot see is the development of soft skills (term used to describe emotional and behavioural skills). It can be assumed that, in this type of teaching method, the barriers of the subjects are broken, they are no longer organized in “boxes”, and the content learned in other subjects so far should be used in a multidisciplinary way. Making a reflection on the criticisms received and thinking about the Brazilian rules system to be accepted into college (the tests are by and large based on content), it seems that many of these people do not believe in the course proposal, this can be attributed to a certain limitation in seeing what is learned in this discipline and its applications, which go far beyond school life and would not be strictly related only to the content to be approved in a university/college exam. Much is said that what is new usually generates discomfort. According to Kotter (2017), when changes or innovations are implemented in organizations, they usually face internal resistance. Phrases such as: “I've been doing this for 30 years” or the famous conventional wisdom which says "you should not mess with a winning formula" corroborate the assumption that human beings have difficulties when facing change processes. For Hernandez and Caldas (2001), the logic for this assumption is that: change is a threat to a pre-existing balance and, therefore, causes uncertainty. In the case of education, this uncertainty seems to be a feeling that has been occurring very frequently recently.

In contrast to these criticisms, the team recently received some feedback from former students who enrolled in undergraduate courses at major national and even international universities, who can already notice the differential they have in relation to other colleagues. Our ex-students had many of these skills developed specifically when compared to other classmates who did not have the same opportunity to undergo this type of learning. This kind of feedback, sent to us by email or reported face-to-face from students who experienced the process, is being constantly received and it reveals the success of the process. An important reflection for this type of active teaching methodology approach is that the result itself, of this type of work, is not immediate. It is not measured by mere approval through the university exams, it will only be perceived throughout the student's life, in the job market, in decision making, in problem solving, in teamwork many years ahead.

Therefore, when a school decides to adopt this type of active methodology, it must focus on long-term results. The feedback received in the future will overcome the memories of the resistance created at the beginning of the process and the teachers will achieve significant learning for the student's life.

4 Conclusion

"Design Thinking" is a way of thinking that is centred on the user, in this case, the student, to help them solve real-world problems in a collaborative and creative way. This report showed that DT is a tool of great contribution in project-based learning and helps in the integration of inter, trans and multidisciplinary content, in addition to experiencing some situations that can enhance some skills such as: teamwork and collaboration; empathy; argumentation and negotiation, communication; reflective thinking and logical reasoning; creativity; prototyping; manual skills and the ability to use different resources (from everyday scraps, metal tools, to more technological resources); time management in a project and resilience and tolerance in the face of some frustrations (projects that did not go as expected, lack of material, of time, of planning or disagreement between teammates). The authors suggest using the DT as a framework for Project-based learning and STEAM approach. Rethinking education is an increasingly recurring demand; therefore, it is expected that with this work, more basic education institutions are motivated to use DT as one of the forms of teaching method and thus disseminate this practice.

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PBL Implementation, Assessment and Management of Change

Authentic assessment as a new approach to assessing experiential collaborative learning (ECL)

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Abstract

On a global scale, educational institutions are continuing to evolve the practice of teaching to provide the necessary skills and competencies for a modern world. There is widespread educational interest in adopting more experiential and collaboratively oriented pedagogies or what we term Experiential and Collaborative Learning (ECL). We use the term ECL as an overarching concept to capture a number of educational approaches or models, such as PBL, Inquiry-Based Learning or Reflective Practice-Based Learning. Despite the surge of interest in such educational approaches, assessment methods are still primarily based on a competitive and summative expression with a strong association to grading. Learning processes based on ECL are characterised by a responsive nature, which challenges the existing assessment methods. As learning processes change from something stationary to something that dynamically changes through analytical and reflective processes, it affects the way we assess learning outcomes. Therefore, there is a need for developing a new perspective on assessment activities to ensure that teaching methods applied for, e.g. PBL, are aligned with proper assessment methods. Also, the methods used for assessment can accommodate a focus on both process and elements of content. In this conceptual paper, we present a theoretical model for approaching authentic assessment with a specific focus on ECL based teaching.

Keywords: Experiential collaborative learning ECL, Authentic assessment, PBL, Higher education

Type of contribution: PBL Review/Conceptual Paper

1. Introduction

The concept of Experiential and Collaborative Learning (ECL) is explored within the context of the research project 'Unified platform for the Future of Learning and Development' (UnFoLD). The research project aims to develop a digital learning platform for scalable upskilling in the workplace and higher education by developing digitalised ECLs, automated qualitative feedback, and learning outcomes. It has become particularly relevant in the face of the COVID-19 pandemic, which has accelerated digital learning from an emerging trend into a megatrend and a "new normal". We adopt the terms Experiential and Collaborative Learning (ECL) as an overarching concept to capture an array of established educational approaches or pedagogical models, such as Problem-Based Learning (PBL) (Spaulding, 1969), Inquiry-Based Learning (Dewey, 1933), Challenge Based Learning

(Apple, 2008) or Reflective Practice-Based Learning (RPL) (Horn et al., 2020), as well as to cover increasingly popular pedagogical and professional formats, such as hackathons (OpenBSD, 1999) and case competitions such as the AAU Case Competition (Aalborg University, 2018). The latter are shorter-lived professional or educational events aimed at rapidly developing solutions to particular problems or exploring a range of solutions to a case, e.g. proposed by an external partner.

Whereas ECL methodologies have proven efficient for developing complex skills and competencies, they often rely on face-to-face interaction and are thus limited in scalability. Thus, the UnFoLD project explores, develops and tests the digitalisation of distinct ECL patterns, including PBL and RPL, to enable learners to develop skills and competencies through experiential, collaborative learning online. A key aspect of ECL, and often compromised in traditional online learning, is feedback and assessment. Even in physical learning settings, it is true where students are often given little or no feedback or qualitative assessment of their work. Assessment of digital learning is currently limited to instructor- or peer-based methods, which makes qualitative and quantitative feedback to large volumes of learners practically impossible, or very costly. Thus, the UnFoLD platform aims to offer different learning experiences with automated, qualitative and personalised feedback, which will serve as a basis for qualified assessment and suggestions for learning actions and trajectories. Thus, the research project aims to develop a learning impact scoring system to map and measure a change in skills and competencies and help learners navigate their learning trajectory. However, such a system requires a deep understanding of assessment methods and how assessment activities can be aligned with ECL to support individual and collective progress monitoring and facilitation.

2. Ontology of Experiential and Collaborative Learning (ECL)

Experiential and Collaborative learning (ECL) is a concept that frames different approaches to learning, e.g. Problem-Based Learning (PBL) and Reflective Practice-based Learning (RPL). These approaches' ontological basis draws on epistemological perspectives related to, e.g. constructivism, social constructivism, sociocultural theory, and learning ecology perspective (Harvey, Coulson & McMaugh, 2016). The ontological basis illustrates humans' view as interconnected and dependent on other humans due to the collaborative focus (Slavin, 1980). Moreover, the experiential element adds practice and activity to humans' development as they are supposed to create, construct, and develop experiential processes. ECL thus goes beyond declarative knowledge by stressing the importance of more inquiry-based approaches with a starting point in real-life problems and needs. Furthermore, the environment or the setting and its affordances are acknowledged as essential elements in the knowledge creation process. PBL draws on perspectives related to problem orientation, participation and exemplarity (Kolmos, 1996), and RPL includes more pragmatic theories such as reflection as described by Dewey and Schön (Horn et al., 2020) and inquiry, dialogue and exemplarity. Thus, the ontological basis is founded on humans and their development process as active, collaborative and creative, not as an individual process but as an authentic, collaborative process where people and their surroundings are interwoven entities.

3. Constructive alignment between ECL and assessment activities

In 2003, John Biigs introduced the concept of "constructive alignment", which supports the connection between the chosen learning strategies and how these are subsequently assessed. This thinking challenges teaching based on ECL concerning creating a connection between the learning processes and the chosen approach to assessment. Thus, it is challenging to create a constructive alignment between the traditional summative and criteria-based understanding of assessment and then the analytical and reflective nature of ECL processes that change dynamically based on the students' inductive exploration. Therefore, there is a need to develop new perspectives on assessment activities to support the theoretical understanding of ECL's learning and teaching strategies. The theoretical debate and discussion around assessment have traditionally been focused on two divergent perspectives expressed as either "assessment of learning" or "assessment for/as learning", also known as the choice between either a formative and summative approach (William, 2018). The difference between formative and summative assessment refers to the intention or purpose of the assessment. Although they sometimes overlap in practice, where formative feedback is combined with summative grading, there are still some essential dividing lines (Hughes, 2014). Formative assessment helps students and teachers identify and close gaps, while summative assessment deals with teaching effectiveness based on a final product. According to William (2018), the differences between assessment of/for/as learning can thus be reduced to the following two sentences;

Assessment for/as learning is supportive, while assessment of learning measures.

Assessment for/as learning uses descriptions of processes, while assessment of learning uses scores

Thus, the primary purpose of "assessment ***of*** learning" is the teacher receiving information about the students' learning level at a specific time (Dolin and Evans, 2018). Assessment of learning has traditionally been used to provide regular grading, as teachers' evaluations are often informed by tests or examinations based on standardised criteria (Harlen, 2005). As summative assessments require clear expectations and deadlines, the teachers tend to focus solely on the content of the assignments, tests, or examinations. There are also examples of teaching using repeated exercises and tests to educate the students on specific questions or types of questions. (Harlen, 2005; OECD, 2013; Hughes, 2014; Darling-hammond, 2017). Assessment ***for/as*** learning, on the other hand, has a more formative character that aims to promote reflection by mapping out the development of the learning processes. It means that assessment for/as learning is based on the teacher's feedback, focusing on improving the student's learning potential and their ability to self-assess how their learning progresses. (Wiliam, 2011).

ECL-based teaching thus calls for an approach to assessment based on assessment for/as learning to create constructive alignment between the teaching- and assessment activities. ECL's primary condition is that the students, through procedural observations, develop a thorough understanding of themselves across multiple dimensions, creating complex demands to the following assessment activities. Through assessment for/as learning, students are more supported in addressing their formal and informal considerations concerning analysing and reflecting upon how their practical understanding and beliefs are affected by their values and experiences. In particular, the assessment activities must reflect how the student's behaviour and normative understandings affect their ability to build professional judgment and professional credibility. As ECL goes beyond declarative knowledge by stressing the importance of more inquiry-based approaches, the assessment activities should not be based on trivial interpretations or predefined ideals. In an ECL based teaching environment, the learning process can never be reduced to mechanical to-do lists. Likewise, it will not be possible to capture the learning outcome through a solely summative and quantitative measurement of the students' learning. Whether it is problem-based learning, reflective practice-based learning or a hackathon, the students must dare to question authorities or traditional understandings and challenge their self-understanding without being subject to teacher control. (Dann, 2014).

New concepts such as "authentic assessment", "performance assessment", "alternative assessment", "ipsative assessment" and "sustainable assessment" (Hughes, 2014; Rodríguez-Gómez and Ibarra-Sáiz, 2015) have emerged as a complement to the more traditional formative and summative assessment methods with the aim of better-capturing learning situations that lead to" *self-awareness of learning needs, self-regulation of the learning process, lifelong autonomous learning and self-determination in decision-making from an ecological and socially responsible perspective"* (Rodríguez-Gómez and Ibarra-Sáiz, 2015 p. 5). In the following section, Authentic assessment is presented as an approach that will, in particular, support ECL-based teaching. Authentic assessment is interesting concerning ECL as it is based on the fundamental idea that the assessment activities are part of the situated practice and contain both summative and formative elements

4. Introducing authentic assessment

Authentic assessment is referred to as **assessment *as* learning**. It has a focus on helping the students to develop practice through the assessment activity, and by that reach a dimension of feedback based on self-regulation, self-efficacy, metacognition (Shewbridge, Jang, Matthews & Santiago, 2011, Earl, 2007; Dann, 2014; Rodríguez-Gómez and Ibarra-Sáiz, 2015). Assessment as learning and thus authentic assessment are alternative to superficial learning approaches based on decontextualised memorisation and lack of integrating or applying knowledge. While the more traditional forms of assessment, such as summative, are based on testing the students to assess whether they have acquired a certain amount of knowledge and skills, authentic assessment has chosen a different approach that deals with whether knowledge can be integrated or put into a community of practice. In this way, authentic assessment is based on some of the ontological understandings of learning that characterise ECL, where the participation of stakeholder or people from an external community of practice constitutes an essential premise for creating learning.

It means that a combination of realism, contextualisation and problematisation can be accommodated and unfolded through Authentic assessment. The students will experience a greater constructive alignment between the teaching concepts that characterise ECL and subsequent evaluations. Authentic assessment emphasises the importance of contextualised tasks not being assessed in a "judgmental" way based on specific goal descriptions and criteria-based assessments as it will limit the authenticity. Instead, It is the educational context consisting of a problem identification that points to a "real-life practice that is the focal point of view of the assessment activity, where students must present their ability to translate and integrate their knowledge (Ashford-Rowe, Herrington and Brown, 2014, Swaffield, 2011, Wiggins, 1990; Newmann, 1997).

Traditional -- Authentic

Selecting a Response ----------------------------------- Performing a Task

Contrived -- Real-life

Recall/Recognition ------------------------------ Construction/Application

Teacher-structured ------------------------------------ Student-structured

It means that authentic assessment is based more on the students' ability to Perform a task than just describing the process afterwards. Next, the assessment activities' framework must be based on a real-life situation rather than a contrived reality. The assessment activity should focus on the students' ability to construct/apply knowledge instead of more summative knowledge reproduction. Another critical aspect of the theoretical understanding of learning that characterises the students' autonomy within the learning process is their ability to take the initiative. This aspect needs to be included in a subsequent assessment situation in order to create constructive alignment. It means a greater focus on peer feedback and self-assessment. Also, students should express their results through a framework of assessment activities that allow the stakeholder or people from an external community of practice to participate (Swaffield, 2011; Ashford-Rowe, Herrington and Brown, 2014).

5. A theoretical model for assessing ECL

The methods of Design Thinking formulated by Stolterman (2008) has informed the design activities through iterative processes. Therefore, this conceptual paper is based on an iterative design process in which several design schemes have been developed based on theoretical design principles (Stolterman, 2008). The development of design schemas uses methods such as sketching, drawing and making artefacts to capture, combine and frame theoretical aspects of ECL and assessment (Kolko, 2009; Krogh et al., 2015). The development of design schemes thus aims at creating a common descriptive language that can qualify the theoretical models for assessing ECL through a focus on the following two aspects: (1) A conceptual mapping that describes the general pedagogical principles regarding key components within ECL and theory of assessment, and (2) Creating a language that can describe and visualise the connection between ECL and Assessment. The development of design schemas is thus regarded as a form of data collection that contributes to developing specific conceptual models for assessing ECL-based learning. The individual design schemas have been continuously qualified and reviewed through sketching processes.

The following section presents a theoretical model for how authentic assessment can support ECL. To frame the learning aspects that characterise ECL, SOLO taxonomy is included to describe the levels at which the students must be assessed based on knowledge, skills and competence.

Solo taxonomy as point of departure for assessment

As previously mentioned, ECL based teaching and learning are characterised by going beyond declarative knowledge and stressing the importance of more inquiry-based approaches with a starting point in real-life problems and needs. Learning concepts such as PBL, RPL or Hackathon is thus based on a complexity that entails working with a taxonomic progression that can describe the acquisition of learning across several levels. The SOLO taxonomy differs from other taxonomies (e.g. Bloom's taxonomy) by addressing the students' learning by demonstrating a level-based advancement focusing on creating connections between different aspects of learning within the learning domain (Biggs & Collis, 2014). Through an authentic assessment, these connections can be about the student's ability to integrate specific fields of knowledge, skills, and attitudes/competencies related to a community of practice. These connections are built around a taxonomic understanding based on the following points;

- Recognisable aspects of knowledge, skills, and attitudes/competencies.
- Recognisable connections of aspects between different areas of knowledge, skills, and attitudes/competencies.
- Recognisable contexts or aspects in which knowledge, skills, and attitudes/competencies construct themselves. It can assign new perspectives to these contexts or aspects to deepen the students' understanding.

Therefore, the SOLO taxonomy is particularly interesting concerning ECL-based learning. It provides an opportunity to create a much more nuanced picture of the three basic concepts of knowledge, Skill and attitude/competence that count as learning objectives in higher education. Next, the SOLO taxonomy, combined with Authentic assessment, will create unique opportunities to create a constructive alignment between the analytical and reflective nature of ECL processes that changes dynamically based on the students' inductive exploration and then the chosen assessment activities. The SOLO taxonomy is built around five levels; pre-structural, uni-structural, multi-structural, relational and extended abstract. Each level contains several taxonomic concepts that describe the extent and depth to which the student can connect their learning's recognisable aspects. It means, for example, that the concepts of knowledge range from the student being able to fx., *name, reproduce, and define* their knowledge compared to a much more complex level of knowledge, where the student can *reflect, criticise, and judge* their knowledge. The same applies to skills and attitude/competence.

Uni-structural	Multi-structural	Relational	Extended abstract
Name, Calculate, Reproduce, Arrange, Decide, Define, Recognise, Find, Note, Seek, Choose, Test, Program, Sketch, Pick	Combine, Describe, Enumerate, Perform serial skills, list, Account for, Apply method, Execute, Formulate, Use method, Solve, Conduct, Prove, Classify, Complete, Process, Report, Illustrate, Express, Characterise	Analyse, Explain, Integrate, Sequence, Relate, Apply, Compare, Contrast, Argue, Implement, Plan, Summarise, Construct, Design, Interpret, Structure, Conclude, Substantiate, Exemplify, Derive, Adapt	Reflect, Evaluate, Theorise, Hypothesise, Generalise, Predict, Create, Imagine, Discuss, Assess, Interpret, Perspectivate, Criticise, Judge, Reason

Illustration 01 - Each level of the SOLO taxonomy contains several taxonomic concepts that describe the extent and depth to which the student can create a connection between recognisable aspects of their learning.

By combining the solo taxonomy four levels with the concepts of knowledge, Skill and competence, two axes arise that form a matrix for how a taxonomic progression of the assessment activity can be created (see illustration 02). Each rubric in the matrix can subsequently be focused and targeted so that a specific perspective of authentic assessment is taken to support ECl-based teaching. The conceptual model (see illustration 03) thus describes the individual rubrics of the matrix in relation to what focus an authentic assessment can have in terms of creating constructive alignment with the theoretical understanding of learning that characterises ECL.

	Uni-structural	Multi-structural	Relationel	Extended abstract
Knowledge				
Skills				
Attitudes/ competensies				

Illustration 02 - The combination of the solo taxonomy and the concepts of knowledge, Skill and competence, creates two axes that form a matrix for how a taxonomic progression of the assessment activity can be created.

Through ECL-based teaching, students must develop the ability to acquire knowledge, skills and attitudes/competencies and subsequently translate and integrate them into real-life practice. It means, as mentioned earlier that the assessment activity should focus on the students' ability to construct and apply knowledge, skills and attitudes/competencies instead of a more summative reproduction. Therefore, an authentic assessment of students' learning at a uni structural level deals with whether students, through fx. *naming, reproducing, and defining*, can apply their knowledge based on a specific external practice or through practical examples. As the students achieve a more abstract and complex taxonomic level in their learning, the assessment activities will focus more on assessing their ability to fx. *reflect, criticise, and judge* their knowledge through having a dialogue with a specific external practical setting or via practical examples.

	Uni-structural	Multi-structural	Relational	Extended abstract
Knowledge	The assessment activities focus on the student's ability to transfer one aspect of knowledge, concepts, ideas, beliefs, and facts through an authentic setting. The assessment activities should address the students ability to fx. name, arrange, define, recognise knowledge with a focus on recognisable aspects through dialogues fx. stakeholder or people from an external community of practice	The assessment activities focus on the student's ability to transfer and combine multiple unrelated aspects of knowledge, concepts, ideas, beliefs, and facts through an authentic setting. The assessment activities should address the students ability to fx. describe, solve, express, characterise knowledge with a focus on recognisable aspects through dialogues with stakeholder or people from an external community of practice	The assessment activities focus on the student's ability to transfer and present knowledge, concepts, ideas, beliefs, and facts in a logically related answer through an authentic setting. The assessment activities should address the students ability to fx. Analyse, Integrate, Relate, Compare, Contrast, Argue knowledge with a focus on how the students present a logically related answer through dialogues with stakeholder or people from an external community of practice	The assessment activities focus on the student's ability to demonstrate an abstract and deep understanding of knowledge, concepts, ideas, beliefs, and facts through unexpected extension. Through dialogues with stakeholder or people from an external community of practice, the assessment activity should address the students ability to fx. reflect, evaluate, theorise, predict, discuss, Criticise their knowledge
Skills	The assessment activities focus on demonstrating skills and abilities within one aspect or discipline. Through an authentic setting, the assessment activity should address the students ability to fx. reproduce, test, program, sketch a task or assignment	The assessment activities focus on student habits and repertories related to demonstrating multiple and unrelated skills and abilities through an authentic setting. The assessment activities should address the students ability to fx. perform serial skills, apply and use method, execute, process, illustrate multiple authentic tasks or assignments.	The assessment activities focus on student habits and repertories related to demonstrating skills and abilities in a logically related procedure in an authentic setting. The assessment activities should address the students ability to fx. analyse, sequence, implement, plan, construct, design-related and authentic tasks or assignments	The assessment activities focus on the student's ability to demonstrate their skills at an abstract and deep level through unexpected extensions created by authentic settings. The assessment activities should address the students ability to fx. create, hypothesise, assess, interpret through authentic tasks or assignments.
Attitudes/ competencies	The assessment activities focus on the student ability to discuss values, attitudes, and emotions through open-ended questions based on one recognisable aspect. Through an authentic setting with participation from stakeholders or people from an external community of practice, the assessment activity should address the students ability to fx. define, choose, seek, arrange recognisable aspect by self-assessment	The assessment activities focus on the student ability to discuss multiple unrelated and recognisable aspects of values, attitudes, and emotions through open-ended questions and self-assessment. Through an authentic setting, the assessment activity should address the students ability to fx. enumerate, account for, prove, classify, characterise multiple unrelated and recognisable aspects through self-assessment and dialogues with stakeholders or people from an external community of practice	The assessment activities focus on the student ability to discuss and present Values, attitudes, and emotions through in a logically related answer through open-ended questions and self-assessment. Through an authentic setting with participation from stakeholders or people from an external community of practice, the assessment activity should address the students ability to fx. relate, construct, interpret, conclude, substantiate their values, attitudes, and emotions in a logically related answer.	The assessment activities focus on the student ability to discuss and demonstrate an abstract and deep understanding of their values, attitudes, and emotions through unexpected extension of open-ended questions and self-assessment. The assessment activities should address the students ability to fx. judge, reason, Assess, Interpret, Imagine through dialogues with stakeholder or people from an external community of practice

Illustration 03 - The conceptual model describes the individual rubrics in relation to create constructive alignment between the theoretical understanding of learning that characterises ECL and the focus of authentic assessment.

Assessment activities that support ECL will primarily focus on the relational and extended abstract levels within the SOLO taxonomy. Also, developing Skills and Attitudes/competencies will be the primary goal of the teaching activities. It does not mean that learning activities addressing knowledge are absent, but more, that knowledge must be seen as integrated into a context or practice or an integral part of Skill and attitude-based activities. Likewise, ECL based teaching requires that the student is supported in a movement from a pre-structural level towards extended abstract mastery. It involves paying attention to creating a "constructive alignment" between the focus of the assessment activities and the level of SOLO taxonomy that the students should achieve.

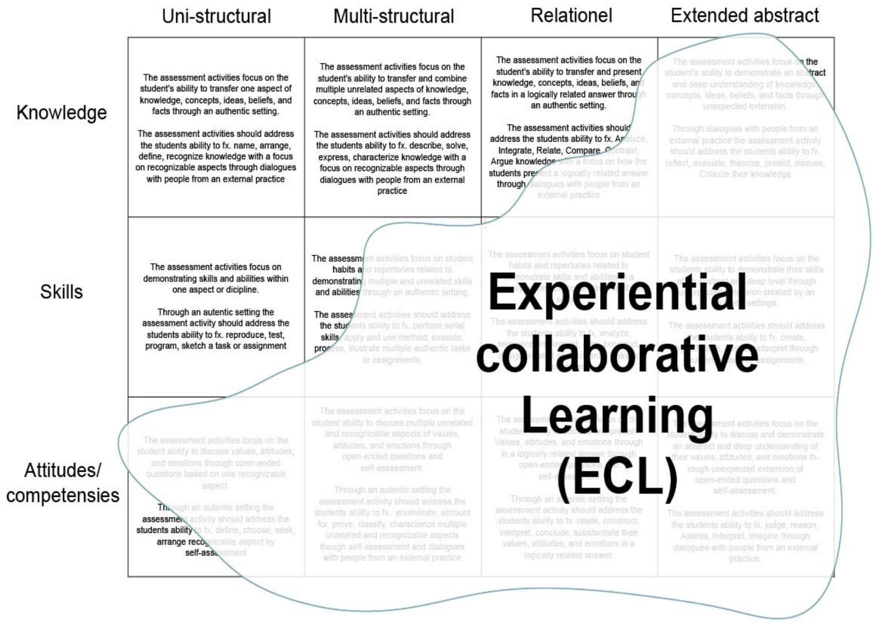

Illustration 04 - Assessment activities that support ECL will primarily be focused on the relational and extended abstract levels within SOLO taxonomy

Based on the matrix (see illustration 03), it is possible to develop specific authentic assessment activities supporting ECL-based teaching. Illustration 05 provides suggestions about which types of authentic assessment activities are particularly suitable for specific taxonomic levels related to knowledge, skills, and attitudes/competencies.

	Uni-structural	Multi-structural	Relational	Extended abstract
Knowledge	Chalkboard spalsh	Wifitti	Review/ post review	Conduct an interview.
	A **Chalkboard Splash** is a tool where all students, based on graphical organising of knowledge, ideas or concepts on a board, records their thinking or conversation	A **wifitti** is a platform where the students can debate **multiple unrelated aspect**s by sending a "tweet" from their Twitter account.	**Peer feedback** provides a structured learning process for students to critique and provide feedback to each other on their work, focusing on creating logically related answers.	When student **interview** a person from an external practice, they will have to respond to unexpected extension of their knowledge

	Uni-structural	Multi-structural	Relational	Extended abstract
Skills	Teacher observation	Portfolio	Experiments/ Demonstrations	Crowd-source a presentation
	This method allows the **teachers** to systematically record the students' observations**,** track student progress, identify individual and group learning problems, and conference with students.	A **portfolio** provides multiple unrelated aspects and samples of the students. Work that shows growth over time. By reflecting on their own learning (self-**assessment**), students begin to identify the strengths and weakness in their work	Students are given an experimental design and procedures and are asked to **experiment** by following the given instructions carefully. The **experiment** involves testing the validity of hypotheses generated based on theories.	Having students run a **crowdsourcing** campaign needs to relate to how potential stakeholders related to their work. In doing so, they will have to demonstrate their acquired Skill in practice

	Uni-structural	Multi-structural	Relational	Extended abstract
Attitudes/ Competencies	Student debates	A series of blog post	Scenario	Exhibition or public workshop
	Structured **student debates** promote competence and in-depth knowledge of substantive topics relevant to practice, allowing students to develop and exercise skills that translate to practice activities. Students debates stimulate critical thinking by challenging established opinions and knowledge	**Blogging** increases the students' awareness of their values, attitudes, and emotions. Due to blogs' nature, the students can share ideas and make their learning explicit, clear and visible to a community of practice.	**A *(future) Scenario*** is a method to assess the students' attitude by asking them to apply their learning to a case by imagining and analysing potential consequences of their work	Students set up an **exhibitio**n in a public space or do an **open workshop/workspace** where stakeholders, together with teachers and interested stakeholders parties, engage with the students' work

6. Conclusion

Whereas ECL methodologies have proven efficient for developing complex skills and competencies, they often rely on traditional assessment strategies such as summative assessment. This challenge is often exacerbated when using digital learning strategies, as digital learning assessment is currently limited where qualitative feedback to large volumes of learners is practically impossible or very costly. To offer different learning experiences with automated, qualitative and personalised feedback, it is essential to have an explicit pedagogical focus that supports the nature of ECl when designing digital assessment methods. Developing a digital learning platform for automated qualitative feedback related to digitalised ECLs requires a deep understanding of assessment methods. This article contributes with a framework for how assessment activities can be aligned with ECL to support the monitoring and facilitation of individual and collective progress. Future research within the UNFOLD project will explore, develop and transform the provided framework into automated and digital assessment activities, which will serve as a basis for qualified assessment and suggestions for learning actions and trajectories.

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Impact That The Change In The Academic Practices From Presential To Virtual Learnig Produced On A Pbl (Problem-Based Learning) During The Covid-19 Virus Outbreak.

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Abstract

The COVID 19 virus outbreak was the opportunity to assume new academic practices or adjust existing ones to the reality of the pandemic. This new reality led to change the learning strategies to assure the interest of the students in the virtual learning.

The TPI (interdisciplinary project course) is subject based on the PBL (Problem-Based Learning) methodologic. In the Dynamic of the course take part 320 students, 20 teachers and 10 people in charge of the course administration.

The course searches to develop a critical mentality in the students, while they work in an interdisciplinary way, making use of engineering design for the conception and development of projects that promote the teamwork. It uses rubrics to evaluate the students' progress and look for the experience of external experts who support students in the analysis of the problem and the development of the possible solution.

At the end of the course an event was made, it showed the result of about seventy projects. In this, the students recognized the importance of learning from interaction, improve their communication skills and interact with principal stakeholders who give feedback on the progress presented during the development of the course. The pandemic allowed the event was virtualized using a platform in which the students built their page and presented their ideas.

The focus of this work is comparing the academic results and perception of the course by the students in terms of experience, the development of skills, and the achievement of the goals. The comparison was made by making a parallel between the face-to-face version and the virtual version giving importance to the use of Information and Communication Technologies (ICT) as an important part of the change. This analysis shows the differences and / or similarities based on the results of the last four semesters (years 2019 and 2020), This allowed to develop strategies for continuous improvement from teaching practice.

Keywords: PBL, ICT, Virtuality, COVID 19

Type of contribution: PBL best practice

1 Introduction

The interdisciplinary project workshop course (TPI), is a course offered by the Faculty of Engineering of the National University of Colombia, is designed under the PBL using the engineering design for the construction and development of a Project in an interdisciplinary way. Among the main objectives, it is intended to promote teamwork and collaborative spirit in students, conceptual and experimental capacity, aesthetic and creative sensitivity, ethical, humanistic, environmental and social responsibility, and the ability to propose, analyse and solve complex problems, generating autonomy, critical analysis, propositional capacity and creativity (Cortés-Mora et al, 2017b).

One of the main focuses of the course is interdisciplinarity, this is a cooperation tool that, based on common objectives, allows to identify the interrelation present in all systems, thus, it develops reflective attitudes in students and involves the teaching role from dependency and complementarity relationships with other subjects and disciplines (Cortés-Mora et al, 2017a).

Over time, TPI has built multiple tools to effectively propose and develop solutions to solve problems that have a social approach and that start from the dynamics of both the University and Colombian organizations, promoting creativity, use of engineering design tools and interdisciplinary work from the external part where it works with the proponents and their environment, government entities and experts on specific topics, but also seeks that all disciplines within the University field are part of or support the formative and entrepreneurial process of the students, which are evaluated according to the level of Development that they present in the elaboration of the solution (Duarte et al. 2011).

2 PBL, and virtual learning tools as a key to success in the change to virtuality

The TPI course is based on the use of project-based learning methodology (PBL), the course allows students to expand their knowledge and develop skills from problem solving as a constructive and self-directed process in that, the ideas arise from an essential question that motivates the student to investigate and acquire their own knowledge through the analysis of the environment. Initially in the face to face course, the student has direct contact with the environment of the problem and can use the infrastructure and physical tools to shape the solution, given the change to virtuality caused by the pandemic; Virtual tools play a very important role since they allow the student to obtain information through the network and to carry out discussions around the conclusions and the information acquired within their work team without having physical contact with the environment. What gives greater independence and allows to maintain the purpose of self-directed learning (Elzainy et al., 2020).

Virtual learning tools are key in the virtual modality to involve students in their own learning, which allows them to live their own experience while they are passionate about the problem and motivated to seek one or more solutions that are appropriate to the needs of the stakeholders, which empowers the student and makes him responsible for the construction of his own knowledge and cognitive development (Guerra et al., 2017).

As the student is the protagonist of their own learning, the teacher becomes a guide who provides tools to contextualize and define the problem clearly, then; guides them to propose solutions and structure the way to understand which of these are viable and which are not. When the process is in the physic classroom, the teacher, meets with his or her work teams and conducts a mentorship. But in this moment not being able to do it this way, live streaming applications such as Zoom or Meet facilitate encounters, improve educators' technological skills (Lajoie et al., 2014), and encourage students to participate in sessions by the accessibility of the tool and the security of being able to work with your colleagues within your course without leaving home.

The methodology of the course is designed both in person and in virtuality to consolidate the work team, which makes the previous knowledge acquired by each member available to contextualize the problem to build new knowledge in order to propose and develop a solution. For this, the construction of useful and concrete contexts allows students to develop a deeper and more strategic approach to learning that is characterized by the intention to understand the relationships between interactions with content, new ideas and prior knowledge; everyday concepts and experiences; and time management that are basic characteristics of a PBL approach (Biggs & Tang, 2011).

When students achieve to understand and develop new ideas supported by their own experience, it is of vital importance within the development of TPI that they use their creativity to communicate them and that is where the use of virtual learning tools combined with the tools for content creation not used frequently in the presence, become essential to facilitate the presentation and communication of ideas within virtuality. As a result of this process, the interlocutor participates actively through his interaction with the contents created and analyses them to the point of actively getting involved in the conception of the problem and the construction of the possible solution.

The contribution of interlocutors who can be mentors, experts, and external participants empowers the student as the protagonist of their own knowledge and encourages them to work on learning management tools that stimulate their curiosity and allow them to continue in an orderly and logical manner the development of the course, these tools must provide the necessary information so that the student can build their solution within the framework of the design supported with relevant information.

One of the most used management tools during all the phases of the course in virtuality, is Moodle, in which students find information for the development of their projects, this has taken a leading role during the pandemic due to its involvement In it Virtual learning objects as a complement to the meetings, in addition to all the learning guides, which allows students to be connected to the course from virtuality and to know what the requirements of each stage are.

Additionally, for the training of students, it is very important to know the experiences of others who have managed their own knowledge, which promotes the development of the necessary skills for the construction of the proposed solution and that is where streaming platforms become the communication virtual channel where the exhibitor must use applications that allow their conference to be more interactive and interesting and that capture the attention of students on the other side of the screen.

Given the importance of the processes of self-reflection, Presentation and feedback throughout all stages, evaluations based on rubrics are proposed in the Moodle platform, which facilitates the evaluation and feedback of the students by their mentor in where much of the learning success is based on the ability of the student to use the technological platform (Dormido, 2004), but it also allows them, through a reflective process, to evaluate their performance and the evolution of the work team and establish actions that improve the aspects that are not developed significantly.

In the methodological innovations, those that seek to actively involve the student in their learning process have stood out, achieving positive results, particularly in understanding concepts and in the ability to solve problems (Deslauriers et al, 2011). In the final stages of the course, students are encouraged to communicate their learning achievements through a speech where they sell their idea. As a final proposal a project fair is developed where innovation plays an important role. The ideas through prototypes, which are evaluated by experts who also encourage their continuation. In this, the students recognized the importance of learning from interaction, improve their communication skills and interact with principal stakeholders who give feedback on the progress presented during the development of the course. In this aspect, the use of tools such as videos and web page development allowed from virtuality to give a significant scope to the deliverables of the students by having a greater deployment and thus allowing the participation of a greater number of people interested in the projects of the subject.

To encourage the student's desire to socialize, compete, and achieve achievements, gamification tools were used, this increased the interaction of students with the platform and allowed them to follow the processes appropriately.

3 Methodology used in the change from face-to-face to virtuality

Due to the emergence of the pandemic caused by COVID 19, a global disruption was caused in education, forcing educators to quickly train in the use of virtual learning tools since the current situation made it imperative to work online and from home. In such a way that E-learning is ratified as a virtual learning space that facilitates the experience in distance training by encouraging students to self-learning (Cook et al, 2008). Thus, the Interdisciplinary Project Workshop (TPI) course had to rapidly evolve from face-to-face to virtuality, to meet the objectives of the subject and provide students with the best possible user experience.

The course has four main stages: setting, preparation and inspiration, formulation and implementation, and presentation. In each of these stages, changes were made in academic practices directly related to the use of different virtual learning tools that were subsequently analysed to determine their contribution in the constructive and self-directed process of construction of students' knowledge.

Table 1: Changes made in the course in the move to virtuality.

Phase	Tool	Presence	Virtuality
Ambientation	Pitch	Exhibition in the classroom 1 minute without presentation. Written protocol and sent via email	1-minute video. OVA was developed to guide the student in their preparation
Preparation and Inspiration	Infographics	Printed or in Pdf face-to-face presentation	Iteractive infographic developed in canvas, Thinglink, exelearning, h5p or another tool. Virtual lift way Meet or Zoom
	Conference	Lecturer in auditorium with Power Point presentation	Lecturer in live broadcast application, use of polls, group sessions, games, forms, to motivate the talk
Formulation and implementation	Initial written work	In pdf in the virtual classroom	In pdf in the virtual classroom
Presentation	Pitch- Prototype-Website TPI-Expoideas	Face-to-face Project Fair with poster and functional prototypes according to modality	Video development, TPI-Expoideas website.

All	Course information and learning tools	In pdf, sent via email. Master class by the teacher in the classroom	Inverted classroom methodology, Development of interactive OVAs, use of the moodle platform with all the interaction.
All	Evaluation	Simple direct qualification or printed rubrics, typed in Excel.	Grade by Rubric within the virtual classroom

Source: TPI 2020 Annual Report

To determine the impact that the change in academic practices generated on the development of the course in the change from face-to-face to virtual modality, the results obtained during 2019 face-to-face modality were compared with those obtained during the virtual year 2020 on:

- The number of projects registered by modality
- Evaluation results obtained by students in the presentation of the infographic, which measures the end of the stages of setting and preparation and inspiration.
- Evaluation results obtained by the students in the pitch session and in the presentation session of the final prototype that evaluate the development of the solution to the problem.
- Rate of Acceptance of Conferences that complement the training of students
- Interactions with Moodle directly from the virtual classroom report
- Overall perception of the course measured as a percentage of favour, evaluated by students at the end of each semester.

4 Results

TPI has measured its performance, based on the perception analysis of the students who take the course, through the results of the proposed evaluations, with criteria that allow within the analysis to make the comparison semester by semester as mentioned above.

4.1 Projects registered by modality

Table 2 presents the comparison of the students' choice of the type of project to be carried out. They can determine which modality their project will be developed among four possible: Research, Entrepreneurship, Consulting or Innovation

Table 2: Project Modalities by Year

Project Modality TPI 2019 vs. 2020				
2019	10%	29%	13%	48%
2020	3%	29%	33%	35%
	Research	Entrepreneurship	Consultancy	Innovation

Source: TPI 2020 Annual Report

In 2020 the trend was oriented towards working with external projects, within the framework of the creation and transfer of knowledge, seeing organizations as allies to promote entrepreneurship and generate progress at the country level, which is totally linked to the PBL and consolidates the third mission of the university.

In turn, the decrease in the research modality can be explained by the impossibility of the students who took the course remotely, to access the different laboratories to carry out their tests. This contrasts with the increase in consulting projects, which can be explained by the ease of communication with the different organizations, as it is not necessary to travel and increases availability for meetings.

4.2 Results in the presentation of the infographic, pitch session and presentation session of the final prototype

Regarding the average grades obtained by the students in the presentation of the infographic, the comparison during the last three semesters is presented in table 3:

Table 3: Comparison of average scores, distributed by assessed deliverable.

Infographic Evaluation Criteria			
Criterion	2019-II	2020-I	2020-II
Qualification	3.81	4.6	3.2
Trouble	3.44	4.35	3.25
SDG	3.56	4.25	3.1
Background	3.36	4	3.35
Context	3.18	4.2	3.35
Actors and Stakeholders	3.21	4.2	3.31
Possible solutions	3.54	4.2	2.91
Bibliography	3.68	4.2	3.35
Presentation of Texts and Images	3.58	4.2	3.58
Oral Presentation of the Infographic	3.88	4.3	3.71
Average	3.52	4.25	3.31

Source: TPI 2020 Annual Report

Table 4. presents the results obtained in the final pitch session, compared during the 2019 and 2020 semesters.

Table 4: Comparison of average scores, distributed by assessed deliverable, PITCH

Pitch Evaluation Criteria			
Criterion	2019-II	2020-I	2020-II
Trouble	3.73	4.2	3.89
Actors and Stakeholders	3.48	3.95	3.62
Solution	3.48	3.97	3,395
Viability Aspects	3.04	3.58	3.18
Interdisciplinary work			3.4
Actual needs	3.14	3.87	3.39
General presentation	4.07	4.42	3.91
Average	3.49	3.99	3.54

Source: TPI 2020 Annual Report

As a result, there is an increase in PITCH's presentation scores for the two semesters of 2020 when compared to the immediately previous year. This can be explained by the ease that students now must have aids such as texts or scripts for their presentations, in addition to no longer having to present before an audience, with different people evaluating and observing them, but now doing it before a screen with their classmates with cameras off.

Table 5 shows the evaluations of the students in the delivery of the final prototype, this is the result of the work carried out with the PBL approach during the semester, where the student within his knowledge construction process presents a solution to the problem analysed at the beginning of the course.

Table 5: Comparison of average scores, distributed by assessed deliverable, Prototype

Prototype Evaluation Criteria			
Criterion	2019-II	2020-I	2020-II
Relationship with the problem	3.68	4.37	3.94
Construction progress	3.79	4.06	3.36
Raw materials	3.75	3.81	3.43
Knowledge	3.73	4.09	3.76
Executive summary	3.64	3.64	3.64
Prototype		3.95	3.85
Interdisciplinary work		4.01	3.44
Average	3.71	4.06	3.6

Source: TPI 2020 Annual Report

In this evaluation a decrease in the rating is observed regarding the semesters 2020 1 to 2020 3, difficulties were evidenced in the construction and functionality aspects of the prototype, in the description of the development and in the methodology carried out to obtain the result. As positive aspects, it should be noted that the prototype presented largely fulfilled the necessary functionality to be able to solve the original problem evaluated in the first phases of the course.

In this aspect, the change to virtuality had a significant impact and may be since the students do not know each other and when working in a virtual way for some teams, the communication is difficult.

4.3 Rate of Acceptance of Conferences

During the courses, different talks have been offered, which have also been evaluated by the students, the results of the acceptance percentage are seen in Table 6

Table 6: Rate of Acceptance of Conferences by Period

Discussion Acceptance Index				
Ethics Talk		82.4	79.8	95.3%
Multiple Offer	78.3	85.5	89.3	90.2
Prototyping Alternatives			88.1	64
Soft skills		89.8	90.7	90
Laboratories			86.1	86.1
How to make a good pitch	91	89.4	96.2	95
Period	2019-I	2019-II	2020-I	2020-II

Source: TPI 2020 Annual Report

The different conferences have shown a very good acceptance by the students with the exception of the prototyping talk. This may be due to the fact that the second semester of 2020 being completely remote (the first semester of 2020 had its first face-to-face sessions and there was no certainty if the different laboratories could be accessed to develop the prototypes) did not present the students a very encouraging about the different options to develop their prototypes with the materials they had at home, so the talk was not perceived as useful.

4.4 Moodle Interactions

This analysis is obtained directly from the virtual classroom, and measures the inputs, queries and interactions with the content and virtual learning objects (VLO).

Table 7: Moodle interaction 2020-1, 2020-3

Phase	2020-I	2020-II
Ambientation	3806	8630
Preparation and Inspiration	3656	7578
Formulation and implementation	2. 3. 4. 5	5907
Presentation	2951	6698
TOTAL	12758	28813

Source: TPI 2020 Annual Report

The virtual classroom played a very important role in the development of the course in virtuality, since virtual learning objects (OVAS) were used, which the students used as a guide for the development of their project, guides, protocols, rubrics and Everything was part of Moodle, which allowed all the information necessary for the development of the course to be concentrated in one place and forced everyone to continuously consult the platform, which increased interactions by 122% compared to the first semester of the year 2020.

4.5 Global assessment of students' perception

Table 8 presents the summary of the students' perception regarding their training process in different aspects.

Table 8: Global assessment of students' perception

Global Evaluation				
Evaluated Factor	2019-I	2019-II	2020-I	2020-II
Methodology	68%	64%	72%	74%
Teaching Performance	79%	76%	76%	83%
Impact for Professional Development	58%	54%	65%	79%
Impact for the Development of Entrepreneurial and Innovative Capacities	54%	56%	63%	72%
Development of Interdisciplinarity	75%	71%	75%	97%
Average	70.5%	66.25%	71.75%	82.5%

Source: TPI 2020 Annual Report

About the global assessment of students' perception, an interesting increase can be seen between 2019 and 2020. In general, students have improved their perception of the impact that the course has had on their training processes.

When reviewing the comparison in the performance of the students and their perception regarding the development of the course, no significant differences are perceived that allow us to deduce that the change to remote classes has impaired the development of the course.

5 Conclusions

When reviewing the comparison in the performance of the students and their perception regarding the development of the course, no significant differences are perceived that allow us to deduce that the change to remote classes has impaired the development of the course.

According to the analysis, all the tools and methodologies evolved to the virtual part with a favourable result in the that the participation of consulting projects increased considerably although in the early stages of the pandemic the change from face-to-face to virtuality slowed down relations with external parties. The different conversations showed very good acceptance, the interactivity was increased with the use of the virtual classroom and the global assessment of the perception of the students regarding the course was notably improved, which shows the alignment of the course with the achievement of the proposed objectives.

However, based on the results obtained, the course coordination has decided to make some adjustments to the design of the curriculum for the year 2021, taking into account that the development of the classes will again be remotely:

- Eliminate the research modality within the possibilities of the course
- Adjust the infographic and recognize it as a baseline that presents the context of the problems identified and complement them with audiovisual material and interactive resources to improve the user experience for the evaluators
- Review the content of the conference on alternatives to prototyping and adjust it even more to the reality of the non-presence of the students
- Have the set of rubrics and evaluations available from the first day of class and collect change suggestions for the next course
- Strengthen relationships with external proponents, for this, each tutor is responsible for establishing contact with proponents and intends to dedicate time within class time, for interaction between proponents and students.
- Modify part of the course methodology in relation to engineering design to meet the requirements of ABET certification.
- The strategies developed during virtuality and the use of Information and Communication Technologies (ICT) have an important role like part of the change. And it is considered that they should continue as strategies for continuous improvement from teaching practice.

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Problem-based Learning: The AfricaLics Experience

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Abstract

Problem-based learning (PBL) holds the potential to improve the quality of education as well as the usefulness of candidates in terms of helping to solve societal problems. Many African universities are currently working to develop ways of integrating PBL and other student-centered learning methods in their curricula and teaching methods. Some are also doing this within the field of 'Innovation and Development' (I&D), which – from a social science perspective – is an emerging academic field in most African countries. I&D is focused on different ways of understanding innovation, and on the potential benefits of innovation for economic and social development, which is the key focus area of AfricaLics.

In 2014, AfricaLics developed a Master Module on I&D based on PBL and other student-centered teaching methods. This was based on a workshop with faculty from a range of African universities. Up-take of the module was initially limited, however, partly because of limited experience at African universities in PBL and in I&D. To mitigate this, a highly interactive and practical training workshop was organised in 2016. Since then, some new courses and curricula that use materials from the course have emerged. AfricaLics conferences have also included a 'teaching track', where experience from implementation of student-centered learning and I&D module materials have been discussed.

In this paper, we focus on the AfricaLics' attempt to foster enhanced PBL practices at African universities within the specific area of I&D. Follow-up with the participants in the two workshops show that some have used the material and experimented with PBL and other student-centered learning methods. Up-take of new teaching methods is not an easy process, however, as many African universities are dominated by traditional teaching methods. Interest and feedback from both students and faculty has been positive, however. We therefore recommend follow-up initiatives to deal with the challenges related to use of PBL practice in African universities.

Keywords: AfricaLics; Problem-based Learning; Innovation & Development
Type of contribution: PBL best practice

1. Introduction

Interactive learning methods, such as Problem-Based Learning, are key for the improvement of the education quality and the impact that candidates eventually have in their local communities and the society (Servant, 2016). In Africa, some educational institutions are making efforts to bridge the gap between education and societal problems. Our starting point for this article is the question: Why and how may PBL and other student-centered learning methods be useful as a teaching tool for expanding innovation and development at African Universities?

An upcoming academic field especially in African countries is the field of 'Innovation and Development' within the social sciences. It focuses on different ways of understanding innovation, and on the potential benefits of innovation for economic and social development. The AfricaLics network was set up to promote this field. The ultimate goal of the AfricaLics research network is to contribute to economic, sustainable and inclusive development in African countries (low, middle-income and high); in line with the Sustainable Development Goals. The network focusses on research and research capacity building linked to understanding the role of knowledge – both science-based and experience-based – and learning among all actors (followers as well as leaders – users as well as producers) as both issues are crucial for understanding innovation.

In 2014, AfricaLics organized a workshop and symposium in Dar Es Salaam focusing on '*Building Innovation Research Capacity in East Africa: developing innovation and development masters modules*'. The workshop led to the development of a Master Module on teaching Innovation and Development using problem-based learning and other student-centered teaching methods. The idea being that individual universities could use the Master Module to develop their teaching in the field in a way that would fit the context of each university. Up-take of the Master Module was initially limited, however, given the fact that few universities had actual experience of working with PBL and other student-centered methods.

Hence, as a follow up, the AfricaLics Secretariat organized another workshop in 2016 designed to support and train academic staff from African universities who were integrating or expecting to implement an innovation and development course into their curricula. The training design was highly interactive and practical with a focus on Innovation and Development issues and interactive based learning techniques, such as PBL.

In this article, we first discuss the importance of PBL for African educational institutions, especially within the field of Innovation & Development (I&D). We then draw on the experience of the 2016 workshop, the idea and design of the workshop as well as the follow-up surveys in order to evaluate the usefulness of PBL and the experiences by the participants who were trained by the AfricaLics experts. Finally, we conclude with some open discussions on the issues raised and some recommendations for the future. The paper is about how PBL inspired teaching approaches introduced by the workshop and the development of the course in innovation and development encourage others to engage more with I&D.

2. Methodology

Methodologically, the paper builds on a combination of methods of thematic analysis and descriptive statistics. We first conducted two surveys with the 19 participants trained in Nairobi using a structured questionnaire. The first survey took place in 2017 and the second one in 2020. The first survey asked strategically selected questions, focusing on the experience of the participants using the material and the interactive PBL inspired methods. Given the four year time frame that had passed since the workshop, the follow-up survey in 2020 did not focus on feedback on the actual workshop, but mainly on whether and how the participants took advantage of the knowledge gained.

The 2017 questionnaires were administered via e-mail where participants were requested to fill and send back the short structured questionnaire within a week. A reminder email with a survey link was sent to a few who had not gotten back with the feedback after the set deadline. Three years later, in October 2020, the follow up survey was done through a phone call interview. This approach was chosen in order to ensure a high response rate, while the COVID-19 pandemic did not allow for any face-to-face interactions. The follow up surveying in 2020 took approximately three weeks, including documentation of the data.

After collecting the data from both surveys, we coded the answers provided by the participants and we identified common patterns and themes that describe their positive and/or negative experience from the workshop but also their positive and/or negative engagement with the material while teaching in their home institutions. The findings are therefore presented in two sub-chapters of benefits and obstacles met when using the workshop training.

2.1 Limitations of the study

We have had to limit the study to surveying solely the academics trained at the AfricaLics workshop, hence leaving out information that we could have gathered from other trainings or from other academics who might have interacted with the Masters' module materials independently (the materials are available on the AfricaLics website). At the same time, we have been unable to conduct any interviews or surveys of students who have attended courses developed by their lecturers and which were inspired by the 2016 workshop. Thirdly, since we had limited time available, we have not been able to interrogate further the details received through follow up phone calls and/or any focus group discussions. These limitations notwithstanding, we believe that the paper does provide useful insights on the opportunities and challenges of introducing new curriculum using PBL methods in African university settings.

3. An introduction to AfricaLics' Innovation and Development Studies

Since its establishment in 2012, AfricaLics has been linking (African) scholars working in the areas of innovation and development with a special emphasis on issues relevant for African countries. The social science subject area known as 'Innovation and Development' teaches different ways of understanding innovation, and the linkages between innovation and economic and social development, including potential benefits and possible negative impacts. Within the AfricaLics community, innovation is broadly defined as spanning from the development and commercialization of "new to the world inventions" to the development, diffusion and use of technology that is new to the user or context in which it is introduced and includes competence building among users of innovation. Technology can mean both a physical product as well as a process and new way of doing things. Innovation and Development Studies research as defined by the AfricaLics network includes the study and management of processes that link technological and social innovation with development. This includes studies and improved understandings of how learning and competence building systems contribute to development processes.

AfricaLics grew out of a field of study known as 'innovation studies' that initially developed out of development economics in the UK, Denmark and the US and which has since spread around the world (Frageberg, 2013; Globelics website). The network was set up because of a recognition that there was limited research done on the African continent by African scholars in the field of innovation studies. A survey in 2014 (Kraemer-Mbula, 2014) highlighted that there were only three universities across the continent which provided a Master's programme with the word 'innovation' in the title and all at Masters level.

As a result, the AfricaLics network, through funding from the Swedish international Development Cooperation Agency (Sida), provides a number of unique networking opportunities and increases access to specialized training on I&D in order to enhance economic and socially sustainable development in Africa. AfricaLics works to support African scholars, researchers and policy analysts especially at their early careers to produce research in the field of innovation studies that is at the global frontier and is relevant to resolving developmental challenges of African communities. The AfricaLics network provides this support in different ways, one of which has been through the promotion of new or improved curricula into African universities. Between 2014 and 2020, the AfricaLics Secretariat has among others developed model Masters and PhD programme materials, conducted PhD Academies, workshops and lectures.

AfricaLics has utilized PBL or PBL-inspired teaching and learning formats and/or promoted the importance of PBL and like-minded teaching and learning approaches. The AfricaLics network has promoted these approaches because the subject area of innovation and development requires such an approach for full appreciation by students and teaching staff of the issues the field investigates. The field of I&D is fundamentally a field of study that is concerned with solving (societal) problems.

4. PBL for Innovation and Development studies teaching in African universities

Originally, problem-based learning was introduced within the engineering and medicine disciplines. In 1960s, PBL was used in Mexico with the main aim of targeting the social groups who could not access medical care and therefore were more vulnerable (Servant, 2016). PBL was later employed more globally and beyond the medical field, to engineering and other disciplines (ibid).

PBL holds the potential to improve the quality of education as well as the usefulness of candidates in terms of helping to solve societal problems. Many African universities such as e.g. Kwame Nkrumah University of Science and Technology in Ghana have realized the need for doing more in this area and are currently working to develop ways of integrating PBL in their curricula and teaching methods. New societal developments have led many African Universities to explore and adjust their pedagogical methods in order to address complex structures of learning. PBL method has helped to build a bridge to the world "beyond the institution, enabling more rapid transfer of knowledge from the spheres of education and research to those of production and structure in business, public institutions and civil society" (Jensen *et al*., 2019).

Curricula with a focus on Problem-based methods provide students with guided experience and aim on the following important goals (Barrows, 1986; Hmelo-Silver, 2004). Firstly, this design helps with the construction of an extensive and flexible knowledge base across multiple domains and sectors. Such knowledge is organized and integrated across the fields by gradually developing flexible application of their knowledge in a variety of problem situations (Hmelo-Silver, 2004). Secondly, the development of effective problem solving skills "includes the ability to apply appropriate metacognitive and reasoning strategies" (Hmelo-Silver, 2004: 240). The students must be able to set learning goals, identifying the gaps in their knowledge and require guidance, while evaluating the process for the task they are engaged in. Lastly, PBL helps students reach an in-depth motivation. Essential motivation occurs when learners work taking into consideration their own interests, challenges, or sense of satisfaction.

Although these goals are largely accepted as overall goals of the PBL method, adoption of a PBL model should take into cognizance different cultures. According to Barrows (1986), the designing of models that have PBL in their core, with educational objectives and purposes, is endless. However, all types of PBL must be evaluated in terms of: (i) type of problems, (ii) assessment methods, (iii) learners' autonomy, and (iv) in which way the teaching and learning occurs. PBL can be implemented at different levels, from just one course to the entire curriculum. To allow implementation several curriculum elements in the PBL environment and learning principles must be aligned.

When it comes to the African universities' environment, we first need to acknowledge the challenges that occur. Curricula are often not responsive to real life problems and many graduates find it hard to find employment after graduation, since many of them are lacking skills relevant to the job market (Kokutse, 2020; Fynn, 2020). The response to these challenges has not been an easy task to address. In general, it requires a combination of technical innovation, political will and new forms of governance, including renewed focus on industrial policies, fight against corruption and negotiation skills. Importantly though it also requires universities that prepare students for an active role in innovation and development of their societies.
Within AfricaLics, we find that a curriculum on I&D that uses a PBL approach and other student centered learning methods is more likely to help students focus more on real life problems and become better at generating solutions to real societal problems. Furthermore, this particular method will prepare students to interact with the wider society. Teachers with knowledge and focus on PBL may focus more on contributing to solving real problems in their own research and thus contribute more to enhanced capacity in innovation and development research. Likewise, future graduates and researchers trained in PBL as part of their studies, are more likely to be even more oriented towards solving real problems (Okolie, 2003) - from issues related to agriculture and food production, to sustainable energy and health challenges and ways of developing more diversified and sustainable economies that can reduce poverty on the African continent. Innovation and Development as a field is multi-disciplinary and hence relevant for various disciplines when combined with PBL - from social science, including economics and business economics, to more technical disciplines such as technological management. A core issue for Innovation and Development studies is how to ensure that national, sectoral and technological innovation systems in Africa may be strengthened and better able to ensure use of existing and new knowledge and inventions.

Based on this thinking and interactions with university lecturers, AfricaLics developed in 2014 a Master Module on 'Innovation and Development' for incorporation into existing Masters' programmes at African universities. The module introduces students to the importance of thinking about innovation in the context of local (community), national and global development (http://www.africalics.org/wp-content/uploads/2017/05/ModelMastersModule-outline.pdf). The module uses a PBL philosophy to guide its methodology, since as mentioned above PBL refers to a way of teaching and learning that: 1. focuses on learning through active enquiry 2. has the teacher as facilitator rather than a top-down instructor 3. Sees students as pro-active, and 4. focus on learning through problem solving supported by theory and practice.

5. Analysis of elements of AfricaLics PBL activities

This paper focuses specifically on AfricaLics efforts to encourage the development of new teaching and curriculum in universities across Africa that utilize PBL and related teaching and learning approaches. We focus particularly on the impact of a workshop held in Nairobi in 2016 that was conducted to increase the uptake of the course on innovation and development for post-graduate teaching and learning materials.

In the workshop that took place in 2016, 19 participants attended. They were selected based on an open call for expressions of interest that was advertised through the AfricaLics' social media platforms and other affiliated networks. The participants were selected by the AfricaLics Secretariat based on an assessment of the letters of motivation and ideas for use of material on the master module of I&D.

The workshop was titled 'Teaching innovation and development: A workshop for university lecturers in Africa' and held in Nairobi, Kenya on 29th November to 2nd December 2016. Out of the 19 participants, 10 were female and the participants were drawn from 17 different African countries. Over 95% of the participants were university lecturers and the majority (n= 10) were PhD holders. Slightly over 80% (n=14) of the participants were from low income countries as per the World Bank classification. The workshop participants also included six facilitators and three staff from the AfricaLics secretariat who assisted in logistics.

The workshop was expected to be relevant for those who were interested in integrating a Masters level introductory course on I&D into their curricula, and/or those who already started using the AfricaLics materials but had faced problems with their implementation. In preparation for the workshop, all participants were asked to go through the Masters module materials and were requested to read a number of the core texts in the materials before the workshop, in order to focus more on the learning and teaching process during the workshop itself.

Thus, the focus of the workshop was on practical training on interactive learning techniques. The workshop was designed to make workshop participants experience the course as a student would. Therefore, the workshop was designed around the Masters module content and included lectures as well as group work exercises taken from the module. Specific learning activities designed for the students to reach the learning objectives included learning sessions on a. The history and definition of innovation and development studies b. Research methods for studying innovation and development studies and c. The relationship between innovation and development research and policy debates. Reflecting on the teaching experience was a constant activity in order to boost the participants' knowledge of the subject matter but also receive an immersive experience of PBL type approaches. The workshop was also designed to enable experience sharing amongst lecturers from different African universities on their classroom teaching experiences, problems they face with teaching and previous experience of PBL. Finally, the participants had a number of experience sharing and evaluation sessions on the course materials and the learning experience. During the training, participants had close interaction through project work on self-selected problems (e.g. new solar system for rural areas). The participants developed Action Plans based on the learning activities to help them implement some of the ideas gained in the course. These action plans outlined short, medium and long-term efforts that they would attempt to make to encourage the uptake of I&D training and teaching using PBL and other interactive teaching and learning methods at their home institutions.

5.1 Surveys' Findings

As noted in the methodology, two follow up surveys were conducted first in 2017 (around a year after the participants had attended the workshop) and a second in 2020. These surveys mainly focused on the Action Plans that the participants had developed during the workshop and their experience after implementing the workshop training in their home institutions.

5.1.1 Utilisation of workshop training: benefits

The first survey showed that some participants had already started using the workshop materials and incorporating them into the existing curriculum within a year after the workshop. Others had already initiated new curricula in the area of I&D, while some participants had used parts of the materials in research seminars. Participants had used the I&D Master module and materials to develop units, train colleagues as well as introducing PBL to students in their teaching classes. Respondents also mentioned that PBL has been very interactive and a good way of getting all students to participate in the lessons. Some of the new courses in which materials from the I&D Master Module had been incorporated mentioned were: Technical Entrepreneurship and Venture Management; Management of Technology Innovation; Technology and Innovation Management; and Innovation Management.

The second survey conducted in 2020 focused on the relevance of the reading and training materials provided in the workshop. All respondents mentioned that the material was very relevant, interesting, educative and informative to date, while some mentioned that they had already been using the material in several occasions, such as training colleagues at their institutions, teaching graduate students and improving the curriculum content in class.

In this second survey, we also wanted to investigate which of the teaching methods (PBL and other interactive methods) were applied at the home institutions. The respondents mentioned that PBL and traditional teaching methods have huge differences. However, it was evident that working in groups activated students' participation in class. Student's outcome was immense, and students were in general more engaging and excited to share and stimulate discussions and debates in class. This also increased students learning interest as the lessons were interesting and discussions were based on real time issues, practical and relatable. These comments can be illustrated by the following quote from one of the workshop participants:

'I have used both the PBL method in the context of classroom teaching and the results have been very good in terms of outcomes for my students. In the classes using PBL, I have registered better student attendance, higher student engagement during class, and greater achievement (higher overall group scores than the classes taught in traditional ways. The students were more engaged while in class, more excited to learn and they said they usually look forward to my classes My experience was that it is easy to introduce the teaching method in my own classes but it was harder to disseminate to other lecturers to use.'

Moreover, some lecturers have already heard positive comments from students who had been exposed to the PBL method. More specifically, some students mentioned that PBL classes were more interesting than others were, which resulted to perform better than the students not exposed to this learning method. Students' feedback showed that PBL is a valid teaching-learning methodology to enhance student understanding of difficult concepts. Students predominantly used lecture handouts and textbooks to prepare for PBL discussions. The following quotations are illustrative of these issues:

"My students were more at home with PBL teaching methods. I did not do any official evaluation but they have often commented that my classes were more interesting than others."

"My students exposed to the PBL have often consistently performed better than the students not exposed to the learning method."

To sum up, it was noticed that there is appreciation of PBL in African universities by both the workshop participants and their colleagues, as well as the students who engaged with this interactive teaching method.

5.1.2 Utilisation of workshop training: obstacles

One of the major difficulties when implementing the developed Action Plans were faced due to institutional protocols, politics and bureaucracies; making it difficult to implement curricula and teaching methods. The first survey (2017) showed that those who made an effort to introduce new curricula had to pass through the university Senate to get approval, which was time-consuming.

Another major challenge mentioned to explain the limited progress made within the first year relates to time constraints. Specifically, the rigidity of teaching timetables was mentioned, which forced lecturers to mix PBL type methods with more traditional teaching in order to cover the target outline by the end of the semester. That said, many of the respondents noted that they have been able to implement some elements of PBL type teaching and learning into their systems.

In the second survey, we also followed up again on the problems participants had encountered in implementing the PBL method and their Action Plans. One response was that PBL method was not well understood in the beginning and integrating it proved to be time-consuming. The respondent believes that this came because of the traditional teaching method that students were used to and a reluctance to embrace change. Lack of resources including administrative support, space and materials were some important practical challenges when implementing PBL. The following quotes illustrate these points:

"The problems I have encountered are not in the actual implementation in class, but rather more of systematic problems. Time involved in learning about the new strategies and redesigning their courses, some of which they have been using for the last twenty years. Some were concerned that the content may not always be correct (They seem to want to stick to what they already know despite the fact that entrepreneurship is a dynamic field that is always changing). (…) Some were concerned about their student's reaction to unfamiliar teaching method and what impact it might have on their course evaluation. The challenges above, both from the faculty side and from the bureaucracy in the system has really slowed down the implementation of my personal action plan. At the same time I took one year off from classroom engagement in order to complete my PhD thesis which has slowed down my progress."

"Apart from skills, related problems are often the lack of resources such as time, administrative support, space and materials. Besides all the planning, PBL resources for students, the design of problems, availability of rooms for PBL-type of discussions, and support staff are important concerns."

Furthermore, one question of the survey was if the participants' colleagues had used the course material or the teaching methods. Only one mentioned that the course material had been used to develop an innovation and Entrepreneurship undergraduate course. Since public institutions' bureaucracies such as approval from Head of the Department and to institutional committees are of great importance in the African Universities, the development of new courses or curricula especially by untrained staff might take a lot of effort and time.

Lastly, the participants during the workshop who engaged with this module raised questions regarding students who lose motivation during project work. For example, many courses are being held with a large number of students, which makes it impossible to do group work. This brings supplementary difficulty to lecturers and supervisors to keep momentum during more interactive teaching approaches:

"The major problem is inadequate cooperation from students who were used to traditional teaching method and were reluctant to embrace change. I mitigated the challenge through persistence."

It is therefore evident that systemic obstacles within the African educational institutions are present. Structures that have been present for decades are difficult to go through rapid changes, especially when there is no proper training regarding the new teaching methods. In general, there is not enough understanding of this teaching method, while the rigidity of university systems reduced the potential to re-structure current teaching systems.

6. Discussion and Conclusion

This article has outlined attempts by the AfricaLics network to support teaching in the field of Innovation and Development that integrates PBL methods. It focuses specifically on the impact of a training workshop held in 2016 with 19 African lecturers. A survey conducted in 2020 served to follow-up on the progress of implementing PBL practices in African universities within the specific area of I&D.

Overall, there is a positive reception of the PBL system by the students evidenced by the fact that they were more interactive, creative and showed increased critical thinking abilities in the classroom. Some lecturers have also shown interest by attending workshops offered at the university as well as using the material given to the AfricaLics participants to develop courses and to teach in their classes. The main challenge is, however, that most African universities have strict institutional protocols, bureaucracies and approval processes that need to be followed in order to introduce a new curriculum or teaching and – not least – assessment methods in the universities. Negative reception of the new methods by some faculty members at the home universities of those trained by AfricaLics has also slowed the process down, as some faculty staff state that they would need training before applying a more interactive teaching method.

Problem based learning – especially when practiced in a group setting – exposes students to learning that is relevant for solving the grand challenges of our time, development of critical thinking, interpersonal skills and a motivation to learn. In a world characterized by rapid global digital transformation and introduction of new technologies, students need to be prepared for engaging with these and this increases the need for innovative ways of learning, including new and more dynamic mindsets.

Through its emphasis on PBL-like teaching methods the AfricaLics network has tried to respond to this challenge, but clearly faces a dual challenge. The network is contributing to the shaping and development of a new academic field in Africa, i.e. the field of Innovation and Development. On the other hand, it has tried to support introduction of innovative and interactive teaching methods in the way the teaching takes place at African universities.

The follow up surveys to the workshop have shown limited results so far in terms of up-take of the methods and materials, but this is perhaps not surprising: changing curricula and teaching methods is a long-term process, requiring time and continued efforts in the coming years. We suggest that a way forward in this respect will be the establishment of more collaborative efforts between key universities in Africa and partner universities from other parts of the world with an interest in developing I&D as a field of social science in Africa and utilizing PBL-like methods for this purpose. Increased efforts to use existing partnerships (e.g. bilateral university programmes) could also be helpful.

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Application of Project Based Learning in an Environmental Engineering Programme

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Abstract

Project-based learning (PBL), a learning environment in which projects drive learning, has been increasingly applied in educational programmes across various disciplines. In terms of Environmental Engineering education, the primary pedagogy still remains “chalk and talk”, although many studies have confirmed its inefficacy. In the last decade, project-based learning (PBL) has been increasingly used as an effective learning method because it provides a pathway for engineering students to experience solving real-world problems as engineers. This paper researches students’ learning experience and skill development in the PBL in one module (Air Pollution) in an Environmental Engineering programme. Students were divided into small teams working on the greenhouse gases (GHGs) (CO_2, CH_4 and N_2O) concentrations on one university campus. With a certain level of supervision, students selected sampling sites, collected air samples, conducted laboratory measurements, calculated GHGs concentrations and presented the group presentations. A questionnaire survey was conducted to understand students’ learning experience and feedback on the PBL. Semi-standardized interviews were employed to provide a micro-level view of the students' study situations, and lessons and challenges. A majority of the students applauded the PBL for its benefit of applying knowledge from lectures to field problems. In contrast to lecture-based learning, students confirmed that their interest and confidence in environmental engineering had substantially increased, together with the development of transferable skills, and understanding of teamwork and engineers’ responsibilities. With the development of transnational education, further research is needed to understand the learning experience of international students, particularly those whose studies are primarily teacher-centred in their home countries.

Keywords: Project-based learning, environmental engineering, engineering education, group work, employability skills

Type of contribution: PBL best practice

1 Introduction

The main pedagogy in Environmental Engineering remains "chalk and talk", although a large body of studies have confirmed its ineffectiveness. Like many disciplines, the practical classes, including field sampling and laboratory measurement, in Environmental Engineering are developed to complement material given in lectures and offer students more experience, which will be essential in their future careers as engineers. However, traditional practical classes have been criticised for their limited level of learning, as students are often unclear regarding learning objectives and incapable of applying the knowledge gained from lectures in the field. Furthermore, these practicals generally allow little space for creative thinking or contextualisation, and they are typically a testing or confirmation of the theories delivered in lectures (Mc Donnell *et al.*, 2007).

In the last decade, project-based learning (PBL) has been progressively applied as an effective learning approach in various engineering education programmes. However, its applications in Environmental Engineering are still very limited. Similar to other disciplines, PBL may offer a path for environmental engineering students to experience addressing real-world issues as engineers and develop various employability skills (Moallem *et al.*, 2019).

This practice study was motivated to start PBL projects regarding greenhouse gas emissions in an Environmental Engineering programme. Two research questions guided the research:
1. How is the students' learning experience during the PBL process?
2. To what extent does PBL improve students' employability skill?

2 Literature review

2.1 Project-based learning

Domin (1999) summarized the procedure, approach, and outcome of four styles of teaching: expository, inquiry, discovery and PBL (Table 1). In Environmental Engineering programmes, the most widely used one is still the expository style.

Table 1: Procedure, approach, and outcome of different laboratory instruction styles (Domin, 1999)

Style	Procedure	Approach	Outcome
Expository	Given	Deductive	Predetermined
Inquiry	Student Generated	Inductive	Undetermined
Discovery	Given	Inductive	Predetermined
PBL	Student Generated	Deductive	Predetermined

Unlike other learning styles, PBL is a learning environment in which projects drive learning. PBL is the student-centred education method in which learners work in cooperatively teams to determine what they need to study (Hmelo-Silver & Eberbach, 2012). With a certain level of supervision, learners have ownership of the study process and they are mainly in charge of making decisions during the PBL (Guerra, 2017). As instructors, they act to facilitate the study process, instead of offering knowledge.

In addition to doing project, the 'know why' is profoundly pertaining to the problem/project design methods used in the PBL (Holgaard *et al.*, 2017). In order to better verify the approaches taken by students, 'know why' is indispensable in the PBL. Identifying and analysing the problems is an important part of the PBL. It is important for the students to think about these problems within the context of the learning programme and also from the personal situation and interest. By this means, students don't simply construct or rebuild their own knowledge – it is a three-way loop study procedure, where “triple loop learning is learning that opens inquiry into underlying whys” (Isaacs, 1993).

After continuous development and improvement, the effectiveness of PBL in education has been widely reported. For example, some scholars have provided evidence on the advantages of the Aalborg University PBL model relating to learners’ growth in teamwork skills, problem-solving skills, independent learning, and leadership (Clausen & Andersson, 2019; Kolmos *et al.*, 2009).

2.2 Project-based learning, sustainability, and Environmental Engineering programme

With rapid global change and a recent pandemic, engineers are not just anticipated to have scholastic knowledge and technical abilities, but also to have practical experience and various capabilities, for example, problem-solving abilities, teamwork abilities, and independent-study abilities (UNESCO, 2017). To meet the increasing requirement of the future engineers, PBL has been developed into an indispensable study approach to establish learner’ different capabilities. In PBL, learners are exposed to real and complicated problems in their daily lives, and they obtain an opportunity to study and work like real engineers in the future. In this process, learners build up useful experiences and construct a bridge to close the divide between college and industry. Due to the advantage in training engineering students, the PBL approach has been increasingly applied in engineering education (Chen *et al.*, 2021).

Environmental Engineering programmes offer training in all aspects of the supply of safe drinking water, the control of contamination, wastewater treatment, air quality control and waste management. Environmental Engineering programmes are closely related to United Nations Sustainable Development Goals (SDGs) (UN, 2021). SDGs aim to deal with the world’s most difficult challenges, such as global warming, biodiversity loss, and air and water pollution. Education plays an important role in teaching the public to be aware of the various SDG crises. Higher education, such as engineering programmes, has an important role to play in training future workforces to mitigate or tackle these sustainability crises (Desha, 2013). For a better sustainability education, researchers have found that pedagogies that promote cooperative problem-solving are essential (Segalas *et al.*, 2010). In engineering education, Coral (2009) and Guerra (2014) have suggested problem-based group projects teaching is one of the most effective approaches to enhance the awareness and behaviour of sustainability. In addition, several researchers have suggested the importance of system-thinking (Dowling *et al.*, 2020) and trans-disciplinarity education (Byrne & Mullally, 2016) in engineering education for sustainability, due to the complexity of the sustainability challenge as laid out by the SDGs and increasing complexity of new technologies, such as AI and 5G.

Despite the extensive application of PBL in engineering education, the application of PBL in Environmental Engineering still remains in infancy. Requires et al. (2018) applied PBL in the Environmental Engineering programme at the University of the Basque Country, Spain, and they found PBL was a very motivating approach for the curricular development and attaining students’ study outcomes. Studying in small groups, learners’ independent-learning skills have also been developed. However, it is still not clearly understood for students’ learning experience and employability skills development in PBL process in the Environmental Engineering programmes.

Taking the above into consideration, this study applied the PBL to an Environmental Engineering programme at a British university. Studying in small groups, students conducted projects to explore greenhouse gas emissions from the university campus. The questionnaire survey and interviews were conducted to understand students’ learning experience and employability capability development.

3 Methodology

3.1 Project implementation

The PBL projects were implemented by a group of 34 Year 3 Environmental Engineering students studying for the Air Pollution module. Figure 1 shows the implementation of the projects. Because of the increasing global attention on climate change, students proposed projects on greenhouse gas emission from the university campus. Supervisors provided the necessary theories in lectures and made them readily obtainable. In addition, supervisors provided an outline of the problems, which are related to the project objectives. Students worked in small teams, searched and read relevant references, completed a literature review, and developed a detailed group project plan. Referring to published work, students identified field work and laboratory measurements and conducted a risk assessment of both field and laboratory work. Students carried out some pilot field and laboratory work, and supervisors provided some feedback on the preliminary results. If necessary, the original project plan might be revised before the formal start of the project. Working in groups, students conducted field sampling and laboratory measurements. Based on the group findings, each group presented a group presentation, and all students also submitted an individual report.

Specifically, the main aim of the projects is to understand the greenhouse gas (GHGs) emissions from one university campus. Students analysed the university campus map and identified five sites with possible various levels of GHGs: 1. a classroom, 2. the university library, 3. a student hall, 4, sport ground, and 5. near a lake (Figure 2). There are different kinds of GHGs. With guidance from supervisors, students focused on three important gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Air samples were collected using a plastic syringe with a two-way stopcock. At each site, three samples were collected. CO_2, CH_4 and N_2O were analysed in the laboratory using an Agilent 7890 B Gas Chromatography with Flame Ionisation Detector (FID) and Electronic Capture Detector (ECD) (Yang *et al.*, 2015).

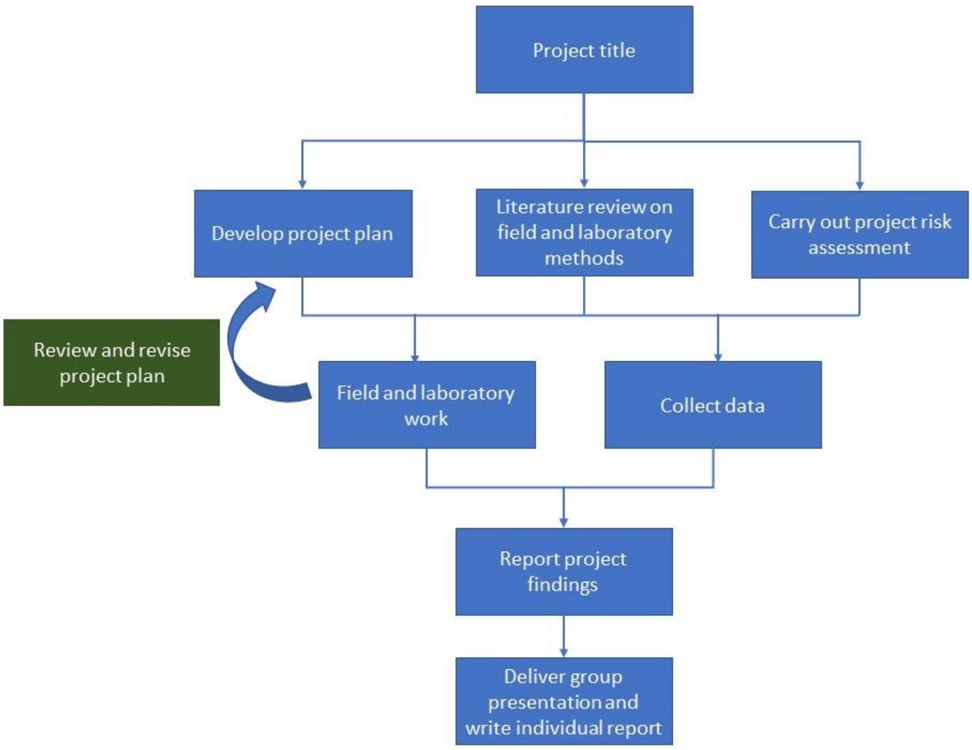

Figure 1: Implementation of project based learning (PBL) in an Environmental Engineering Programme (After Mc Donnell *et al.*, 2007)

Figure 2: Sites for collecting air samples on one university campus. (1) Classroom, (2) Library, (3) Student hall, (4) Sport ground, and (5) Near a lake. The map is from Google Earth.

On completion of projects, each team was required to give a 15-minute group presentation, a graded coursework weighting of 20%. The key criteria searched for were capability in analysing data, presenting their team findings, together with the ability to respond to questions. In addition, each student will submit an individual report, with an assessment weight of 80%. The supervisors looked for the evidence that students had conducted some research on the topic, correctly analysed the data, and clearly written the report.

3.2 Survey of students' learning experience and skill development in the PBL

To understand students' learning experience and skill development in the PBL process, a questionnaire survey was conducted. Semi-standardized interviews were also employed to provide a micro-level view of the students' learning experience and skill development during the PBL process. A total of seven students were interviewed to explore their learning experience during the PBL period. To analyse the interview data, this study applied a qualitative thematic analysis method, characterised by small sample size, abundant data analysis and a focus on transferability instead of generalizability (Braun & Clarke, 2012).

4 Results

4.1 Greenhouse gas emissions from one university campus

Students worked in groups and collected air samples from five sites on the university campus using plastic syringes with two-way stopcocks (Figure 3) and measured the GHGs concentrations in the laboratory. The results indicated higher GHGs concentrations on the campus than the global averages (Table 2). There is large variation in CO_2, while much smaller variations in CH_4 and N_2O on the campus. The coefficients of variation in CO_2, CH_4 and N_2O between the five sites were 39.31%, 10.12% and 9.38%, respectively (Table 2). Specially, the indoor environment (classroom, library, and student hall) had much higher CO_2 concentration, with a mean of 703.63 ppm, than outdoor environment (sport ground and lake), with an average of 427.60 ppm.

(A) (B)

Figure 3. Students collected air samples in a classroom (A) and near a lake (B) using plastic syringes with two-way stopcocks.

Table 2. Concentrations of greenhouse gases (ppm) on one university campus.

Sites	CO_2	CH_4	N_2O
Classroom	557.84	2.387	0.416
Library	531.45	2.359	0.430
Student hall	1021.61	2.454	0.458
Sport ground	368.01	2.321	0.420
Whiteknights Lake	443.91	2.660	0.420
Global average	*411.29*	*1.872*	*0.332*

4.2 Questionnaire Results

According to the questionnaire survey results, more than 90% students agreed that the PBL inspired them to learn more about the module (Figure 4). 98% of students definitely agreed that this module was designed in a way to help them learn. 96% of students definitely agreed that the teaching method, PBL, helped to create a sense of belonging within the module cohort. 98% of students definitely agreed that there were adequate opportunities to interact with other students on the module. Students' competencies have been developed significantly during the PBL process. In particular, 92% of the students definitely agreed that this module enabled them to develop their abilities as independent learners.

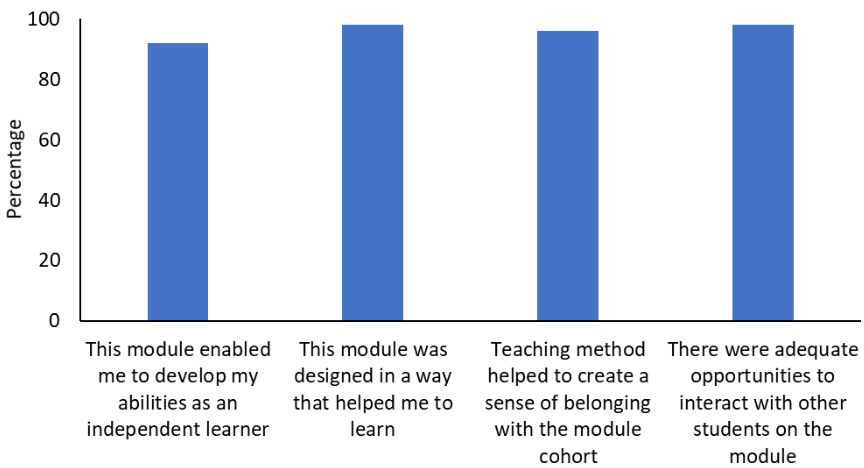

Figure 4. Percentages of students definitely agree with the evaluations of the module.

4.3 Interview Results

In order to make interview results more visible, the words that are most used throughout the interviews were counted and the most repeated words were applied to create a word cloud (Figure 5). Project, group, students, and together were mentioned very frequently by the interviewees.

Figure 5. A word cloud extracted from interview transcripts.

4.3.1 Students enjoyed PBL

Similar to the questionnaire results, PBL has received positive feedback from interviewees. Students enjoyed the PBL and started the projects very quickly, as exemplified by one student:

> *I think the students in our group have been very active in the project. After the instructor introduced the project-based learning, we immediately discussed it. Well, that's very great.*

Unlike the traditional teaching of "chalk and talk", the PBL gave students the opportunity to get to know each other and work on the same project. This was echoed by many students, as exemplified by the following comment:

> *It is harder to interact with classmates in other modules, but the group projects mean you can speak with new people you don't know before.*

4.3.2 PBL linked knowledge with practice

In the PBL, the fundamental change of students' learning is the chance to connect theories to practice. Traditionally, theoretical knowledge was generally obtained from lectures. When learners carried out PBL, they were immersed in these real-world problems and learned and worked in small teams. This real-life link is a means to perform professional training, i.e. engineering training. In addition, learners were trained to be independent learners and more responsible for their projects. More importantly, once again, the PBL gave students an opportunity to apply the knowledge they learned to various projects. For instance, one student stated:

> *I know about the knowledge of climate change and global warming, but I have not yet noticed the CO_2 emissions from our university campus. These projects gave me an opportunity to apply what I learned in practice, in the real environment around me.*

4.3.3 PBL developed multiple skills

Working on the same project, students need to communicate with other team members, collaborate with others, develop their sampling methods and laboratory measurement skills, and conduct all work within a limited period. Different from the traditional learning approaches, students have more opportunities to establish their abilities through the PBL process. Students addressed their growth of teamwork skills, communication skills, problem-solving skills, and time management skills. With the development of teamwork skills, students were proud of the achievement of group work, as exemplified by one student:

> *Because we all contributed to the process, it showed the efforts we made together.*

During the teamwork, students learned from their team members. For example, one student began to think about air pollution from different angles:

> *Group projects can expand your thinking in many ways. For example, I might think about how air pollution is produced, but other students either think about the details from another point of view. ……For me, it broadens my knowledge. ……It complements my shortcomings.*

5 Discussion

The student-led projects were successfully conducted on one university campus. The results indicate higher greenhouse gas emissions from the university campus. In addition, CO_2 indoors is higher than outdoors, and the similar phenomena has been observed in other places (Lee & Chang, 2000).

Same to many studies (Kolmos *et al.*, 2019; Prosser & Sze, 2014; Schwartz *et al.*, 2001), this research shows students welcome the PBL and their comments on PBL are generally positive. In terms of the students' PBL learning experience, most students liked the new form of learning. Due to the strong interest in the projects which were originally proposed by students in small groups, students were very active and started the projects without any further waiting. This has been confirmed by many interviewees. Through the PBL, students in this Environmental Engineering programme knew more about their classmates, and even knew some new classmates whom they had never met before. Employability skills have been essential for all engineering education programmes. In this study, almost all interviewees have praised the PBL for its importance in enhancing their team-work and communication skills. With the rapid development of new knowledge and technology, engineering graduates should be lifelong learners. Therefore, it is essential to train the engineering students to be independent learners during their time at the university. As shown in Figure 1, more than 90% of students applauded PBL for the significance of improving their independent learning skill. Similarly, a study at Taylor's University suggested that the majority of students have improved their employability skills, for example, team-working, analysing data, problem-solving, report writing, presentation and time management, through PBL (Hsiung, 2019). Students also stated "It (PBL) was nice working more closely with people from my class" (Mc Donnell *et al.*, 2007). With a certain level of supervision from instructors, students "learned to do more by themselves" (Mc Donnell *et al.*, 2007). In PBL, the opportunity to use various equipment to measure air quality excited students' interests and made the study process more engaging. Learning by carrying out projects also sustains learners' deep learning, and improved learning outcomes were widely reported (Kolmos *et al.*, 2009; Schwartz *et al.*, 2001).

To explore engineering identity, Godwin (2016) proposed a theoretical framework that included three dimensions: performance, recognition and interests. The engineering identity was advanced via collaboration with team members within the practice community. Due to the PBL's advantages in linking theories with practice, PBL can reduce the gap between universities and industries, enhancing learners' study performance and future job performance. In the interviews, students have emphasized the importance of linking knowledge with practice in PBL. In the teamwork on GHGs emissions from the university campus, students have recognized the strengths of other team members and learned to collaborate with each other. In the meantime, many students had become more interested in the Air Pollution module and chose to do the related topics for their dissertations.

With the rapid development of transnational education, an increasing number of international students are studying in European universities (Yang, 2020). Some international students have not conducted any PBL in their home universities. Scholars have found that cultural differences can cause some challenges for international students' PBL experience (Du & Hansen, 2005). A recent survey of six international students found that the PBL is an effective way to develop their teamwork skills, communication skills, problem-solving skills, emotion and time management skills, while these students have some difficulties in the beginning of the PBL and more support is required (Chen *et al.*, 2020).

Similar to many studies, there are some limitations in the current research. There are seven students in the current interviews. In future studies, a larger sample size will further enhance our understanding of the effect of PBL on Environmental Engineering students' learning. As Chen et al. (2020) have pointed out the study challenges of international students in the PBL process, more researches are needed to understand the learning experience of overseas students, particularly those whose studies in home countries are heavily in teacher-centred mode.

6 Conclusion

This practice paper presents an initiative to apply the PBL in the projects of greenhouse gas emission from one university campus in an Environmental Engineering programme. The questionnaire and interview survey results provide evidence to confirm that PBL can effectively relate the knowledge from lecture to practice, including field sampling, laboratory measurement, analysing data, writing reports, and orally presenting results. Because the projects were proposed by students working in small groups, most students showed strong interest in actively conducting the projects with team members. While the majority of the students enjoyed the PBL, students have emphasized the improved employability skills including team-work, communication, data analysis, and presentation. Especially, more than 90% emphasized their enhanced independent learning skills during the PBL. Further research could include challenges for international students in the PBL and extra help or training for these students.

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Development of Diverse Assessment Methods for PBL Implementation at a Course Level in Engineering Education in Qatar

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Abstract

While the current literature collectively agrees that Problem and/or Project-Based Learning (PBL) is a useful instructional methodology, the majority of the literature has been based on the assumption that all PBL stems from the same practices across engineering disciplines. In civil and structural engineering, although the current literature agrees that PBL is an effective approach, there is a lack of a clear understanding of how PBL is implemented and learning outcomes are assessed in response to different course demands. This paper reports the practices of designing diverse appropriate assessment methods to meet the different learning objectives in four PBL undergraduate courses within the civil and mechanical engineering programs at Qatar University following the principle of constructive alignment.

Students from all four courses were PBL beginners, while in courses 1 and 3 the instructors were piloting PBL as their first experience. The various assessment methods were developed in response to the nature of the subject, course objectives, and students' levels. Improved student motivation, engagement, and active participation in teamwork has been observed by all the instructors. The ongoing change initiatives toward PBL as the four courses described in the current study provide a basis for an initial change action and suggest a longer-term plan involving more instructors and students to engage in the change. The experiences shared in this study can be used as inspiration for not only engineering educators in Qatar but also higher educational educators in general.

Keywords: Implementing PBL, Qatar, assessment, civil engineering

Type of contribution: PBL best practice

1 Introduction

The main goal of Qatar University as far as education is concerned is to be regionally recognized for the provision of holistic education that is transformative, learner-centric, research-informed, competency-based, digitally-enriched and entrepreneurial. Based on this goal, several initiatives have been proposed to transform the education process towards student-centered model versus the traditional teacher-centered counterpart. In the literature, the teacher role for the teacher-centered is given an analogy of “sage on the stage” while in the student-centered learning, the teacher is considered as a “guide on the side”(King, 1993). In fact, many consider the teaching-centered method as passive learning and the student-centered as active learning as far as student involvement is concerned (Benedict, 2010; Kelly et al., 2005; Pluta et al., 2013). Researchers have studied this differentiation for years and have found that, while individuals have various learning styles, on average, people remember: 10% of what they read, 20% of what they hear, 30% of what they see, 50% of what they see and hear, 70% of what they say and write, 90% of what they do (Landauer, 1986). A student in passive learning can be disengaged, disempowered, bored, unmotivated, cramming for tests, and of superficial knowledge. In active learning, however, a student can easily be engaged, empowered, exited, motivated, having fun, and of deep knowledge (Raginsky & Rakhlin, 2011). Several benefits have been identified out of a successful implementation of Problem-based learning in chemical engineering at McMaster University including improved grades, improved response to learning environment, and gained problem-solving and lifetime skills (Woods, 1996).

2 Literature review

Project/problem-based learning (PBL) has been defined in the literature in different ways. In the definition of the problem-based learning, Savery provided PBL as “It is an instructional (and curricular) 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). Problem-based learning was also defined by Word (2003) as a process largely dependent on learner to set goals, and outcomes, where the students (learners) are independent, self-directed, working in groups with each member has a role to play (Word, 2003). The process also enhances the communication skills of all members and encourages decision making (Azer, 2004).

At Qatar University, the implementation of project-based learning is a new practice that came in response to the College of Engineering initiative to adopt student-centered approach. As a team project, the assessment of the student activities remains a challenge, particularly when shifting from lecture-based learning (LBL) to PBL. The past decade witnessed numerous arguments in relation to assessing the work of teams in a PBL setting in an effective manner, yet these arguments revealed varied opinions and practices (Borrego et al., 2013). The main challenge has been related to finding types of assessment methods that are suitable for students that help them attain the learning outcomes of the course (Kolmos & de Graaff, 2014). In fact, the literature revealed that little has been reported on the way the students perceive the assessments and being convinced of their suitability. Consequently, the student perception of the different assessment methods should be examined in a PBL setting (Zhao & Zheng, 2014).

The assessment method of PBL vary and may be specific to the field, domain, or type of study. In engineering, these methods may include technical reports, laboratory report, peer assessment, design drawings, prototype, collaborative teamwork assessment, or even self-assessment (Maskell, 1999). In the assessment of the PBL at the University of McMaster University, regular exams were used to evaluate the students’ work in an attempt to compare between there results of the exam when PBL was adopted versus the traditional lecture based counterpart (Woods, 1996). The assessment results indicated that PBL led to an average significant improvement over two years of offering. The suitability of PBL for engineering education was examined in the work of Perrenet et al (Perrenet et al., 2000). The study concluded that PBL is more advantageous and motivating to students in the early years of their engineering study provided that supervised practice and direct mentoring are provided.

It is also important to consider the progress of offering knowledge in engineering programs that requires demonstration of problem-solving and teacher-guided discussions. A consistent assessment system is necessary to account for the student efforts through PBL. It was found that, according to the students working in PBL, earning credits in PBL appears to be much easier than passing the subject course examinations (Perrenet et al., 2000). Yadav et al studied the impact of problem-based learning (PBL) on undergraduate electrical engineering students' conceptual understanding and their perceptions of learning using PBL as compared to LBL (Yadav et al., 2011). For achieving this goal, the students completed pre- and post-tests, where the test was given before and after the concepts were explained (Maskell, 1999). The study concluded that attained knowledge learnt using PBL method was twice as that when tradition LBL was adopted.

The assessment continues to be a crucial practice, one that has to accommodate the students' perception and help satisfy measuring their progress and their attainment of the course learning outcomes. Embedded in a constructivism approach, the model of constructive alignment (Du et al., 2019) emphasizes the agreement among learning process, assessment methods, and therefore the course learning outcomes. While the concept of constructive alignment has been prominent in facilitating instructors with course designs across several disciplines in higher education (Wang et al., 2013), it is also in line with the principles of PBL design and practice. Therefore, in order to better facilitate deep learning and higher-level learning outcomes, PBL instructors are urged to adapt alternative assessment in a way that is aligned with the course goals and objectives through the principles of make the course learning outcomes clear, achieving course learning outcomes, and developing alternative assessment tools to count for the real efforts provided by the students and respecting their perspectives.

In general, adopting multiple assessment types is desirable so that the students can find multiple ways to show their level of mastering the topic. In PBL setting, it is important to emphasize the learning process and also the context-based learning (Segers & Dochy, 2001). Self-regulating learning can be facilitated through adopting to formative assessment intending instead of conventional summative assessments in order to assess the student performance so that measure can be taken to enhance learning (Segers & Dochy, 2001). In this regard, it is important to determine key performance indicators in the shape of dimensioned well design rubrics and assessment criteria to help engineering students focus on learning objectives rather than only on marks (Dancz et al., 2017). It was shown that PBL outcomes in engineering courses can also be assessed using a model based on computer-supported learning management systems which help integrate communications, collaboration and cooperation among team members and between a team and the coach (Hussain & Jaeger, 2018).

At Qatar University, the lecture-based learning is dominating, yet as the efforts augment towards adopting pedagogical innovation. Although the students are more familiar with a teacher-centered environment, they show relative acceptance of student-centered counterpart. This necessitates the importance of gaining a profound understanding of how the students pass through the learning process and what challenges they encounter (Prosser & Sze, 2014). Therefore, this study targets exploring the effectiveness of alternate assessments of PBL courses and how the students in engineering programs perceive such assessments.

3 Design and Assessment of PBL courses

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 (J. Biggs, 2003; J. B. Biggs, 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).

In response to an initiative of the College of Engineering at Qatar University to adopt student-centered learning pedagogies for the aim of increase the student engagement and motivation. The study in Engineering at Qatar University has been dominated by the learning approach in which the education process is centered on the instructor in a typical traditional lecture-based learning mode. Students can take some lead and ownership in the learning process while exploiting the technological advances in information sharing and the fast development of contemporary educational tools and products such as software, online sources, etc. Therefore, allowing the learning process to become student-centered can better motivate the students and prepare them for a better career.

The assessment remains an essential concern when implementing teaching and learning innovation (J. Biggs, 2003). The framework of constructive alignment (J. B. Biggs, 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.

The study presented here represents pioneer implementations of project-based learning approach by enthusiastic instructors in the College of Engineering at Qatar University over the period of Fall 2018 – Spring 2020. Prior to starting the PBL experience the instructors participated in professional learning program through multiple workshops to learn the specifics of PBL. Such training was essential for the instructors to start their first real experience teaching PBL in their classes.

3.1 First course: Design of reinforced concrete structures

This course was the first project-based learning course Instructor A taught to civil engineering students. In teaching the design of reinforced concrete structures course, Instructor A focus on bridging the gap between the analysis of structures that has been taught to the students in a pre-requisite course and design of concrete structures that is the focus of this course. Instructor A has also emphasized to connection between both the analysis and design so that the students appreciate the importance of evaluating the effect of the different loads on a structure to how the structure will eventually be dimensioned and characterized.

The 33-student class was divided into six groups of 5 or 6. The students were first introduced to the PBL as a learning pedagogy versus the lecture-based learning (LBL). The course learning outcomes have been updated to emphasize the PBL desired outcomes that go beyond the students' ability to technical issues. The updated outcomes assured the need to gain communication, writing, and presentation skills. In addition, the learning outcomes also included teamwork suitability and ability to self-learning in addition to utilizing most up-to-date technology.

Every group of students provided a real live problem that enables the course learning outcome when solved successfully. With the guidance of the instructor, the problem was shaped up to be a multi-story building where the students needed to achieve the course learning outcomes. Instructor A utilized alternative assessment tools for assessing the achievement of these outcomes, namely: 1) Interim report 1: 15 %; 2) Interim report 2: 15 %; Final report: 30 %; 3) Presentation: 15 %; 4) Final Exam: 25%. Students used cloud storage for sharing the different files and provided their presentations on YouTube.

The projects were used to assess the ability of the students in designing columns, continuous beams and two-way slabs and foundations. The students experienced evaluating the loads of slabs, beams, and walls. They also learned how to utilize software for exact evaluating of bending moment, shear forces and reactions. Instructor A has been also keen here to teach student modern and contemporary methods of structural design of reinforced concrete members using computer software packages. The emphasis here was to make sure that the students can judge the output of the software results and not just taking them without critic. The students were taught how to expedite their design calculations and obtain the results of a structural design problem, as time is an important factor when they work in industry after graduation. As potential engineers, they learned that time is of essence.

3.2 Second course: Design of reinforced concrete members

Instructor A taught this course mainly in Project-based mode, in which the course learning outcomes were achieved through "doing" instead of only "knowing." The assessment tools used aimed at enabling the students to achieve the course learning outcomes through deep learning instead of surface or superficial learning. A mix of diagnostic, traditional and authentic assessments has been used. The assessment tools included both formative and summative assessment tools.

Formative Diagnostic Quiz

In teaching the "design of reinforced concrete members" course, CVEN 320, in Fall 2018, Instructor A focused on bridging the gap between the structural analysis that has been taught to the students in a pre-requisite course and design of concrete members that is the focus of CVEN 320. Instructor A has also emphasized to the connection between both the analysis and design so that the students appreciate the importance of evaluating the effect of the different loads on a structure to how the structural member would eventually be dimensioned and characterized (designed). To assess the student capability in understanding key structural analysis concepts, Instructor A gave a low stake formative diagnostic quiz where he requested from the students to evaluate the maximum bending moment value of a beam. Typically, this important step that precedes evaluating the design of a beam in flexure. This formative assessment tool helped identify weaknesses or struggle in the analysis component so that Instructor A could address such weakness immediately.

Summative authentic assessment

Instructor A's target when teaching CVEN 320 through project-based learning was to familiarize the students with the workspace they will be working in when they graduate. Therefore, through the authentic assessment, Instructor A planned his PBL assessment tools so that the students would perform practical tasks that imitated real-world challenges they usually face in design offices. The tools used for the authentic assessments were:

1- Summative interim report of the project (worth 20% of the total grade)
2- Summative final report of the project (worth 25% of the total grade)
3- Summative individual presentation on accomplishment in the project (worth 5% of the total grade)

Both the interim and final reports on the project had specific mandates or tasks that had to be done by each group of students constituting teams. The emphasis here was on learning through doing. The mandates enabled achieving the course learning outcomes.

Formative and summative traditional assessment

In an environment of PBL, which is essentially group work in nature, this type of traditional assessment was needed for this course to:

1- Assure that all students are acquiring the necessary knowledge of the course.
2- Inform the instructor about the variation in the students' level of knowledge. In case that some students in a group show lacked knowledge, based on this type of assessment, they would be communicated with to advance their knowledge through more engagement, cooperation, and collaboration with their group while fulfilling the mandates of the project.

3- Cover some of the theoretical aspects requiring more of “knowing” than “doing.” This was important so that the students would cover both theory and practice sides of the course.

The assessment methods in a lecture-based environment include: 1) Formative homework assignments (5%); 2) Summative/formative midterm exam (10%); 3) Summative final exam (25%)

Laboratory experiment project

This assessment tool weighted 5% of the maximum grade, along with other class activities such as a field trip, and online videos exposed the students to the practical side of the course. This assessment tool aimed at linking theoretical concepts particularly those utilizing terms such as compressive strengthen and rupture strength of the materials, to reality. Therefore, the students in the laboratory components measured these quantities through conducting, analysing and interpreting the results of experiments. This assessment tool was also used to assess the Accreditation Board for Engineering and Technology (ABET) student outcomes related to conducting experiments.

3.3 Assessment rubrics for reports and presentations

For both Courses, CVEN 422 and 320, the accomplishment of the students was assessed against well-detailed rubrics provided to the students along with the mandates of both interim and final stages of the project at the beginning of the semester as part of the course syllabus.

As for the individual presentations, Instructor A used an innovative idea that made conducting the presentation flexible and fair while utilizing the trend in technology of video broadcasting using YouTube. Individual students were asked to film themselves while given a maximum of 5-min presentations that were uploaded to YouTube that Instructor A assessed. A student had to follow specific instructions and be aware of the evaluation criteria of the presentation, which are 1) Visual Aids, 2) Oral Presentation, 3) Body Language, and 4) Fulfilment of Responsibilities. Clear and detailed rubrics were also given to the student as part of the course syllabus that they needed to be aware of when preparing their presentation. This way of this innovative assessment allowed the students to refer to their videos on YouTube when they had questions about their assessment.

3.4 Third course: “Selected Topics in Construction Engineering & Management

The instructor of the course, as an educator within the College of Engineering at QU, found out that PBL is one of the most important missing components in engineering education in our region. One of the most important pillars to prepare graduates for the local job market is their ability to work as part of the whole team successfully. And PBL team formations, communications and management is one of its own natural characteristics. Additionally, the literature in engineering education shows very positive and successful results based on PBL implementations.

The instructor as Dean of Engineering PBL implementation is of an extreme importance to the College of Engineering in general to adequately and sufficiently prepare our graduates ready for the current 4th Industrial Revolution engineering education requirements, which requires our teaching and learning strategy to be adopted for focus on three characteristics: industrial engagement (industry-centric) in the delivery of learning outcomes, elevate, enhance and strengthen the interpersonal skills of our graduates and finally, improve the ability to work as part of a whole team mimicking real case working scenarios.

The third hidden motivation is the natural blending of entrepreneurial skills in our graduates which could be achieved naturally based on PBL pedagogy rather than traditional LBL.

The goal and plans of this implementation were to unlock the students’ typical boundaries towards seeking information and utilize the proper tools to become self-educated based on many technology-based tools, techniques and resources. For example, in traditional LBL learning, most students are locked and only focused on the assigned learning resources such as: lecture notes and assigned textbooks. In contrast, using PBL technique exposed the students to many other resources to achieve their learning outcomes such as:

online approved learning videos, industrial mentors' sessions, and practical technology-based systems in addition to their PBL -based group discussions. The PBL facilitator's lecture notes, textbooks and handouts are becoming only elements within a large pool of resources instead of being the only resources. So, in reality students are becoming lifelong learners by default. Obviously one of the main goals is to explore the students' adoptability towards PBL pedagogy in general. The average student spends more than 16 years of his life learning based on traditional LBL, and the goal here was to change the mindset of students. Such goal was the most challenging one. However, in general students have no issues when it comes to PBL course setups as most of them quickly adopt to the new situation.

The implementation of PBL in this course

The most important factor of the implementation is the enthusiasm of the PBL mentor. Another factor is to carefully plan the PBL content and clearly define the problem that the students need to investigate. Choosing the right amount of learning resources, technology tools and techniques is another important step towards successful PBL implementation. That was achieved by purchasing several approved training videos for one of the technological tools used by the students.

Building Information Modelling or (BIM) was a successful topic to be implemented in the course since it got many technological tools and packages that facilitate teamwork engagement. Care was taken such that the first PBL implementation becomes appealing to all students; yet, it allows the students' group to compete among each other. Based on the above a competitive rubric was carefully designed such that all groups are exposed to a minimum project submission requirement; however, they will be able to compete among each other's based on their level of knowledge acquired throughout the PBL session.

Having few of the PBL sessions mentored by a group of industrial mentors revealed very positive results in the ability of students to quickly adopt to their project submission requirements. Monitoring the PBL sessions and responding to questions during the typical PBL session is another key success factor in order to clearly document lessons learned from the first PBL implementation.

Individual assessment is one of the most challenging part; however, the assessment was done based on the final group presentation, and an embedded project-related key question in their unified final exam. The weight of such question was almost 40% of the final exam mark.

A student-to-student training guide and session was delivered. It appears that students usually reveal their own tips, tricks and shortcuts more efficiently to other students. So, in this course it was used in a very positive way. The analogues approach in real situation is usually referred to as train the trainers.

The learning outcomes in this course CVEN 482 "Selected Topics in Construction Engineering & Management" aimed to:

1- Introduce the students to the different construction project management typical life cycles, project management terminology and overall project evaluation methods from client's perspective.
2- Construction planning and scheduling methods such as the critical path method (CPM), precedence method (PM or advanced CPM), project monitoring & control based on earned value method (EVM), and computer applications using Oracle Primavera P6 system.
3- Scheduling optimization techniques and overall resources' management.
4- Introduction to Building Information Modelling (BIM) and its standards and typical workflows.
5- Introduction to BIM applications related to projects with emphasis on 4D and 5D BIM techniques.
6- Hands on BIM authoring tools and 4D and 5D applications.

Students are assessed in two ways: as groups based on their PBL project and individually using several embedded exams and final presentations. Typical grading breakdown for this course is as follows: 1) Interim report 25%; 2) Final report 40%; 3) Two exams 20%; 4) Final presentation 10%; 5) Four homework assignments 5%. Typical group & individual assessment breakdown is as follows: 1) Interim report 25% (group); 2) Final report 40% (group); 3) Two exams 20% (individual); 4) Final presentation 10% (group &

individual); 5) Four homework assignments 5% (group). Also, two embedded exams' questions related to their PBL project case study is allocated for exam 1 (midterm) and exam 2 (final). Overall PBL group assessment is 75%.

3.5 Assessment of the presentation for CVEN422, CVEN 320, CVEN 482

A frequently adopted method for students to orally present and defend their project is that the students give a shared presentation before the instructor of a course where all group members take turns on the stage. This method is mostly efficient within the time limit of a course duration, nevertheless it does not allow the instructor to distinguish among individual efforts or to control the time allocated to each student. Even if time allocation can be controlled, it does not necessarily provide deep insights with the limited time each student has. In addition, by the end of the presentation, the students will not be able to receive a clear justification of the score they have received, as grading in this case is highly subjective.

The course instructors developed an alternative way of assessing individual efforts in a group learning setting via utilizing YouTube in their PBL group work through their end-of-term presentations. The students were required to give individual filmed presentations.

In their preparation of their presentations, the students had to study a set of rubrics for scoring, e.g. Table 4 for one of the courses, CVEN422. The rubrics included four main elements: Visual Aids, Oral Presentation, Body language, and Fulfilment of Responsibilities. The advantage of using this new method for sharing individual presentation is four-fold:

1- Learning of the content,
2- Learning through practice and experience,
3- Learning through facilitated feedbacks and reflection, and
4- Learning with the support of technology.

3.6 Fourth Course: Introduction to Design

This is a cornerstone mechanical engineering course offered to sophomore year students. This course introduces mechanical engineering, the design process and skills, and explores unique challenges of solving problems. It provides students with practical experience of translating engineering design theory into practice. Skills developed will enable students to create a concept, provide justification and documentation, build and test a working prototype, report on the proposed manufacture of the product using current engineering practices, whilst ensuring economic viability. Students will also learn how to conduct market analysis and develop a basic business plan. Being a sophomore level course, it is an ideal place to introduce PBL. This course is offered for the first time in Spring 2020 with an enrolment of 27 students. The entire course is taught by using project-based approach.

Students were given a challenging problem at the beginning of the semester. This problem requires a sustained iterative inquiry for a period of the semester. To make the problem authentic, real world problems was introduced and the students had to meet the clients. To create motivation and self-ownership, students are allowed to modify the project based on their meeting with the client, but within a limited framework. The course is broken down into three phases of the design process: (1) product definition (2) concept selection (3) product realization. At the end of each phase, students are required to reflect, and if possible, critique their progress. This is also done by meeting the clients. The final stage of the project is public presentation, where the students will have a life audience to share their findings. This will help them to be motivated in the project knowing that the team has to make a life presentation.

The class was broken down into nine teams. In the lecture, scaffolding activities were done to engage students in the design thought process. Various case studies were used in class activities. The students later, in tandem, had to start working on their projects in the lab with minimal assistance from the instructors. There are weekly questions related to the project that needs to be answered by the students.

Here is where the assessment comes in. The most crucial assessment used are the project deliverables. Almost every week there is a project deliverable. These deliverables are both individual and team submissions. This is important to ensure that (1) progress is taking place on a weekly basis and (2) all students are involved in the project. The project deliverables accounts for near 30% of the coursework. The final report (business plan) accounts for 30%, prototype develop 10%, teamwork 15% and presentation 10%. The remaining 5% are for other in class activities to fulfil the remaining course learning outcome requirements.

4 Reflection of instructors

In this paper we provided information on diverse assessment methods developed in four different PBL courses in College of Engineering, Qatar. Students from all the four courses were PBL beginners, while in course 1, 2 and 4 the instructors were piloting PBL as their first experience. The various assessment methods were developed in response to the nature of the subject, course objectives and students' levels. Improved student motivation, engagement and active participation in teamwork has been observed by all the instructors (Du et al., 2019). The instructors, in particular, and the authors of this research contribution, in general, have conducted meetings at the beginning, during and at the end of offering the PBL courses. These meetings aimed at collecting views, discussing challenges, and sharing experiences leading to forming general reflection of instructors. A few implications can be drawn from these reported experiences to inspire further expansion of PBL implementation within the institute. First, the PBL experiences in the above-mentioned four courses were all explorative in which instructors adopted various PBL practices and assessment modes following the PBL principles. This may in hope to encourage the remaining colleagues that PBL is not one stationary recipe but is rather adjustable to the context of each course. Thus, second, implementing PBL is not a wholesale mode but rather, the instructor plays an important role in developing their own belief in PBL and creativity in developing an appropriate approach. Third, PBL implementation is highly contextual particularly in an environment that PBL can be only implemented at a course level at its initial stage. Reflection on our experiences suggest that a transition is necessary to support PBL beginners in exploring and experiencing a progressive change of practices and beliefs. In addition, at an institutional level, a progressive approach to change is necessary in the given context to document the initial success and challenges before a comprehensive, organization-wide approach to PBL implementation is to be decided upon.

To summarize, the ongoing change initiatives toward PBL as the four courses described in the current study provide a basis of an initial change action and suggest a longer-term plan involving more instructors and students to engage to the change. The experiences shared in this study can be used as inspiration for not only engineering educators in Qatar but also higher educational educators in general.

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In this book we present the contributions from the International Research Symposium on PBL (IRSPBL2021), organised by the Aalborg UNESCO centre for PBL in Engineering Science and Sustainability.

The IRSPBL 2021 has collected 21 contributions from 13 different countries, all compiled in this book. The contributions cover a number of relevant topics: blended PBL environments and online learning; sustainability, creativity and interdisciplinarity; PBL implementation for professional competence development; assessment and management of change.

This book represents some of the newest results from research on PBL and best practice to inspire other practitioners to innovate their teaching and learning activities. We hope that you will find the book useful and inspirational for your future work.