AISHE Academic
Practice Guides

04

An Introduction to Enquiry/Problem-based Learning

Facilitate – the Irish Network for Enquiry/Problem-based Learning

This series is dedicated to the
memory of our dear friend
and colleague, Dr John Panter,
15 April 1941 – 13 November 2015.

Suaimhneas síoraí dá anam dílis

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Introduction to AISHE Academic Practice Guides

The All Ireland Society for Higher Education (AISHE) is pleased to bring you a new series of booklets, each of which offers guidance on a particular theme, for practitioners in higher education. Entitled the AISHE Academic Practice Guides, the series is designed to support the development of teaching and learning in practice.

The booklets are written by practitioners, for practitioners. Based on experience and scholarship, each guide offers an overview of the particular topic to help readers situate the experiences presented in other sections of the booklet. Case studies or examples of practice from contributors' higher education experience are presented and, finally, each booklet suggests resources that the reader may find helpful in their own practice.

We wish to acknowledge the National Forum for the Enhancement of Teaching and Learning in Higher Education for supporting this publication series. We also acknowledge the work of all those colleagues, networks and communities of practice who contributed to the project through writing, providing case studies and co-ordinating contributions in order to bring the series to publication.

Moira Maguire, AISHE President
Saranne Magennis, Series Editor

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An Introduction to Enquiry/Problem-based Learning

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Foreword

This booklet is one of a series commissioned by the All Ireland Society for Higher Education (AISHE). This particular publication is contributed to the series by Facilitate – the Irish Network for Enquiry/Problem-based Learning. It is intended as a first step for colleagues who are new to enquiry/problem-based learning in higher education.

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The booklet is organized into two sections. Part 1 provides an overview which answers the broad question of what is enquiry/problem-based learning. Part 2 presents four case studies of enquiry/problem-based learning. The booklet draws on a few key texts but particularly on another publication by Barrett and Cashman (eds) entitled *A Practitioner's Guide to Enquiry and Problem-based Learning* (2010).

We are grateful to the National Forum for the Enhancement of Teaching and Learning in Higher Education for supporting this publication. We also acknowledge the help of our AISHE colleagues, particularly Saranne Magennis and Moira Maguire, and the work of those colleagues who contributed case studies to this publication.

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December 2015

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Part 1 – Introduction to E/PBL

Yvonne Delaney, University of Limerick
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This booklet – purpose and audience

The purpose of this booklet is to provide readers with an introduction to enquiry/problem-based learning in higher education institutes. Specifically, we hope it will introduce readers to the pedagogical approaches associated with enquiry/problem-based learning.

The booklet is intended for any intelligent reader interested in the topic. It will be of particular interest to colleagues working in higher education in Ireland.

Overview – What is Enquiry/ Problem-based Learning?

John Savery in his article entitled 'Overview of Problem-based Learning: Definitions and Distinctions' (2006) notes that Problem-based learning (PBL) as an instructional approach has been used successfully for over 30 years. He explains that PBL 'is an instructional (and curricular) learner-centred 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' (2006: 9). In considering its origins, Savery draws on Boud and Feletti's 1997 book *The challenge of problem-based learning* who note that 'PBL as it is generally known today evolved from innovative health sciences curricula introduced in North America over 30 years ago' (1997: 2). That work began in medical education in the 1960s in McMaster University, a public research university in Ontario, Canada, through Burrows and Tamblyn. From its origins in medical education the adoption of PBL and other variants has spread to the health sciences more broadly, to science and engineering, to business, to education and the social sciences and, admittedly to a lesser extent, to the arts and humanities.

In terms of defining PBL, we acknowledge what our Facilitate colleague Terry Barrett describes as 'the classical definition' of PBL where it is:

> *the learning that results from the process of working towards the understanding of a resolution of a problem. The problem is encountered first in the learning process.*
>
> (Barrows and Tamblyn, 1980: 1)

Connecting PBL with EBL we note Barrett and Cashman's comment that 'Problem-based-learning is a specialised form or subset of enquiry-based learning' (2010: 8). We see E/PBL as part of the broader provision of collaborative active approaches and adopt Kahn and O'Rourke's relationship between the 'enquiry' and the 'problem' where the E of E/PBL is used 'as a broad umbrella term to describe approaches to learning that are driven by a process of enquiry' (Kahn and O'Rourke, 2005). Thus, Problem-based Learning (PBL), project based learning, case based learning and, indeed, undergraduate research could be included under the broad heading of enquiry-based learning. In order to explore this idea, however briefly, to begin with we will consider 'pure' PBL.

'Pure' Problem-based Learning (PBL) – some characteristics

In its original form, and in current iterations, PBL has a few key characteristics and one model which are often cited. In terms of characteristics, PBL is a learner-centred approach where students' learning is triggered by a problem given to them by a teacher/tutor/facilitator.

In very simple terms, as the students work through solving the problem they achieve the desired curricular learning outcomes. As the UK Physical Sciences Centre notes, 'In PBL, the curriculum is organized around the problems. Consequently, students learn the "content" that is required to solve those problems' (Overton, 2010: 2). Some specific characteristics of PBL are as follows:

- *students work collaboratively in small groups to solve the problem. At times they will need to work by themselves but this will be to research an aspect of the problem so that they can return to the group with additional information*
- *students define the learning outcomes as part of the learning process*
- *students take responsibility for their learning under the guidance of the tutor*
- *problems/triggers should be 'real life' and authentic*
- *the problem simulations (or triggers) must be 'ill-structured and allow for free inquiry' (Savery, 2006: 13)*
- *the lecturer acts as a tutor/facilitator to help students to learn collaboratively; the tutor does not give the students the answers*
- *as part of the problem solving process students adopt and rotate various roles in the group including chair, scribe, group member etc.*
- *assessment associated with PBL should reflect PBL pedagogy.*

A more comprehensive list of these and related characteristics is provided by Savery where he draws directly on the extant literature in this area.

In terms of approaches, the PBL model most frequently cited is the Seven Steps/Jumps Method which originated with Schmidt (1983) in Maastricht. Schmidt's seven steps are:

- *Step 1: Clarify terms and concepts not readily comprehensible*
- *Step 2: Define the problem*
- *Step 3: Analyse the problem*
- *Step 4: Draw a systematic inventory of the explanations inferred from step 3*
- *Step 5: Formulate learning objectives*
- *Step 6: Collect additional information outside the group*
- *Step 7: Synthesize and test the newly acquired information. (1983: 13)*

Barrett, O Neill, Stanton and Cashman (2009) offer a contemporary adaptation of this model which is also influenced by the work of Barrows (1988). In their model they note a pre-step which involves 'Setting the Climate'. Their seven steps then are:

- *Step 1: Read the problem/trigger*
- *Step 2: Define the kernel of the problem/trigger*
- *Step 3: Brainstorm*
- *Step 4: Discuss and Synthesise*
- *Step 5: Formulating Learning Issues*
- *Step 6: Independent study*
- *Step 7: Professional Practice Debate (cited in Barrett and Cashman, 2010: 9)*

PBL as part of EBL

As Kahn and O'Rourke note, EBL is usually organised around 'collaborative work in small groups or with structured support from others, thus promoting the social interaction and cohesion that can be difficult to achieve in a mass system' (2005: 1). Savery in his work compares PBL and EBL (noted in his text as Inquiry-based Learning) commenting from the outset that the 'two approaches are very similar' (2006: 16). Both approaches are active, learner-centred and grounded in critical thinking and collaborative approaches; in EBL students are co-enquirers in learning and identified as partners in the process. What Savery identifies as the primary difference between the two is the role of the tutor: 'In an inquiry-based approach the tutor is both facilitator of learning and a provider of information' (2006: 16). The latter is not true in PBL. For us, as Kahn and O'Rourke suggest, the employment of EBL as an umbrella-term for enquiry driven learning processes, incorporating PBL, is probably the most useful.

What does everyone do in the E/PBL process?

Barrett and Cashman have a very comprehensive outline of the roles of the tutors and those of students in PBL teams. Many of these roles would be replicated in other EPL approaches. Barrett and Cashman's elaborations on the roles of those involved in PBL are reproduced here, verbatim, with the kind permission of the authors.

THE ROLE OF THE TUTOR IS TO:

- *Facilitate the PBL process, not to give a mini-lecture*
- *Listen very attentively to what students are saying and the learning that is taking place in the team*
- *Encourage a welcoming and challenging learning climate*
- *Ask questions that encourage critical thinking*

- *Encourage students to link theory and practice*
- *Encourage students to be responsible to complete high quality independent learning*
- *Facilitate students to reflect on their learning, the development of key skills and the performance of the team*
- *Facilitate the review section of the tutorial*

Students all work on the problem and in addition some students take on the roles of: chairperson, scribe, reader and timekeeper.

THE ROLE OF THE CHAIRPERSON IS TO:

- *Encourage the participation of all team members*
- *Not necessarily to talk first and certainly not to talk at length*
- *Facilitate the team to make and work within agreed ground rules*
- *Stimulate the debate by encouraging discussion of different viewpoints and asking questions*
- *Use the PBL process as a scaffold for the team to work on the problem*
- *Ensure that someone summarises at the end of a tutorial*
- *Check that everyone is clear what learning issues the team has decided to work on.*

THE ROLE OF THE SCRIBE IS TO:

- *Record the ideas of the team on the whiteboard so that this can be used as a shared learning environment*
- *Write the learning issues that the team decide to work on clearly*
- *Work both verbally and visually on the whiteboard and invite other team members to write on the whiteboard if they want to illustrate a point*
- *Summarise and synthesise the learning from the problem on the whiteboard*

THE ROLE OF THE READER IS TO:

- *Read the problem aloud at the start of the process*
- *Re-read the problem again when the team decide this is useful*
- *Draw the team's attention to key elements of the problem*

THE ROLE OF THE TIMEKEEPER IS TO:

- *Help the team to manage their time in tutorials*
- *Remind the team appropriately about how much time they have left in the tutorial*

In different contexts it may be necessary to use other roles e.g. observer, photographer or roles that mirror specific professional situations.

What are the advantages?

All active collaborative approaches to learning have many benefits for students. In E/PBL, aside from the content knowledge which students should gain, students develop a range of skills, competences and habits of mind which can contribute to the overall attainment of graduate attributes. These might include:

- *critical thinking and analytical skills*
- *interpersonal skills - knowledge and experience of working in a group*
- *communication and presentation skills (oral and written)*
- *the ability to construct one's own learning through the integration of new knowledge with existing*
- *independent learning and organization skills/habits of mind*
- *research and information/critical literacy skills.*

We hope also that E/PBL is enjoyable for students and that they find it engaging and motivating.

Some challenges and potential barriers

As with any pedagogy, especially one which is deemed new or innovative, there can be challenges associated with implementation and barriers to adoption. These might include:

- *lack of buy in/resistance to change by staff, by students and/or by senior management*
- *lack of suitable student learning spaces on campus*
- *inflexibility of curriculum/assessment strategies*
- *lack of staff expertise with regards the pedagogy and lack of staff development to help with introduction*
- *new approach at odds with traditional approaches and associated perception of being high risk; anxiety around substituting new ideas for existing approaches*
- *sustainability; where adoption does occur it can be 'bolt on' or 'one off' in nature leading to difficulties to do with sustainability.*

In addition, E/PBL approaches work best where they are curricular in nature. Success is largely dependent on collaborative, curricular/programmatic approaches which may prove challenging to achieve.

Other considerations

E/PBL should be seen as an option in the portfolio of active and/or experiential pedagogies on offer to students in higher education. It should connect directly with related approaches and ideally might culminate in more formal and more substantial undergraduate research. While a curricular approach is desirable, where this proves impossible a commitment to enquiry-based approaches across the disciplines and across the year groups would be a good beginning.

As with many active learning approaches, connecting with colleagues in the Library is essential. E/PBL pedagogies rely on students' information literacy and their capacity to find good information to substantiate their claims and/or make their case. Collaboration with Library colleagues is necessary and will prove fruitful.

In terms of staffing, E/PBL can be demanding with regards to staff student ratios, especially in the first year. However, as students learn how to work in small groups, in an enquiry/problem-based manner, the scheduled contact time with staff often decreases.

In an ideal world, each E/PBL group would have a dedicated room/space where they could work for a semester or whole academic year on a project. This would have significant resource implications. Where it is not possible to have a dedicated space, small group rooms or open plan rooms which could be partitioned temporarily and could be booked/used on spec would be very useful for students.

The biggest commitment for any institution with regards to E/PBL is the willingness of staff to engage with the pedagogy and the supporting of these staff in this intention.

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Part 2 –
Four Case Studies

As we mentioned at the outset, the aim of this handbook is to provide an introduction to E/PBL complete with useful, practical advice on its implementation.

To further help in this regard, we are providing some examples about how we use E/PBL in our disciplines and our various institutions.

We trust that this material will help you to work out what might be best for you and your students in your setting.

The case studies are:

- *Integrating a PBL Pilot Module into an Electronic Engineering Programme*
- *Using Web 2.0 technology to enhance the delivery of problem-based learning*
- *PBL is Undergraduate and Engineering at the University of Limerick – rationale and application*
- *PBL in a Software Engineering Classroom*

Integrating a PBL Pilot Module into an Electronic Engineering Programme

CONTRIBUTORS

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NAME OF INSTITUTION

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Context – description of your education/institutional setting

The Department of Electronic Engineering at Maynooth University, Ireland was established in 1999 and graduated its first cohort of engineers in 2004. In recent years, a number of faculty involved in the undergraduate electronic engineering programme have become interested in the use of problem-based learning in general and specifically in how to most effectively integrate PBL into the programme. We looked in detail at Aalborg University in Denmark where PBL has been used extensively in engineering and science education for over forty years. An engineering professor[1] from Aalborg was invited to Maynooth in November 2011 and facilitated two PBL workshops, one aimed at the entire Maynooth University faculty and one customised specifically to an engineering education context. The following June, three faculty members from the department visited Aalborg University to observe first-hand the so-called Aalborg model which is often referred to in the literature as Project-Oriented Problem Based Learning (POPBL). Between September 2012 and January 2013 these same three faculty members completed a part-time online diploma in PBL with Aalborg University [Aalborg 2015] while at the same time developing a pilot PBL module to be integrated into year 1 of the above 4-year engineering programme. This pilot PBL module was implemented during semester 2 of the 2012/13 academic year and has since been adopted and further refined as a substantial component of the engineering programme. In the following academic year a follow-on PBL module was developed and introduced into year 2 of the engineering programme. This case study gives a brief overview of the mistakes made and lessons learned in developing these PBL modules and integrating them into the programme.

[1] Professor Lars Peter Jensen

Description of how, where and with whom you have used E/PBL

This case study is based primarily on the design, implementation and evaluation of a group Problem-Based Learning (PBL) pilot module with a cohort of first year students on the BE in Electronic Engineering Programme in the Department of Electronic Engineering, Maynooth University, Ireland.
In an ideal world, PBL 'modules' are best integrated at the curriculum design stage such that they closely align with appropriate 'taught' module content in such a way as to provide a structured mechanism for each project group to discuss, reflect on and apply the content of these taught modules in specifying, orienting, analyzing and ultimately solving the problem upon which their group project is based. In the case of our PBL pilot, as is more often the case in practice, we were looking to retrospectively 'insert' our PBL pilot module into a conventional lecture-based programme having a number of service-taught modules delivered by other departments e.g. maths, physics etc. Such constraints meant that a complete curriculum redesign was not an option. The literature reflects this reality and Moesby (2004) offers detailed guidelines relating to making an iterative change from a conventional engineering programme towards a fully integrated PBL one. Such adjustments frequently reflect DeGraff and Kolmos' (2003) common characteristics of PBL models. These characteristics relate to

- *Programme or Curriculum Structure*
- *The Peer-Learning Process*
- *Alignment of Assessment and Learning Outcomes*

These guidelines and characteristics, along with the staff training which we received from Aalborg University [Aalborg 2015], proved invaluable in the design and implementation of the pilot PBL module in the context of the existing programme.

As outlined above, the pilot PBL module was implemented during semester 2 of the 2012/13 academic year. The module involved a total of 18 students working in 3 project groups. The initial group sizes were 5, 6 and 7 though 1 student withdrew from the programme during the semester. Although the pilot module was based on the Aalborg PBL educational model, it was adapted to take account of local contextual differences such as student demographics and prior experience of group project work as recommended in [Moesby 2004]. The pilot module was integrated into the second semester of the four-year conventional engineering programme such that the project theme was closely associated with previous and parallel taught module content while still allowing significant scope for student direction/ownership. The project module comprised one third of the total student workload i.e. 10 out of 30 ECTS credits which equates to a nominal total of 250 hours project work per

student over the semester. Further details of the 4-year engineering programme and how the pilot PBL module was integrated into it are presented in [Lawlor et al. 2014].

Key benefits of using E/PBL for students, staff and the institution

A range of evaluation instruments were employed including detailed student quantitative and qualitative surveys and independently facilitated student and staff focus groups. The pilot module proved very effective as a means of enhancing student engagement and promoting effective peer-learning. Of the 17 students who completed the module, 15 expressed a preference for PBL relative to conventional teaching methods. The beneficial outcomes of the pilot were largely consistent with the expected benefits associated with PBL. For a comprehensive review of such expected benefits see, for example, [Hoidn 2014]. Other unexpected benefits associated with the staff workload and student and staff satisfaction also emerged and are described below.

STAFF WORKLOAD

One of the primary objectives of the pilot was to investigate the feasibility of making a transition from our existing educational model to a fully integrated PBL model for the entire BE programme. This investigation involved a detailed analysis of the resources required in carrying out the pilot. We compiled a detailed record of the staff time required on all aspects of the pilot, namely, weekly group facilitation, workshops, assessment of interim and final reports, presentations and interviews. Based on this record, to our surprise, the pilot proved significantly less (approx 50%) demanding of staff time than the workload associated with 10 ECTS credits worth of conventional module delivery.

STUDENT REACTION

As part of the end-of-pilot survey we questioned the students on how they felt the PBL approach worked for them in relation to their development of certain key skills often associated with PBL. As shown in Table 1, the overall student reaction was generally positive although 8 of the 17 students were unsure as to the effectiveness of PBL for exam preparation. In the focus group session, the students indicated several positive aspects of the pilot which they felt had worked well, namely, the workshops, the reflective journals, the online discussion, the practical application of theory, the group work, the self-directed learning, the 'real-life'/experiential learning and the 'variety of roles' which they had the opportunity to experience.

Table 1
Student overall response in relation to certain skills

Instruction – place an 'X' in the appropriate box for each of the statements listed below	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
PBL is an effective method of learning for me.	5	10	2		
PBL prepares me for my exams.	1	6	8	2	
PBL prepares me for my future professional life.	8	8	1		
PBL improves my teamwork skills.	9	6		2	
PBL improves my written communication skills.	4	9	4		
PBL improves my presentation skills.	7	10			
PBL has motivated me to learn.	5	8	3	1	

STAFF REACTION

An unanticipated outcome from the staff perspective was that despite some short-comings of the PBL pilot implementation, all three staff involved in the pilot found the experience far more interesting and enjoyable than the conventional module delivery. For example, all three felt that reading one substantial group project report having significant elements of self-directed and peer-learning was far more gratifying than reading several sets of individual lab reports where students have simply followed pre-defined procedures without necessarily having to reflect deeply on the development of those procedures or having to devise and refine their own analytical procedures in orienting and addressing their group problem.

Contributor's reflections – inspirations and aspirations

One of the key points of Professor Jensen's workshop in November 2011 was that based on his 40 years of experience of the Aalborg educational model[2] (initially as a student and later as a member of the faculty) the single most effective learning intervention is the peer-learning which takes place within the project groups. This key point certainly inspired us to find out more about the approach and challenged us to reflect on how best to organise our curriculum with a view to harnessing the power of peer-learning. In addressing this challenge, one of our primary aspirations was to learn from the wealth of PBL literature in order to avoid repeating mistakes of the past.

An unfortunate feature of much PBL research literature is that it assumes a dichotomy between direct instruction and problem-based learning and attempts to measure the relative effectiveness of these as two alternative approaches. Best practice in PBL, however, calls for a systematically aligned mix of direct instruction and related group project work [Hoidn 2014]. Systematic alignment of the assessment methodologies with the programme learning objectives is another characteristic of best practice in fully integrated PBL models. DeGraff and Kolmos (2003) cite the absence of such alignment as 'one of the classic mistakes made when changing to PBL' (659). If important process competences are to be effectively achieved, then this importance needs to be reflected in the assessment methodology. Fundamental to this alignment of assessment methodology with programme learning outcomes is the percentage allocation of marks to the programme components. At Aalborg University project work accounts for 50% of the students' time and this percentage is also allocated to the project assessment [Moesby 2004]. Our current level of PBL integration is still some way off this 50\50 ideal but our experience to date has been very encouraging and we are therefore continuing to explore curriculum migration possibilities to bring us closer to this ideal.

[2] Professor Jensen started in Aalborg as an engineering student in 1974.

Despite the small number of students involved in the PBL pilot, the findings were very encouraging and suggest, subject to further validation, that the PBL model is an effective way to engender a range of important skills such as communication skills, teamwork, enquiry-based learning, peer-learning, project management, collaborative and individual innovation and creativity all within the context of mastering the electronic engineering discipline-specific learning outcomes. These preliminary findings inspired us to proceed to introducing a follow-on PBL module into year 2 of the programme.

For the purpose of the year 1 PBL pilot, in line with the Aalborg model, we conducted group interviews as a significant element of the assessment. However, we have since moved to the use of individual interviews and find this approach to be more appropriate for the assessment of target learning outcomes at an individual level.

Finally, for anyone interested in PBL for engineering education, some introductory training in group facilitation is strongly recommended [Aalborg 2015] before or during a PBL pilot study.

Resources we found useful (limited to 5)

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Using Web 2.0 technology to enhance the delivery of problem-based learning

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Context – description of your education/institutional setting

Distance learning (DL) provides a route for healthcare professionals to update their skills, undertake Continuing Professional Development (CPD) and gain employment or promotion opportunities through flexible part-time study. The School of Biomedical Sciences at Ulster University has been at the forefront of the development of DL programmes, delivering a range of courses for professional development in the health sciences via the Blackboard Learn Virtual Learning Environment (VLE). The growing availability of interactive web based tools both within the VLE environment and outside of it provides opportunities to deliver the social and constructive learning opportunities required for PBL.

The term "Web 2.0" is used to encapsulate the way that the internet or "Web 1.0" can promote user participation by sharing control of content, and providing richer user experiences. Web 2.0 has subsequently become shorthand for those services such as wikis, blogs, social networks, social bookmarking, podcasting and immersive worlds which allow users to add their own content as opposed to providing them with static information. These affordances align with the philosophy of PBL. We therefore explored whether they could be used to enhance the PBL experience for DL students.

Description of how, where and with whom you have used E/PBL

In this case study, Illustrative examples are provided of the way in which we have used a range of Web 2.0 technologies to provide triggers and deliver the seven-step or Maastricht method described in the overview section of this booklet. Furthermore, the way in which the use of Web 2.0 technology can facilitate scaffolding and assessment of PBL is explored.

PROVIDE TRIGGERS

Online newspapers, social network sites such as Facebook and YouTube, micro-blogging sites (Twitter) and curation sites (Scoop-it, Pinterest, Google groups), provide a rich source of authentic and current triggers.

Typically, there are opportunities to comment on these resources directly on the open platform; however, for the purposes of PBL, links to the triggers can be provided from closed groups e.g. closed Facebook groups, or Google groups, allowing the students to develop their understanding in a private space or 'walled garden'.

Application of 2.0 technology to the Seven-step PBL method

1. ***Clarify terms:***
   Working in an online environment allows the collaborative production of a vocabulary. Identifying and defining the unknown concepts and phrases in the problem description provides the foundation for a shared understanding of the problem.

2&3. ***Define and analyse the problem:***
   Mind mapping tools (e.g. Freemind®, X-Mind® and Inspiration) can be used to promote brainstorming and creative thinking though visualising the problem and facilitating the identification of the underlying issues, concepts, phenomena that need to be understood in order to solve the problem.

4. ***Review collated ideas and information:***
   The mindmap can be used to construct viable hypotheses, however, as the students gather information, a wiki can be a useful work space through which the group can share knowledge and resources.

5&6. ***Formulate learning objectives and independent study:***
   Wikis allow all users to comment on and edit the contributions of others; in this way the group can construct their learning objectives. Students can be encouraged to keep personal blogs or private pages on the wiki, to record their reflections throughout the period of independent study.

7. ***Synthesis and reporting:***
   Privacy settings on the wiki can be changed at the end of the project to disseminate findings to a wider audience. If the original trigger was available via a public resource, students could be encouraged to post their final conclusions or comments on the public site. This approach supports students as they develop a professional digital identity, providing a 'pathway out of the walled garden'.

SCAFFOLDS

As the students work in the online environment the tutor can observe the PBL process and introduce scaffolds as and when required to support the needs of individual groups. The tutor can follow the PBL process online, help diagnose misconceptions, promote evaluation of multiple perspectives and ensure the students are on track to meet learning objectives. For example, a blank glossary page could be provided on the wiki, prompting questions can be added to wikis or mindmaps, and links to resources can be provided.

ASSESSING THE PBL PROCESS

PBL aims to develop higher cognitive and transferrable skills and improve long-term knowledge retention; however, assessment in PBL activities is often not matched to these outcomes. One of the benefits of using Web 2.0 technology is the digital 'footprint' that remains as students work through tasks, allowing the tutor to assess the PBL process. Contributions are automatically tagged, enabling the identification of individual submission and facilitating the assessment of individual group members at various stages of the process.

Key benefits of using E/PBL for students, staff and the institution

One of the key features of Web 2.0 technologies is their collaborative nature. As such they lend themselves to PBL learning environments where no one member of a group, including the tutor or facilitator, may be considered an expert. Many aspects of Web 2.0 conform to the learning goals of PBL: facilitating communication; sharing of resources and joint document production; promoting active learning; and providing a platform for the development or construction of knowledge. Additionally, basing the PBL process within the on-line environment can facilitate the provision of multimedia triggers and promote students to consider the medium through which they might disseminate the problem outcomes. Students also develop their digital literacies as they complete authentic tasks online; these skills and competencies are widely recognised as critical attributes for employability.

As the provision of distance learning programmes increases to meet the growing demand for flexible learning and continuing professional development, effective use of Web 2.0 technology can improve engagement for DL students and provide opportunities for the social interactions and collaboration required for effective learning. Our experience indicates that Web 2.0 technology, provides additional benefits which include supporting and promoting collaborative learning, facilitating scaffolding and providing mechanisms for self and peer-assessment.

Consequently, we suggest that it should be employed when working both on-campus and DL students. Thus, whilst PBL has been traditionally characterised by the social interactions that occur during group working and the central role of the facilitator, our experience has indicated that Web 2.0 technology can enhance the PBL experience for on-campus students.

Contributor's reflections - inspirations and aspirations

PBL challenges the concept of learning as a teacher-led dissemination of information that is often abstracted from society and the real-world. The ubiquity of online tools and technologies can further disrupt the traditional approach to education, supporting students as they become independent learners. Publicly available Web 2.0 technologies can be used as private learning spaces (which also raises questions around the need for VLE's and the role of institutional information technology). Evidence has indicated that students (and teachers) wish to keep their social networks separate from their professional or academic networks, however, this does not preclude having a social interface and an academic interface. In PBL it is expected that students identify appropriate resources to solve a problem; this should include the use of appropriate information and communication technologies.

The availability of Web 2.0 technologies, both within the University IT infrastructure and the public domain, should provide the opportunity for a less prescriptive approach to the use of technology, allowing students to identify the most appropriate tools for the task. Learning and teaching is being transformed by these tools where supporting learning within the public domain connects learners to the real world and encourages life-long and life-wide learning practices.

Resources we found useful (limited to 5)

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PBL in Undergraduate Civil Engineering at the University of Limerick – rationale and application

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Context – description of your education/institutional setting

The impact of access to the World Wide Web on today's higher education can be seen by the ever dwindling attendance at lectures – particularly lectures that focus on the delivery of content over context and insight. Continuing in this vein heralds the demise of the lecture as students choose not to attend unless value is added to the content.

In 2007 staff at the University of Limerick (UL) were planning a new programme in civil engineering. Acutely aware of the above trend, the programme design team believed that any new programme must be founded on a pedagogy that will motivate and engage the student in the joy of learning. The team chose a student centred pedagogy known as Problem Based Learning (PBL).

In PBL students are guided in how to solve problems through working in small teams and using questions raised during group discussions. These questions spark enquiry and in turn requests for instruction on the knowledge or concepts necessary to develop a solution. Since its launch in 2008, the programme continues to attract interest from national and international educators and is professionally accredited by Engineers Ireland.

Description of how, where and with whom you have used E/PBL

In 2008 civil engineering was one of a number of programmes in UL adopting PBL as an instructional model. However, civil engineering was the only programme to adopt this pedagogy at undergraduate level. The rationale for this decision stems from a belief that it will deliver civil engineers that are flexible and capable of responding to the needs of a world undergoing constant change.

PBL is introduced from day one of the programme and permeates through all four years. Triggers or problems are used to drive the learning. The duration of each trigger varies from one week to semester long activities and can involve one or multiple modules.

For example, at the end of first year, students engage in a semester long trigger; they respond to a client's need to cross a body of water in the 'Bridge Project'.

In this exercise the students, working in small groups, conceive ideas, test materials, analyse their structures response to loading and hence design and assemble their creations for public display at an end of year celebration.

This trigger illustrates what can be achieved through the sharing of ideas, expert guidance and the group's learnt experiences from childhood through to young adulthood. The fruits of this trigger are captured in the short video available at https://www.youtube.com/watch?v=7LHvledm3aY.

First year triggers are designed to build on the students' prior knowledge, applying and extending their understanding of the sciences and how these are applied in solving real open-ended problems. It also encourages the young engineers to 're-engage' with their childhood creativity in exploring the aesthetics, elegance and economy of the various structural forms being explored. Each team member undertakes an assigned role (which rotates week-on-week) until one of many feasible solutions is agreed. This work is undertaken under the watchful eye of an experienced engineer who facilitates and, if necessary, guides the learning in PBL sessions.

There is excellent engagement with this project and students go far beyond what is called for in the brief. They develop a sense of pride in their accomplishment and gain tangible experience of being an engineer at this early stage in their education.

The process repeats in subsequent years but the complexity of the triggers grows as the students progress through the programme. Some second year triggers include the design of an earthen dam to protect buildings along the banks of the River Shannon against flooding and the design of siege towers. Also, in second year, the students design a water treatment plant for the town of Ennis. A novel integrated design project involving four modules takes place in the autumn semester of third year. In this an architect designed multi-storey reinforced concrete building is developed for a site exhibiting challenging ground conditions. In final year, real construction disputes are tried in moot court. In this cooperative learning experience UL law students hire UL civil engineers to investigate engineering defects and failures; they then write an expert report and provide expert testimony in court.

Key benefits of using E/PBL for students, staff and the institution

The observations and lessons learnt through many of the trigger experiences provide a rare opportunity for the young civil engineer to prototype a design.

The learning embedded in these experiences could not be developed in a traditional lecture scenario where the meanings of scale, touch, behaviour, context and sense of accomplishment and belonging are absent.

We find PBL encourages students to take responsibility for their learning. It also facilitates a thought process and assimilation period that is flexible and adaptable to individual student's pace of learning. Such thought processes are often severed by the restrictive imposition of the clock in traditional lectures.

The PBL approach enhances and reinforces learning as the students naturally develop links between new material, their prior knowledge and life's experiences. This opportunity seeds a framework for lifelong independent learning. The rigour of the PBL 'process' in seeking solutions to open-ended problems builds belief in the students' professional judgment and also boosts their confidence when presenting designs in public fora. Verbal communication skills are also developed during individual interviews held to evaluate learning at end of triggers.

The PBL process is centred on teamwork and thus develops many additional skills which would not occur in a traditional mode of delivery. For example, alongside enhanced communications skills discussed above, the students working on the bridge project learn about laboratory and field health and safety issues associated with their design, how to survey a site, how to order materials, develop fabrication skills and meeting construction deadlines which may involve working during inclement weather.

Committed students excel in this model, reflecting a level of maturity in their approach to learning. Candidates relying on cramming for an end of semester examination tend not to do as well in PBL. It is therefore important to provide a proper induction for students when they first encounter PBL and to emphasise the importance of the continuous nature of learning advocated in this model. Finally, the process also lends itself to reflective practice. This is a powerful technique for reinforcing what has been learnt and identifying any remaining gaps in knowledge that require further work or assistance. Again, reflective practice does not come naturally to young undergraduates and guidance and feedback on their reflective logs is required.

With the first graduates of the programme having just three years professional experience at this stage, a quantitative assessment to measure the impact of the PBL approach with supporting statistics has not yet been undertaken.

Anecdotal feedback from students however shows a positive response to their educational experience. Furthermore, employer feedback gathered during the department's quality review audit in 2012 suggests that graduates of the programme excel at undertaking independent research when tasked with a new challenge. One employer also stated that 'the UL civil engineering graduates tend to have advanced their work to a good level before seeking guidance from their supervising engineer.'

Contributor's reflections - inspirations and aspirations

Over the past seven years a tremendous body of work has and continues to be undertaken on the UL civil engineering programme. This involves tweaking and improvement of triggers based on observations during each iteration. Listening and responding to the student voice is an integral part for the programme's success as is continued research and networking with national and international champions of student centred pedagogy.

It is clear that successful learning can only be accomplished through partnership. Students need to commit to a process that requires consistent work and regular assessment throughout the year. They must build trust in their mentors' ways and means of helping them to become excellent engineers. Staff, in turn, need to develop well-considered and tested triggers and provide structured feedback at appropriate times. They must also exercise patience and compassion in their dealings with students. Empathy and a supportive environment are necessary in facilitating the students' transition from secondary education to third level, particularly with respect to the non-academic challenges that this can entail.

Reflection and dialogue by staff and students following each learning experience has been instrumental in improving the overall coherence of the programme – it has helped free up strongly held views and introduce openness to new ideas. For example, in the initial years of the programme I questioned the value of the lecture believing that all learning could be facilitated through the PBL process alone. However, I now recognise the need for scaffolding to support learning. This is particularly important when dealing with undergraduate students whose learning experience to date is founded on a didactic approach which, until now at least, has been the model adopted in secondary schools. Moving from didactic instruction requires careful consideration and support if students are to make a successful transition to independent discovery learning.

Moreover, students still need to learn the procedures, facts and skills necessary for their development and success as professional engineers. Therefore, we now complement our PBL sessions by adopting other pedagogies and appropriate use of technology. The civil engineering team employ a range of techniques including active learning lectures, flipped learning and case studies. The team also employ audience response devices (clickers) to engage and motivate students to discuss challenging concepts in class. These devices provide instant anonymised feedback to the students while allowing the lecturer to evaluate the level of understanding and to take immediate remedial action to address any misconceptions.

After twenty years in higher education my involvement with this programme over the past seven years has been a unique and inspiring experience. Seeing students forming bonds with their peers and enjoying each other's company in an environment that facilitates learning continues to reward and motivate me. The students' stimulation of thought, sharing of ideas and demonstration of commitment to their educational formation and growth as engineers continues to be a strong motivator of the team.

Resources we found useful (limited to 5)

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PBL in a Software Engineering classroom

CONTRIBUTOR

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NAME OF INSTITUTION

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Context – description of your education/institutional setting

In the Department of Computer Science and Information Systems our courses focus on the design and development of software systems. This requires that students have an understanding of and analyse how people use systems – although not necessarily computer-based systems – in particular contexts. Building on this foundation, knowledge students learn how to convert the user understanding and analysis into a system design. This is done by using a variety of design techniques, for example, process and data modelling. The systems design is used as input to writing programs. These are then integrated into a full system, and testing completed.

Graduates from the department must understand the theory of software engineering. In addition, they need to be able to apply this theory in practice. Some modules that they do are very practice-based; some modules are theory-based. The introduction of problem-based learning to some courses can strongly enhance students' capacity to move between these two types of learning and to combine them.

In our taught courses, which are one-year Higher/Graduate Diploma, BSc and MSc., I have used problem-based learning (PBL). In various modules across these courses, I have used PBL by giving one problem at the start of the semester, and students, in their groups, have been facilitated in their learning with a mixture of meetings, short lectures, presentations, and interviews with practitioners (Richardson et al., 2011). The Higher/Graduate Diploma class however is different and I have focused on this particular group for the purposes of this case study

Description of how, where and with whom you have used E/PBL

I was tasked with teaching Development of Information Systems to the Higher Diploma in Software Development and Graduate Diploma in Computing, and was faced with a dilemma – how does one teach analysis and design to a class of 50 highly-motivated students in one semester, in order to ensure that they learn both theory and practice?

Given my previous teaching experience, PBL seemed like a good solution; however, I could not use it in the same (or even similar) format to how I had been using it with 4th year BSc and MSc students.

I decided that the class would be conducted through a series of problems, with each problem building on the previous problem. Overall, the students would be expected to analyse and design a system, but we would do so as a class throughout the semester.

The overall problem which we decided to use was where students were expected to 'Design a Computer System for a Bicycle Shop'. This would contribute to 60% for the module. I chose a Bicycle Shop for a number of reasons:

- *In general, people would be familiar with the concept of a bicycle shop.*
- *The bicycle shop example is gender-neutral. I could have chosen a sports equipment shop, which might have been interpreted as being male-focused, or a dress shop, which could have been seen as being female-focused.*
- *Within a bicycle shop there are a number of different and distinct elements such as selling bicycles, renting bicycles, repairing bicycles, inventory control, financial control, employing people etc. This variety allows for the development of a better system (as distinct from software) design.*
- *This variety allows for the development of a better system (as distinct from software) design.*

My approach to the class was to endeavour to combine theory with practice. Theory was normally presented through short lectures. Sometimes, I presented theory, and then asked students to solve a related problem. More often, though, I allowed students to work through the problems and then presented theory. The latter approach ensured that when I was lecturing, we had concrete examples which the students themselves had solved. The module consisted of 12 weeks, each scheduled with 2 hours lectures and 1 hour tutorial. However, in reality these morphed into generally 3 hours of PBL combined with short lectures.

I broke the problem down into 4 distinct parts, each part worth 10% completed by groups of 4 students. The sub-problems were to:

- *Identify the transactions within a bicycle shop*
- *Model the transactions as expected in a new system*
- *Identify the data elements within a bicycle shop*
- *Model the data elements with attributes and characteristics in the proposed system.*

Students worked on each problem during class time, starting by writing their thoughts on flip-charts. They were encouraged to walk around the room, discussing proposed solutions and answers with other groups. At various points, I held debates and discussions, within groups, between groups and within the full class. Where a theory lesson was required, I would give a short lecture.

In addition to this project, students were required to write an individual reflective journal, worth 20% and to complete a final exam worth 40%.

Key benefits of using E/PBL for students, staff and the institution

Students who undertake the Higher Diploma in Software Development, and the Graduate Diploma in Computing, either have a Level 8 qualification in a non-computing discipline or have relevant prior learning and/or prior experiential learning. Both courses have an applied bias with an emphasis on practical work and hands-on experience, which ultimately provide participants with the skills necessary for the analysis, design, testing, implementation and maintenance of computer based information systems in a commercial or industrial environment.

As a result of the entry requirements students are normally well-qualified, either through their education or previous work experience. The challenge with this class is to teach them software analysis and design in a short space of time. While undergraduates are taught in 8 semesters and complete some capstone projects, group and individual, through which they learn, this class have 2 semesters of taught modules, one of which is 'Development of Information Systems'. Following this, many of them go directly to industry.

The benefit to these students in learning through PBL is that they gain practical experience in a focused learning environment. They are learning new skills and techniques, and, rather than this just being book-learning, they experience applying their learning to the development of an information system. Because they do this within groups, they learn other transferable skills such as time management, meeting chairing and group management.

Many of the students in these classes have relevant prior experience and learning. Through PBL, they are enabled and encouraged to bring this to their own group work. They also disseminate their own background and experiences among their classmates. In this manner, students are engaged in peer learning and come to see the importance of this approach. This is extremely valuable and an experience not often given to students.

I also benefit from using PBL. I learn from the students and we all enjoy the interactive, participative nature of the approach.

In addition, I often have opportunity to disseminate the research that I have been undertaking and this makes classes very stimulating for me. When doing PBL, I see the world through a different lens and am often on the lookout for problems which I can use in class. From the students' perspective, they find that the benefits of PBL extend beyond the classroom in to job interviews where they often discuss their involvement in this type of learning. This in turn contributes to our reputation as a progressive University, something which is important for both students and employers.

Contributor's reflections – inspirations and aspirations

Before I started using PBL, my lectures were normally given as MS PowerPoint presentations. I would prepare slides on the subject theory and talk for about 50 minutes. I was constantly looking for ways to generate and maintain student interest – asking questions, getting students to work in small groups for a few minutes, taking a break and letting students relax about half-way through a lecture – those hints that I would have picked up at various courses. I sometimes brought my research into these lectures, but more from the perspective of having examples to present to students. While I was probably teaching quite well, I think students would have found it difficult to listen and absorb during each 50 minute lecture. The content was often difficult to understand and, while I expected students to be able to apply the theory to practice, I did not give them very realistic problems or situations within which they could learn. Students sat in rows and rarely talked to each other.

Through doing PBL this situation has changed totally. It is rare for me to give a full lecture – in fact, my lectures are normally less than 10 minutes and focus on topics which have come up in class which I need to present to all students. We put sheets of paper on the lecture theatre wall, students stand up and work on their problem, writing up their solutions and discussions for all to see. I circulate and they circulate around the room. They interact, discuss, critique and enhance proposed solutions. In addition, I can point them towards research on the topic which has been carried out locally, nationally and internationally.

Through using PBL my enjoyment of lecturing has increased dramatically. I have always loved teaching, but my use of PBL has allowed me to interact with students at a level which is not possible when presenting while standing at the front. I have been given many insights into industry-based examples through student discussion. While I maintain control of classes and student-learning, I am pushing out the boundaries of students' learning beyond where it would normally be.

Students are learning actively. They understand now why theory is important and they see in a realistic manner how it can be implemented. We often discuss how their other modules can integrate with the subject matter from the module, Development of Information Systems. This was never possible before the introduction of PBL.

The use of the Reflective Journal is also important. Firstly, it allows me to identify what individuals have contributed to the group project and they also discuss the learning that they have done as individuals. In addition, it has been mentioned by External Examiners as an important element in ensuring that students participate in the project. Due to the interaction within class, I can easily identify where students are not undertaking the required work and often take the opportunity to discuss their personal role in the project.

Resources we found useful (limited to 5)

[1] Richardson, I., Reid, L., Seidman, S. B., Pattinson, B., Delaney, Y., (2011) *Educating software engineers of the future: software quality through problem-based learning*. IEEE Conference on Software Engineering Education and Training. Hawaii, USA, 22nd-24th May pp 91-100.

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