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The Implementation and Evaluation of a Project-Oriented Problem-Based Learning Module in a First Year Engineering Programme

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ABSTRACT

This paper describes how a circuits-based project-oriented problem-based learning educational model was integrated into the first year of a Bachelor of Engineering in Electronic Engineering programme at Maynooth University, Ireland. While many variations of problem based learning exist, the presented model is closely aligned with the model used in Aalborg University, Denmark. Key learning outcomes, implementation features and an evaluation of the integrated project-oriented problem-based learning module over a two year period are all presented within.

Keywords: Collaborative enquiry-based learning, peer learning, problem based learning

INTRODUCTION

Since its foundation in 1974, the Aalborg University has developed a world-wide reputation as a centre of excellence in problem and project based learning, particularly in the disciplines of Engineering and Science (Kjersdam & Enemark, 1994). This educational model is widely known as the Aalborg PBL model and is founded on problem-based project work. Here, the project is an integral part of the education model and hence the project-oriented problem-

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based learning terminology. The literature shows that PBL, as an educational model, has many important pedagogical benefits, including improving active learning, encouraging a deeper approach to learning, improving self-directed learning, improving the consideration of interdisciplinary knowledge, developing a professional identity and developing responsibility. In addition, students also improve various process competencies such as project management, collaboration, teamwork, conflict resolution, and communication skills (Biggs, 2003; De Graaff & Kolmos, 2003; Hmelo & Evensen, 2000; Kolmos, 1996; Savin-Baden, 2003).

This paper presents the implementation and integration of a PBL model, in the form of a circuits-based project, into the first year of the Electronic Engineering degree programme at Maynooth University, Ireland. It was endeavored to align the model with the Aalborg PBL model insofar as resources and infrastructure allowed. At the end of the semester, the students were surveyed for their feedback on this new style of learning for them. Feedback for two different years was obtained. Both staff and students were also given the opportunity to express their thoughts and opinions through special focus groups. The results from this evaluation process showed significant support for the PBL educational model.

The rest of the paper is structured as follows. Section 2 outlines the context for and the aims of the new PBL circuits-based project module. Section 3 shows how this module was integrated into the first year of the Electronic Engineering programme at Maynooth University. Implementation issues such as facilitation, team selection, and assessment deliverables are presented in Section 4. Section 5 documents the evaluation process for the PBL module and presents a summary of the key feedback obtained. The paper concludes with suggestions for future work in section 6.

CONTEXT AND AIMS

The Department of Electronic Engineering at Maynooth University offers a standard four year Bachelor of Engineering in Electronic Engineering programme. Each academic year consists of two 15 week semesters, 12 of which are used for the delivery of relevant material and the other 3 consist of study and examination periods. Each semester contains 30 ECTS (European Credit Transfer System) of work, typically consisting of six 5 ECTS modules. These modules consist of standard lectures, tutorials, laboratory and/or assignment work and are usually delivered in the traditional style of the lecturer presenting material to the students through lectures.

The issue with the pre-PBL programme was that students were not exposed to any significant team-based project work. The programme did contain teamwork elements, but these generally consisted of 2 or 3 person teams working to complete short laboratory work within a module. Students only carried out their first substantial project in their final year of the programme where they are required to undertake an individual 20 ECTS project over the course of the full

academic year. Furthermore, while students undertook a professional skills module in first year that covered communication skills, they never had a genuine opportunity to put these skills into practice until their final year project, at which point they had little or no opportunity to receive useful feedback.

The Department felt that the introduction of a PBL model early in the programme would alleviate many of the aforemetioned issues. As such it was decided to include a 10 ECTS PBL module in year 1 with the aim of achieving a number of key learning outcomes. These included students being able to apply project-based learning to solve unforeseen problems, discuss any ethical issues, environmental impacts and health and safety issues associated with the project, write a technical report, prepare and deliver an oral presentation, defend their work via an interview and demonstrate good time management and project planning in the execution of their project.

INTEGRATION OF THE PBL MODEL

The conventional (pre-PBL) first year of the Electronic Engineering programme is presented in Table 1. In order to integrate a circuits-based PBL module, EE105 Professional Skills and EE107 Engineering Design were replaced with a 10 ECTS circuits project, as presented in Table 2. The EE109 Electronic Material Science module had to be moved to the first semester to accommodate this change.

Year 1 – Semester 1
EE101 Electronic Engineering Fundamentals
CS141 Introduction to Programming
EE103 Digital Systems 1
EE104 Physics for Engineers 1
EE105 Professional Skills
EE106 Engineering Mathematics 1
Year 1 – Semester 2
EE107 Engineering Design
EE108 Computing for Engineers
EE109 Electronic Materials Science
EE110 Physics for Engineers 2
EE111 Electric Circuits
EE112 Engineering Mathematics 2

Table 1 – First year programme pre-PBL (all modules are 5 ECTS)

The project forms a significant component of semester 2 and is directly supported by the taught modules EE101 Electronic Engineering Fundamentals, EE103 Digital Systems 1 and EE111 Electric Circuits, as highlighted in italics in Table 2. It is also indirectly supported by both the mathematics modules and the physics modules, as these provide the fundamental principles used in the engineering related modules.

Year 1 – Semester 1
EE101 Electronic Engineering Fundamentals
CS141 Introduction to Programming
EE103 Digital Systems 1
EE104 Physics for Engineers 1
EE106 Engineering Mathematics 1
EE109 Electronic Materials Science
Year 1 – Semester 2
EE108 Computing for Engineers
EE110 Physics for Engineers 2
EE111 Electric Circuits
EE112 Engineering Mathematics 2
EE199 Electronic Circuits Project (10 ECTS)

Table 2 – First year programme post-PBL (all modules are 5 ECTS unless otherwise stated)

Conducting a significant group project provides students with the opportunity to experientially develop their design, technical writing, presentation, and teamwork skills. This covers the key elements of the removed modules EE105 and EE107. In addition, the lecturers of EE105 and EE107 acted as facilitators for the new PBL module. Hence the overall structure of the first year programme and the staffing resource issue remained largely unchanged. This allowed for a relatively seamless introduction and integration of the particular PBL module within the BE programme.

In Aalborg University, the supporting taught modules are in the same semester as the project and are primarily delivered in the first few weeks of the semester. The project is run in parallel but the majority of this work usually takes place in the later weeks of the semester once the taught modules have been completed. Unfortunately, our current infrastructure does not support this upfront demand on teaching as several of the modules are taught by other departments within the university. By way of compromise, and in order to minimise

disruption to the existing setup, the project was deliberately placed in the second semester so that modules EE101 and EE103 could be delivered as they are, and in full, in the first semester.

IMPLEMENTATION

The PBL module was first introduced in semester 2 2013 and presented once again in 2014 to a new cohort of first year students. Key implementation details are now presented and justified.

Workshops - In Denmark, and indeed much of mainland Europe, students enter university at the average age of 19 years. In Ireland, this figure is 18, with some entering as young as 17. Thus, Irish students tend to be generally less mature than their European counterparts. In addition, incoming Irish university students have very little prior experience of group project work whereas the Danish primary and secondary education systems involve group-work components. As such, it was important to ease the transition of the students from the conventional taught lectures to the student-directed self-learning that PBL entails. As part of this transition, a series of 5 workshops were included within the PBL module. The topics covered included the concept of PBL, teamwork, design fundamentals, ethics, technical report writing, and presentation and interview skills.

Team Formation - Two different team selection processes were employed. In 2013, students were allowed to self select their teams, as per the Aalborg PBL model. The class initially consisted of 18 students and it was agreed at the start to have a maximum of 3 groups. The self selection process resulted in 3 quite different groups and contained 7, 6 and 5 team members respectively. Each of the groups was randomly given a project specification. In Aalborg University, students choose their own project in agreement with a supervisor.

This selection technique resulted in the creation of a ‘leftover’ group. As the term suggests, this group consisted of those students that were not in attendance on the day the teams were selected and also the perceived weaker students in the class. This group had significant problems throughout the semester including poor communication, poor teamwork, multiple conflicts with no real resolution and, ultimately, poor project work. It was no surprise that this group failed their project as a result. The key problem with this group was the fact that several of the students simply did not engage and/or did not even turn up for meetings on a regular basis.

In 2014, groups were formed based on the students’ ranking of various project specifications. In this case, the class consisted of 26 students and it was decided to have 4 groups of no more than 7 members. The final selection resulted in two groups of 7 and two groups of 6 and all

students were given either their first or second ranked project. The problem of the leftover group did not materialize in this case.

Similar to the first year in the Aalborg model, slightly larger group sizes (i.e. greater than 5) were employed in order to provide the students with the potential challenges in relation to project planning, time management, communication and conflict resolution that a large group typically entails.

Deliverables and Assessment - Each group of students had to submit an interim report and presentation (worth 20%), a final (technical) report and presentation and interview (worth 70%), and a process report, consisting of a set of reflective journals (worth 10%). The reflective journals had to be submitted approximately every two weeks during the semester and had to consist of both team and individual reflections.

The interim report and presentation was due mid way during the semester and documented the group's progress up to that point. The final report and presentation was due at the end of the semester and documented the overall project work. The actual assessment also included individual interviews to determine each student's level of knowledge and understanding of the work carried out. Akin to the Aalborg model, the group was interviewed together in the same room, with each individual member getting asked their own questions. Questions covered all aspects of the work, as presented in the group report. At the end of the interview, the assessors discussed and agreed a suitable grade that best reflects each student's interview performance.

The use of the interim assessment allows students to experience the assessment process firsthand and better prepares them for the final report and interview at the end of the semester. In the Aalborg model, the final grade depends solely on what happens on the day of the end-of-semester group presentation and interview, while the Maynooth model grade also allows for partial credit to be gained during the semester.

Facilitation - The role of the staff in PBL is to act as facilitators to each of the groups. They encourage and support the students in their pursuit to acquire new information and to carry out their project work. They do not get directly involved with the project itself. The groups are responsible for all aspects of the project, including organizing meetings with the facilitator, booking suitable meeting rooms, writing agendas, etc. In cases where this does not happen, the facilitator should not, in general, intervene or try to arrange a meeting for the team.

However, as this was the first time the students were exposed to the concept of PBL, it was decided that for the first 5 weeks the facilitators would have a little more direct involvement in the process. Thus, teams were required to meet with their assigned facilitator at least once a week, regardless of what progress they had achieved. At the end of week 5 the facilitators

then adopted a more *laissez-faire* approach to facilitation and encouraged the students to take more control of the direction and management of their own project.

Timeline of Events - Table 3 shows a weekly breakdown of the various events relevant to the PBL module. Students were given this information at the start of the semester so that they had an overall picture of key milestones. It should also be noted that teams were selected and project specifications were handed out in the very first week of semester so that students had the maximum amount of time to work on their given project. The deliverables were spaced as evenly as possible over the course of the semester and the actual final interviews and presentations were held after the standard end-of-semester exam period, to allow the students adequate time for preparation.

Week #	*Events* / Actions Required
1	*Workshop 1, Team Formation*
2	*Workshop 2*
3	*Workshop 3*
4	*Workshop 4,* Reflective Journal Due
5	*Workshop 5,* Interim Report Due
6	**Interim Report – Presentation& Interview,** Reflective Journal Due
8	Reflective Journal Due
10	Reflective Journal Due
12	Final Report Due, Process Report Due
13 – 14	*Assigned Study / Exam Weeks*
15	**Final Report – Presentation and Interview**

Table 3 –Timeline of important events

EVALUATION

The PBL model was evaluated using both student survey forms and student and staff focus groups. The latter were organized and hosted by an independent PBL expert. The survey form comprised a set of quantitative and qualitative questions and was completed by student participants from both 2013 and 2014. In total, there were 42 completed survey forms

received. Table 4 presents the average and standard deviation of the ratings given by the students for a range of statements, as shown. Students were asked to rate each statement on a scale of 1 (strongly disagree) to 5 (strongly agree).

Statement	Average rating (1–5)	Std. dev.
PBL Learning Experience		
PBL is an effective method of learning for me	4.33	0.72
PBL prepares me for my exams.	3.07	0.92
PBL prepares me for my future professional life.	4.51	0.55
PBL improves my teamwork skills.	4.48	0.77
PBL improves my written communication skills.	3.98	0.81
PBL improves my presentation skills.	4.50	0.51
PBL has motivated me to learn.	4.24	0.82
Facilitation		
I had good access to my facilitator.	4.38	0.70
I made good use of the access to my facilitator.	4.05	0.82
I have no difficulty in questioning my facilitator.	4.19	0.71
I am happy with the amount and type of feedback provided by my facilitator.	4.21	0.92
Physical Resources		
The physical environment is suitable for me to participate in PBL (eg. room, furniture, etc.)	4.38	0.58
There were adequate resources (software and hardware) available for your project work.	4.38	0.54

Table 4 –Survey results (42 responses) – 1 to 5 represents strongly disagree to strongly agree respectively

In general, students found the PBL experience very positive and rated it highly as a motivating and effective means of learning. As expected, they felt that PBL improved their communication, presentation and teamwork skills and better prepared them for their future professional life. Students were, for the most part, happy with their facilitator. However, it is worth noting the difference in rating between the two different sets of students for this category, as presented in Table 5. Clearly, the students in 2014 found the facilitation significantly better than the students in 2013 (i.e. the pilot version of PBL). This improvement is likely related to two key factors. Firstly, having been through a full cycle of PBL, the facilitators had gained invaluable experience of the process and were, subsequently, in a better

position to facilitate the second set of students. The second factor relates to improvements made in communication of the PBL process and the role of the facilitators to the students. The first cohort of students were not as well informed of the process as the second set of students, largely due to lack of experience of the participating staff at the time.

Statement	Average 2013	Average 2014
I had good access to my facilitator.	3.88	4.72
I made good use of the access to my facilitator.	3.41	4.48
I have no difficulty in questioning my facilitator.	3.88	4.40
I am happy with the amount and type of feedback provided by my facilitator.	3.47	4.72

Table 5 –Survey results on Facilitation

In terms of the qualitative student feedback and also that obtained from the focus group with the independent expert, there were some very insightful comments to support the above data. One student noted that "*PBL worked really well in the sense that it encourages students to be more liberated in terms of learning".* Another student stated that they "*liked working as part of a team".* It was something that they had *"never done before and found to be quite interesting".* Interestingly, a few of the students noted communication as an issue stating that they felt that "*the communication side of PBL was difficult. It was hard to communicate with everyone and even with the facilitators as"* they *"could be waiting a few days for a reply from an email."* One student noted that "*some of the team mates did not work and therefore put the team under pressure".* This issue was echoed by several other students also. In addition, many of the students felt that, as a group, they "*didn't always use the time constructively.*"

The facilitators found the PBL experience very different to their typical taught modules, but richly rewarding and enjoyable. They found the students to be significantly more motivated about their work and felt that the peer learning within the teams was a highly positive and worthwhile aspect of the PBL approach, noting that "*it was great to see groups of students working together as a team."* In particular, the facilitators enjoyed reading and examining the final reports, as it was far more interesting than the standard repetitive lab reports associated with conventionally taught modules. This was simply due to the fact that the PBL reports tended to contain new material and information that would not be found in a typical lab report. They also observed that it took time to get accustomed to facilitating as opposed to teaching and noted that "*not being able to get involved with the team and taking direction of the project was challenging at times*".

Overall, both facilitators and students found that the new style of learning through PBL was a

worthwhile model and were keen to see the learning process also integrated into later years of the BE in Electronic Engineering degree programme.

CONCLUSIONS

This paper has presented the implementation and evaluation of a PBL educational model in the form of a significant circuits-based project in a first year Electronic Engineering programme. Students found the experience challenging and time consuming but enjoyable, beneficial and ultimately a worthwhile exercise. The PBL model also provided the students with a valuable opportunity of experiencing a range of skills, including teamwork, leadership, communication, research, time management, and project management. The facilitators also enjoyed the experience and found that their students were significantly more motivated in their project work. Future work will consider the integration of the PBL educational model into later years of the BE programme.

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References

Biggs, J. (2003). Teaching for Quality Learning at University. 2nd ed., Buckingham: SRHE/Open University Press.

De Graaff, E. & Kolmos, A. (2003). Characteristics of Problem-Based Learning. *International Journal of Engineering Education*, 19(5), 657-662.

Hmelo, C. & Evensen, D. (2000). Problem-based Learning – a Research Perspective on Learning Interactions, Lawrence Erlbaum Associates Publications, London, 1-18.

Kjersdam, F. & Enemark, S. (1994). The Aalborg experiment: project innovation in university education. Aalborg: Aalborg University Press, 1994.

Kolmos, A. (1996). Reflection on Project Work and Problem-based Learning. *European Journal of Engineering Education*, 21(2), 141-148.

Savin-Baden, M. (2003). Facilitating Problem-based Learning: Illuminating Perspectives. *The society for Research into Higher Education & Open University Press*, Berkshire.