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6th International Research Symposium on PBL

PBL, Social Progress and Sustainability

Edited by
Aida Guerra
Fernando José Rodríguez
Anette Kolmos
Ismael Peña Reyes

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Impact of PBL and company interaction on the transition from engineering education to work

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Abstract

In order to identify transition issues from engineering education to work, the PROCEED-2-Work project follows a cohort of Danish engineering students. The project is a continuation of a previous research project PROCEED (Programme of Research on Opportunities and Challenges in Engineering Education in Denmark) where one of the sub-projects has followed the students who started their studies in 2010. In the PROCEED-2-Work project, data was collected in 2015 among the engineering students on their expectations for work once they graduate.

A comparative analysis of engineering students from Aalborg University (AAU) in 2015 with the rest of the Danish engineering students educated at the other Danish engineering institutions has been conducted in order to study the implications of a comprehensive PBL model (problem and project based learning). The hypothesis is that students who have been educated in an intensive PBL environment would be better prepared for a work situation than other students.

The results indicate that there are significant differences between the two groups on a variety of factors. There is no significant difference between AAU students and other Danish engineering students in regard to technical knowledge and professional methods, but in the areas of society and environment, business and organisation, AAU engineering students all assess the variables significantly higher. The study shows that students with interaction with companies during the program, including collaboration on problem solving, internships and company visits, score significantly higher regarding the extent to which they think it has helped them prepare for work. Furthermore, the study shows that both internship and project work prepare students for work to a higher degree than the more theoretical courses. However, a comparison between internship and project shows that project work scores slightly better than an internship in relation to how prepared the students find themselves for work.

Keywords: Problem based learning, employability, university/company interaction

Type of contribution: Research paper

1 Introduction

Employability has been on the political as well as the research agenda for some decades as gaps have been identified between education and work; e.g. a McKinsey report indicates that we are far from creating bridges between work and education (Mourshed, Farell, & Barton, 2012). The Royal Academy, UK, also points at similar problems, noting that graduates are not able to go straight into a job and work, and that companies and organisations have to invest in this transition process since graduates do have a shortage of skills. There is a general belief that the curriculum should be improved in this regard (Lamb et al., 2010; Spinks, Silburn, & Birchall, 2006).

The transition from education to work is a rather complex process to study. In general, there may always be transition problems when moving from one institutional culture to another, such as from academia to business. Different institutions have different practices and thereby different cultures. Therefore, there are also methodological considerations required in order to study the transition, as it involves both:

- a diverse theoretical focus on educational learning combined with aspects of professional identity, culture, organisation and retention of knowledge.
- a diverse group of actors (from educational side: students, academic staff, parental background, family; from employer side: managers, Human Resource Units, colleagues etc.).

In reviewing the literature, there are many reports on employers' requirements and graduates' experiences, but fewer on academic actors' views on the transition issues. However, all recommendations point at a change in education (Kolmos, Holgaard, & Bylov, 2016).

In the literature, there are very few studies on academic attitudes to employability. A Swedish study indicates that academic staff with professional work experience are more positive compared to staff with no professional experience (Magnell, Geschwind, & Kolmos, 2016; Magnell & Kolmos, 2016). Other studies find that academic staff rate knowledge and competences contrary to employers' and graduates' views, especially in relation to critical thinking.

There are very few studies on students' approaches to and learning of the employability skills. Students will always react to a formal curriculum with the objective of passing their exams, and they will mirror the priorities set in the curriculum. However, students also want to get a job. Studies conclude that the students' priority of employability increases as their studies progress (Moreau & Leathwood, 2006) and that students expect their academic knowledge and competences to be of importance. They do, however, voluntary work outside university as a way of adding value to the academic competences (Tomlinson, 2008).

A longitudinal study of business students uncovered their view on which transferable skills might be necessary for a later work situation (Tymon, 2011). Data was collected in the first, second and final years. During their education, the students found that employability mattered more as time went on, and that the students' confidence in expressing themselves increased. The students also found that an internship was the most efficient way to learn about employability as well as teamwork, etc.

Problem and project-based learning (PBL) has been pointed at as a solution to bridge these gaps. A Swedish study indicates that the best way to integrate employability with education is through company projects where students learn to apply their academic knowledge on concrete problems and experience a work environment, or through co-curricular activities, which are often more open and problem-oriented compared to the traditional curriculum (Stiwne & Jungert, 2010). However, there are few studies showing evidence that PBL actually has a positive impact on their readiness to enter the workplace.

In this article, we will present data from the Danish PROCEED-2-Work project on Danish engineering students' expectations and readiness for their future work situation (Kolmos & Bylov, 2016; Kolmos & Koretke, 2017).

The PROCEED-2-Work study is a longitudinal study of the cohort of enrolled engineering students in 2010. It is a continuation of a completed project, funded by the Strategic Research Council: PROCEED (Programme of Research on Opportunities and Challenges in Engineering Education in Denmark). PROCEED-2-Work follows a cohort of students enrolled in 2010 and on into the labour market to analyse their understanding of the engineering profession and expectations of working life. Surveys were sent out to all Danish engineering students enrolled in 2010, and with follow up surveys in 2011, 2015 and 2016.

In Denmark, PBL is a common teaching and learning methodology for all engineering institutions, where institutions assign project work and initiate projects with companies. However, the degree of application of PBL in the curriculum may differ considerably from one institution to another and from one engineering program to another, in terms of: 1) how many projects students are involved in, 2) how much of the entire curriculum is based on projects, 3) how the progression is throughout the study, 4) how open and problem-oriented the projects are, 5) how the projects interact with the taught courses, and 6) how the projects are supervised or facilitated.

A full mapping of these questions does not exist, but what we know is that Aalborg University stands out compared to the other universities by having: 1) students involved in at least 10 projects for a master's degree, 2) 50% of the entire curriculum based on projects, 3) the students complete projects from the first semester onward that involve learning PBL competences, 4) a mix of open and more narrow problems to work on, 5) most projects interact with the taught courses in a semester and 6) all project groups work are assigned a supervisor/facilitator.

Therefore, we decided to make a comparison between:

1) the engineering students from Aalborg University with the rest of the Danish engineering students to see which impact an institution with a systemic PBL approach combined with traditional lectures would have on the students' experience of the transition from engineering education to work.
2) the students who have been involved in some kind of interaction with companies and students who have not had any experiences with company interaction.

As PBL is based on an intention to simulate a professional practice and contribute to real-life problem identification, problem analysis and problem solving, our hypothesis would be that students from larger scale PBL institutions would find themselves better prepared for work life compared with students from lower scale PBL institutions, and that students with some experience with companies would find themselves better prepared compared with students who have no engagement with companies.

2 Methodology

In the PROCEED-2-Work study 2015, we focused on students' views on the transition process, and we have selected two main variables to study this: students' experiences on how ready they feel and how they experience their own competences. As the study focuses on students in their final semester, their expectations and confidence in how ready they experience themselves to move into a new organisational culture is regarded as an important factor for their choices.

The construction of the survey is inspired by the Academic Pathways Studies of People Learning Engineering Survey (APPLES) by the Center for the Advancement of Engineering Education, US (ABET, 2011; Atman et al., 2010). According to Atman et al. (2010), their variables were inspired from the ABET criterion three program outcomes list (ABET, 2011) and the National Academy of Engineering report, *The Engineer of 2020* (National Academy of Engineering, 2004). In the PROCEED-2-Work project, an adjustment has been made to accommodate Danish conditions (Kolmos & Bylov, 2016).

It is a longitudinal study with a cohort of 3,969, including students starting out in 2010 and additional master's students enrolled at the master's level. Of the 3,969 students, 1,141 responded to the survey in 2015, resulting in a response rate of 29%. This response rate has not been corrected for the percentage of students who dropped out of the study since their enrolment in 2010, which will be about 25%. Out of the

1,141 respondents, there are 295 AAU students and 846 students from other Danish engineering education institutions, see table 1.

Table 1: Respondent group, gender and institution

	AAU	Other Danish Engineering Institutions
Women %	33.6%	28.3%
N	N=99	N=239
Men %	66.4%	71.7%
N	N=196	N=607
Total N	N=295	N=846

The analyses of the data have been partly based on frequency analysis, cross tabulations and t-tests in order to find whether there are significant differences between students from AAU and students from other Danish universities.

Table 2: Readiness factors (Kolmos & Bylov, 2016)

Variable	Constructed factor	Reliability test: Cronbach's alpha
Contemporary issues Ethics Global context Societal context Environmental impact Social responsibility	Factor 1: Society and environment	0.851 (N=986)
Conducting experiments Data analysis Engineering analysis Engineering tools Problem solving Maths Science	Factor 2: Technical knowledge	0.774 (N=976)
Business knowledge Communication Creativity Design Leadership Life-long learning Management skills Professionalism Teamwork	Factor 3: Business, organisation and transferable skills	0.752 (N=980)

Table 2 show the factor analysis of the readiness factors. Factor analysis has been carried out inductively and the varimax rotation principles have been applied. For all factors, the Kaiser-Meyer-Olkin Measure (KMO) has been conducted, requiring a total correlation of above 0.7 as an acceptable correlation (De Vaus,

2002). Additionally, the Cronbach's Alpha test was carried out as a reliability test. All factors have a coefficient of 0.7, and can be said to be reliable and useful for later analyses (De Vaus, 2002).

The factors are very well aligned with the theoretical understanding of the three different university modes: the academic-oriented mode 1, the market-driven mode 2, and the community-driven mode 3 (Jamison, Kolmos, & Holgaard, 2014). In the academic mode 1, theoretical knowledge is prioritised (Factor 2: technical knowledge), whereas the market-driven mode 2 is oriented toward business knowledge, management and competences, etc. (Factor 3: business, organisation and transferable skills). The community-driven mode 3 has a society orientation with a general education and value orientation (Factor 1: society and environment).

3 Findings

In Figure 1, the engineering students at AAU score slightly, yet significantly, higher on the readiness factors of "society and environment" and "business, organisation and transferable skills" than the engineering students at other institutions. For the readiness factor "technical knowledge", there is no significant difference. The factor analysis indicates that students at AAU, compared to students from the remaining Danish institutions, differ in particular in their readiness in relation to contextual aspects in engineering education; this is the case for both business and the broader society context.

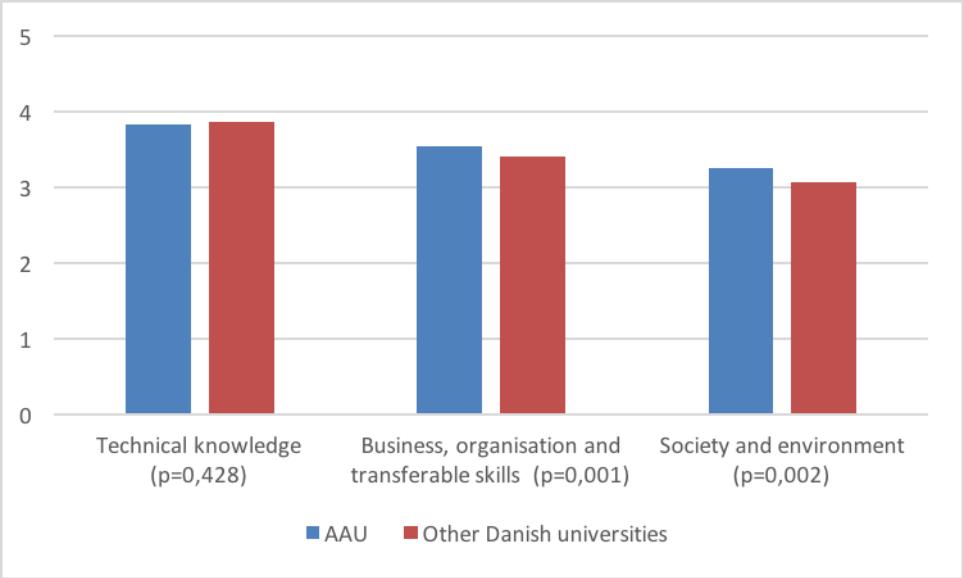

Figure 1: Readiness factors and institution. N=1000-1009. Average, T-test.

The single variables in the constructed factors show that the students from AAU find that they are better prepared regarding eight out of the nine significant single variables, compared to students from other institutions, se table 3. The students from other Danish institutions are better prepared in relation to mathematical skills. In the factor of "society and environment", students from AAU estimate that they are better prepared for all the single variables of "societal context", "contemporary issues", "social responsibility", and "environmental impact". For the factor of "business, organisation and transferable skills", there are significant differences in relation to, "communication", "teamwork" and "management

skills". Finally, the AAU students also scored significantly higher for the single variable "problem solving" in the factor relating to technical knowledge.

Table 3: Readiness and institution. *Only significant variables presented. Significant level: ***=p<0.01, **=p<0.05, *=p<0.1 N=1000-1009*

	AAU	Other Danish Institutions
*** Societal context	***	
*** Contemporary issues	***	
** Social responsibility	**	
* Environmental impact	*	
** Problem solving	**	
* Math		*
*** Teamwork	***	
** Communication	***	
** Management skills	**	

3.1 Readiness, institutions and project work

Looking at the findings, there is no doubt that for the Danish engineering students, PBL is a factor in the students' experience of readiness for their coming jobs. Furthermore, the Kolmos and Bylov report (2016) indicated that students experienced projects at the master's level of special importance for providing an understanding of their future profession. Following that argumentation, we have asked what kind of interaction the students had with companies in their projects.

Table 4: Degree of interaction with companies comparing students from AAU and other Danish institutions. N=863-881. ***=p<0.01, **=p<0.05, *=p<0.1.

	AAU	**Other Danish Institutions**
Company visits in relation to the semester theme	2.65	2.55
Worked on a project proposed by a company	2.18	2.19
Cooperated on problem solving	2.16**	1.98
Formulated the problem of the project in cooperation with a company	1.99*	1.85
Internship in a company (more than a month)	1.66**	1.52
Internship in a company (more than a week)	1.62**	1.42

Table 4 shows the results of the average level comparing the interaction with companies in project work for AAU students and students from other Danish institutions. The conclusion is that AAU students generally have a higher average for almost all variables, and the difference is significant regarding the variables "formulated a problem in cooperation with a company", "cooperation on problem solving", as well as "internship in a company (more than a month/week)". It appears that students from Aalborg University seem to have more interaction with companies than the average student from another Danish University.

When we look at whether the students felt that the interaction with companies did prepare them for the future labour market, AAU students generally score higher than students from other Danish universities, see table 5. There are significant differences in three of the six variables related to cooperation on problem solving, internship (more than a week) and the gain of company visits. Thus, students from AAU not only experienced a higher degree of interaction with companies in the program, but they also experienced that this interaction prepares them more for a work situation after graduation than for students at other Danish universities.

Table 5: Impact of relation to companies in project work on the readiness comparing students from AAU and other Danish institutions based on the question: To what extent do you think that the following activities have helped you to get ready for the labour market? N=573-756. ***=p<0.01, **=p<0.05, *=p<0.1.

	AAU	**Other Danish Universities**
Internship in a company (more than a month)	3.02	2.86
Cooperated on problem solving	2.97*	2.79
Worked on a project proposed by a company	2.86	2.87
Internship in a company (more than a week)	2.78*	2.58
Formulated the problem in project in cooperation with a company	2.75	2.74
Company visits in relation to the semester theme	2.55**	2.38

3.2 Company projects and readiness factors

As already indicated, all Danish institutions offer possibilities of project work, although this is not the same as requiring that all students will experience projects. In the following section, we will focus on the comparison of students who have had projects with companies or internship versus students who did not, in order to find out the impact on the students' experience of readiness for work. In table 6, we show the readiness factors for all students across all Danish institutions comparing students with or without experience with specific kinds of interaction with companies and related this to the three readiness factors: "society and environment", "technical knowledge", and "business, organisation and transferable skills".

It seems that relating to and cooperation in projects with companies during education makes students feel more prepared to apply competencies related to "society and the environment" and "business, organisation and transferable skills".

The internship variables appear to provide increased significant more readiness related to the factors "society and environment" and "business, organisation and transferable skills", while students who have not attended internship experience a significant higher degree of readiness in relation to technical

knowledge. These results can mirror what students are exposed to in the curriculum, if in the educational program there is more focus on the technical knowledge and less focus on the two other readiness factors.

Table 6: Types of relation to companies and readiness factors ***=p<0.01. **=p<0.05. *=p<0.1.

	Whether the study activity has been applied	Society and environment	Technical Knowledge	Business. organisation and transferable skills
Internship in a company (more than a month)	No (N=476-485)	3.04	**3.93*****	3.35
	Applied (N=370-377)	**3.21****	3.77	**3.53*****
Internship in a company (more than a week)	No (N=522-531)	3.05	**3.92*****	3.37
	Applied (N=326-330)	**3.20****	3.77	**3.53*****
Company visits in relation to the semester theme	No (N=191-195)	2.84	3.88	3.25
	Applied (N=656-664)	**3.20*****	3.86	**3.49*****
Cooperated on problem solving	No (N=341-346)	2.97	3.82	3.30
	Applied (N=492-499)	**3.22*****	3.89	**3.52*****
Formulated the problem of the project in cooperation with a company	No (N=372-378)	2.97	3.85	3.32
	Applied (N=476-484)	**3.22*****	3.87	**3.53*****
Worked on a project proposed by a company	No (N=246-248)	3.04	3.76	3.34
	Applied (N=603-615)	**3.15***	**3.90****	**3.47****

On all the three project variables: “cooperated on problem solving”, “formulated the problem of the project in cooperation with a company”, and “worked on a project proposed by a company”, there is a similar pattern that the students felt themselves better prepared for the two contextual factors of “society and environment” and “business, organisation and transferable skills”. However, in the area of “technical

knowledge", the students who applied any of the project variables in education scored higher compared to the students who did not have applied projects, and, for one of the variables, there is even a significant difference: if students have "worked on a project proposed by a company" they perceived themselves to be significantly readier in relation to all the accounted factors.

4 Discussion

The PROCEED-2-Work study was not designed to study PBL, but indeed to study the transition from education to work where teaching and learning methods are some of the core variables. The data presented here represents two different perspectives: 1) comparison of AAU and other Danish engineering students' responses to their experience of readiness to the future work situation, 2) comparison of all respondents' type of activity combined with a view on company interaction and readiness factors.

The differences in the institutional frameworks in relation to PBL, however, make it possible to analyse the readiness of engineering students at AAU, who are educated in an intensive PBL environment, just as they are about to enter work life as a professional engineer. This study has identified significant differences even though many other Danish universities have implemented elements of PBL in their curricula.

PBL, institution and readiness

Kolmos and de Graff (2014) present three approaches to characterise PBL: a learning approach, a social approach and a contents approach (Anette Kolmos & Graaff, 2014). The learning approach stresses authentic real-life problems, not only as a starting point for learning, but also as a reference point for the learning process as such. The social approach underlines learning as a social but also as a participant-directed act. The contents approach stresses interdisciplinary and exemplary learning in PBL, and the need for interaction between theory and practice. With this focus on real-life problems, interdisciplinary co-creation of knowledge, exemplarity and participant-directed knowledge, it might not be that surprising that AAU, with their comprehensive PBL model, stands out in educating for business, organisation and transferable skills as well as for society and environment. However, it is remarkable that there are no significant differences when it comes to the technical knowledge factor, and when looking at the single variables, the only significant difference is connected to Maths (and only with $p<0.1$).

Taking the different knowledge modes into consideration, the results thereby indicate that PBL pushes the model of knowledge from mode 1 toward mode 2 and 3, and therefore can be a driver in educational change. The community-driven mode 3 has a society orientation with a general education and value orientation, which is often missing in engineering education and which is highly relevant for learning to analyse problems, ensuring that the relevant problems are solved. However, when considering the readiness factors, it is also worth noticing that when we compare the level of readiness in the different factors, the level of readiness still follows the same order at AAU as in other Danish universities. On average, students have the highest level of readiness in the field of technical knowledge, then business, organisation and transferable skills and lowest rated is society and the environment. The AAU data, however, show that it is possible to raise students' readiness to face the need for mode 2 and mode 3 knowledge, without making a comparable compromise with preparedness in relation to technical knowledge.

Of course, it can then be discussed whether it is considered to be the "right" knowledge, skills and competences for engineering students when they have, in fact, entered the workplace. Such discussion calls for further research.

Projects versus internships

The results of this study also indicate that there is a documented difference between internship and projects. Projects in education seem to give the students an idea and picture of their future profession. In the projects, they have the possibility for various forms of interaction with the external stakeholders – normally the companies. They have the opportunity to visit companies and to collaborate on analyses of the company problems and projects. However, they do not experience a daily routine in the same way as if they had been in an internship.

Internship on the other hand, gives students the opportunity to experience another organisation in which they have to share their academic knowledge in new ways. However, the outcome of internship is not always efficient and is very dependent on the company's ability to facilitate the student internally. Several EU projects have looked at developing guides and sharing experiences on how to improve the outcome of internships (Henriksen, 2013). Seen from a curriculum point of view, where institutions are always struggling with overloaded curricula, these guides and shared experience would provide an advantage.

Comparing the results on internship and projects in companies is quite relevant for finding ways of integrating practice into education. Projects and internships are two different methodologies, which sometimes can also be combined. Seen from a curriculum point of view, projects might be preferred as these still are done according to academic learning outcomes and are facilitated by academic staff.

5 Concluding remarks

This paper has presented a comparative analysis of engineering students from Aalborg University (AAU) with the Danish Engineering students educated at all other Danish engineering institutions. Even though Danish engineering education is characterised by an extensive use of PBL methods, AAU is one of the universities that stands out due to a comprehensive PBL model.

The hypothesis was that students who have been educated in an intensive PBL environment would be better prepared to the work situation than other students. The results indicate that there are significant differences between the two groups on a variety of factors. There is no significant difference between AAU students and other Danish engineering students in regard to technical expertise and professional methods, but in relation to factors of "society and the environment", "business, organisation and transferable skills", AAU engineering students all assess the variables significantly higher. This points to PBL as an effective method for educational change in engineering education that takes into consideration the business context as well as broader societal challenges.

Furthermore, the study shows that students from AAU experience more interaction with companies during the program, and at the same time the AAU students score significantly higher regarding the extent to which they think that cooperation in problem solving, internship and company visits has helped them to get ready for work. This is closely related to the contextual and exemplary nature of PBL. Real-life problems are contextually rooted and thereby should be addressed "out there" in close collaboration with the actors involved in identifying, analysing and solving the problems at hand. Academic communities are among those actors, but they are far from the only ones.

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