Seeding Enquiry-Based Learning in Electrical and Electronic Engineering: Case Study 1 – Optoelectronics

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Abstract - Enquiry-Based Learning (EBL) was developed in the third-year, Electrical and Electronic Engineering (EEE) module Optoelectronic Devices and Systems. Problem-Based Learning (PBL) is an instance of EBL, where the students’ enquiry into a topic is triggered by an initial problem or scenario. This module begins with a PBL exercise, which covers display devices. The students are asked to imagine that they are a small company that is about to develop a new large screen High Definition Television (HDTV) consumer product for the market in a few years. This links enquiry into existing and emerging display technologies with the specification and standards for HDTV. It also requires the students to project market trends and technological advances into the near future. Key decisions in the design of the scenario, consideration of the learning environment and the form of assessment are described, emphasising flexibility in approach and sensitivity to the context of this development.

This development is in the second year of its delivery. The results of an integrative evaluation, drawing on questionnaires, participant observation, student focus groups and discussions with staff, will be presented. The varying experiences of three groups will be presented, highlighting the impact of both internal and external factors.

Index Terms – Electronic Engineering, Enquiry-Based Learning (EBL), Optoelectronics, Problem-Based Learning (PBL).

INTRODUCTION

The development of professional and personal skills in engineering students is becoming increasingly important. A recent survey of employers, conducted by the IET (Institution for Engineering and Technology) [1], highlighted a mismatch between the skills required by electronic engineers and the skills that graduates possessed. This finding is in line with similar studies and engineering education reviews in both America and Australia [2]. PBL is an instance of EBL [3], where the students’ enquiry into a topic is triggered by an initial problem or scenario. The students following in this enquiry engage in the subject matter at a much deeper level, whilst gaining professional, personal and life-long learning skills in a process integrated with their core subject learning [4].

This paper and its companion paper (Case Study 2 – Robotics) report on some of the teaching and learning developments that arose at the University of Manchester, from a collaborative PBL initiative with University College London and the University of Bristol, supported by the IET [1] and HEFCE (Higher Education Funding Council for England). In Manchester, PBL has been introduced into three third-year units, in the areas of VLSI design [5], Optoelectronics and Robotics, and also as part of the second-year tutorial system as a preparation for a team project [6].

This paper describes the context of the module, and the implementation of a PBL exercise into it. It then describes the evaluation of the PBL exercise drawing out the experience of three groups of students. There then follows a discussion of the issues arising from this experience.

IMPLEMENTATION

Context

Optoelectronics Devices and Systems is an optional, 10-credit, third-year, second-semester module delivered through lectures with problem-solving tutorials delivered towards the end of the module as preparation for the examination. The contact time for the module is two 50-minute sessions per week. The summative exam represents 75% of the module. The remaining 25% of the module is taken up by a written assignment. The module is divided into two main sections: display technologies and communication systems. The former is a descriptive review and the latter a more quantitative treatment of the science and technology, representing the major portion of the module.

Scenario

In many respects the components for a PBL were already in place: the more descriptive display technologies theme combined with the individual report. Display technologies provided an accessible and motivating topic for enquiry, since television is a very tangible component of people’s everyday experience. Also the diversity of display technologies, the development of new technologies and the

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Introduction of new formats onto the market provide a stimulating and changing topic for enquiry.

The students were asked to imagine that they are a small company that is about to develop a new large screen HDTV consumer product for the market in a few years’ time. This links the enquiry into the existing and emerging display technologies with the specification and standards for HDTV. It also requires the students to project market trends and technological advances into the near future.

Timing

This topic fits naturally at the beginning of the module, providing a lighter introductory topic before the more technical optical communications section. Placing the PBL exercise at the beginning of the module has the additional benefit of avoiding the peak workload times for the students which occur later in the semester, when they are likely to encounter coursework from other modules and be preoccupied by completing their third year projects.

A disadvantage, however, is that for the first couple of weeks of the module, students are still deciding which optional modules to select, so the size and make-up of the class are uncertain and fluctuates. This is mitigated partially by giving over the first two or three sessions to introductory talks on the module in general, displays specifically and PBL. The following four to five sessions, depending on the groups’ progress, are given over to team meetings. The students are then given a further two weeks to write up an individual report on their research.

Resources

The lecture had in place a series of detailed notes as handouts for each component of the module. The first volume of these notes, covering the electromagnetic spectrum, colour perception and display technologies, were provided in the introductory lectures as a starting point for the enquiry. Students were also referred to the PBL, Information Searching and Group Working guides that they were provided with in their second year.

It was anticipated that the majority of resources would be accessed via the Internet, through searching technical databases, in the form of review articles from professional journals and technical reports from manufacturers. Students were given instruction on the use of technical databases at the end of the first team meeting.

Another resource that was offered to the students was the lecturer’s expertise. He offered to provide explanation and clarification of anything that the students found difficult during their enquiries, on either an individual or group basis.

Learning Environment

This module was scheduled to take place in a raked lecture theatre. This was not considered conducive to group work, so a flat lecture theatre with movable desks was found for the first year of the team meetings. For the second year there was only one group, consequently team meetings could be convened in the lecturer’s office.

Process

During the team meetings, the students in their groups:

• discussed their understanding of the scenario;
• shared their current knowledge and ideas on the topics involved;
• made decisions on how to address the scenario;
• identified what specific topics, or learning objectives, they needed to research in order to progress their enquiry;
• allocated who was going to investigate which topics;
• made arrangements for keeping in contact with each other between the scheduled facilitated sessions.

Between the team meetings the students would conduct their individual research on the topics allocated. The next team meeting would then begin with the students sharing the findings of their individual research with the group and discussing how their findings affect their perceptions of the scenario. Then the process of identifying learning outcomes and planning their group research was repeated and refined.

Facilitation

Two facilitators were present for these sessions. One facilitator was the lecturer, the other a non-specialist who also acted as a participant observer.

The lecturer began the team meetings with an outline of what he hoped they would achieve, outlining the process steps and types of decisions that should be made by the end of the meeting. This provided a clear sense of purpose and direction for the meeting, especially for groups that were more hesitant and uncertain about how to progress. During some parts of the meeting he absented himself from the room to allow less inhibited discussions, especially during the decision and allocation phases. At the close of the meeting he asked the group to summarise their decisions and intended directions of enquiry, providing feedback and encouragement. In the year when there were two groups this was a plenary session, allowing a cross-fertilisation of ideas between the groups.

Throughout the facilitation sessions, the lecturer was sensitive to the progress and coherence of the groups and provided appropriate levels of support and direction to ensure that the group progressed.

The non-expert facilitator adopted a less interventionist approach, observing and listening to the groups’ discussion and making infrequent suggestions when they were felt appropriate.

Assessment

The PBL was assessed solely through an individual 2500 to 3500 word report, based on the groups’ research. This being a substantial portion of a third-year module, the marking of a team product and mechanisms for assigning individual marks might have been contentious. The method chosen was seen as an appropriate low risk option for this level of course, where teamwork is not an explicit learning outcome.

Delivery

The PBL exercise was first delivered in the second semester of 2005-06 to 2 groups of 4 and 5 students. It was repeated in
the second semester of 2006-07 to a group of 10 students. Both cohorts contained a mixture of both home and foreign students. The apparent discrepancy in the group sizes will be explained below under Focus Groups and Observations.

EVALUATION OF THE PBL PROCESS

Methodology

An integrative evaluation [7] was conducted, drawing on questionnaires, assessment, participant observation, student focus groups and the reflections of staff, where the focus is on understanding the experience of the students engaged on the PBL exercise. The questionnaire data was collected for the first year cohort, observations and focus groups were conducted for both years of delivery.

Questionnaires

Given there were only a small number of students involved in this activity, these results should be taken as indicative only. Even substantive results may not be significant. However, the response rate is good (78%-89%), so the results can be taken as representative of these students.

The Study Process Questionnaire [8] measures the students’ approaches to learning, whether deep or surface. On average the cohort came out as having a Deep Learning Attitude of 31.4 and a Surface Learning Attitude of 22.0. This is not significantly different from other second and third year groups (F(3,62)=0.12, p=0.95 & F(3,62)=0.82, p=0.49).

Confidence Logs [7] measuring the students’ confidence on a five-point Likert scale against the intended learning outcomes for the PBL were collected pre and post the PBL exercise. The results are summarised in Table I. For all save the first learning outcome (image perception) there are increases in confidence. This first topic was discussed in the introductory lecture and notes, but did not form part of any conventional lectures.

The Perceptions to PBL questionnaire is a bespoke questionnaire generated for the IET PBL initiative, its results are summarised in Table III. From these results there is a very positive reaction to the PBL exercise, with the students: enjoying the exercise, wishing to learn this way again and general agreement to most of the statements, with the exception of mild disagreement to preferring to learn through conventional lectures.

Assessment

Comparing the results of the coursework assessment across the years (Table IV), including the year previous to the introduction of the PBL exercise, show consistent results for the two PBL years. However these appear to be substantively higher (9%) than the non-PBL coursework, however this is not statistically significant (p=0.09).

If this difference were to be substantiated, it could be that the additional support provided by the group meetings and the sharing of the research process amongst the team might be leading to an improved final report.

Comparing the paired coursework marks with the final examination marks for the 2005-06 cohort. These results are
summarised in Table V. There is a strong correlation (Pearson’s correlation coefficient \( r = 0.84, p=0.18, N=7 \)), this suggests that the assessment is ‘fair’, that is, the marks reflect ability. The average coursework mark is 5% lower than the exam mark, not statistically significant \( (p=0.17) \), this might suggest better performance in the exams and greater familiarity with this method of assessment.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004-05 – No PBL</td>
<td>57</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>2005-06 – PBL</td>
<td>65</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>2006-07 – PBL</td>
<td>67</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>All 3 Years</td>
<td>62</td>
<td>15</td>
<td>35</td>
</tr>
</tbody>
</table>

**TABLE V**

**PAIRED COMPARISON OF COURSEWORK AND EXAM MARKS FOR 2005-06**

<table>
<thead>
<tr>
<th>Assessment Component</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coursework</td>
<td>65</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Exam</td>
<td>70</td>
<td>15</td>
<td>7</td>
</tr>
</tbody>
</table>

Note: Summary for students with both a coursework and exam mark only

So far we have considered the assessment in terms of the marks that it has produced. The generally very high quality of the reports was reflected in the increased assessment marks. There is evidence in all the reports that the students have engaged in a process of research, have made appropriate selection of these findings and have demonstrated understanding of the display technologies and the demands of the market through reporting these in their own words.

What does differentiate the reports is not the underlying research or understanding of the devices, but the ability to integrate and synthesise this into a coherent report. The weaker reports show a less smooth integration of the ideas and an over-reliance on the words of the sources. An extreme example this year used substantial blocks of accredited text from source materials, the selection and structuring was appropriate but did not lead to a coherent report and missed an opportunity to demonstrate their own understanding of the subject.

**Focus Groups and Observations**

The participant observations and discussions from the focus groups will be combined here to form vignettes of the experiences of the three groups that engaged in the PBL exercise over its two years of delivery. It is interesting to reflect that all three groups were ostensibly provided with the same stimuli: scenario; facilitation and learning environment. However, factors both internal and external to the groups produce differing experiences. It seems to be an inevitable consequence of this more student-centred and collaborative approach to teaching and learning that these variations in experience will be more likely to occur. The group, its internal dynamics and ownership of the learning become a central part of the learning environment. The experiences of the group and its members also become more exposed.

**Group A, 2005-06**: This group of five students included a socially confident young man, who had been particularly impressed by the *learning pyramid* [10] (Figure 1), presented during the introduction to PBL briefing. Taking on board the point that the highest retention of knowledge came from teaching the subject and linking this with the sharing research findings stage of the PBL process, he concluded that to gain the most out of this exercise he should use this part of the meeting to ‘teach’ the other team members about his findings.

This helped him in his mastery of the material, helped the other team members in understanding his findings and also set the tone for the group meetings to be a lively sharing of ideas.

The experience of this was also shaped by some of the other members of the group. By chance, though possibly a consequence of this group being formed from the back of the class, this group had a higher proportion of ‘sporadic attenders’. It should be noted that their sporadic attendance continued throughout the taught part of the course, so was not a reflection of their attitude to PBL in particular. However, it was considered disruptive by the core active members of the group, especially near the end of the process when a group member who had been absent throughout most of the process reappeared and time was spent bringing her up-to-date.

This group, particularly the individual mentioned above, was very appreciative of this PBL experience and commended it as a way of learning. He would even select a module that used PBL over a conventionally taught module, if they were comparable in other ways.

**Group B 2005-06**: This group of 4 students, perhaps due to being formed from the front of the class, contained members who were more diligent in their attendance and engagement with the process. This group was made up, however, of more diffident students, who were perhaps less confident about sharing their ideas and contributing at length to a group discussion. Whereas in group A the primary mode of information sharing was through discussion, in this group information was shared principally through exchanging literature. This group created a website, where they posted documents and links to websites that they had found as a group resource. The process this group followed was to read and digest their shared findings prior to the meeting. In the meetings, any decisions would be made very quickly in a business-like, consensual manner, but with minimal discussion. They then found it difficult to use the rest of the
meeting constructively. The facilitator found it difficult to draw out any discussion or debate, since all the issues seemed to have already been agreed. The energy levels in these meetings were a lot lower than those of group A.

This group appreciated the intentions of the PBL exercise, especially the group work and collaborative aspects. Some of them had previously been out on placement and appreciated that the professional working environment consisted almost entirely of teamwork projects. However, they felt that this was really only a small ‘taste’ of PBL and thought that they would benefit from greater exposure to collaborative, team-based projects, citing the Embedded Systems Project, a team project that had recently been introduced into the second year as an example. This group, while supportive of the PBL exercise, felt that they had not introduced into the second year as an example. This group, while supportive of the PBL exercise, felt that they had not had sufficient opportunity to gain the required skills to be successful and felt dissatisfaction that they were not using their team meetings productively. This suggests that more different intervention from the facilitator would be beneficial to this group.

Group C 2006-07: If sporadic attendance was an issue for group A, it was more so for group C. With the exception of a few core group members, there seemed to be different students attending each meeting. New students were joining the group that it may not otherwise have access to. It should be considered that it may not otherwise have access to. It should be noted that the Chinese students in this group were frequent attendees and preferred to focus on the technical aspects taught in the lectures and tutorials.

Two Chinese students commented that they felt at a disadvantage in relation to report writing, due to their language skills, preferring the numerical aspects of the course. They did however feel that one of the things that they were able to contribute to the group was finding sources of information in Chinese and essentially translating it to the group. This may be a useful means of empowering foreign language students in group discussions more generally, suggesting that they may be able to share resources with the group that it may not otherwise have access to. It should be noted that the Chinese students in this group were frequent attendees and preferred to focus on the technical rather than market aspects of the enquiry.

DISCUSSION

On the whole this appears to be a successful implementation of PBL, well received by the students who have worked well to produce high quality reports. During the process a number of issues arose concerning PBL as practised in this context. These will now be discussed.

Students’ reactions to this style of learning are very different. Some students seem to take it very naturally. Others find it difficult to understand what is expected and how best to engage with the process. This can be seen in the different reactions to the process in groups above. This may be a result of the students’ preferred learning styles and their expectations of learning, based on their cultural backgrounds and educational experience. This also has an impact on the level of support and skills that the facilitators need to bring to the process.

It is perhaps naïve to expect students to spontaneously develop the requisite process skills by simply providing them with an opportunity to do a PBL exercise. Consideration is required of how to appropriately facilitate a group to develop these skills, without taking control of the process from the students.
In the lectured version of this course, the lecturer was able to cover a wider range of issues in the time. A consequence of moving to a PBL exercise has been to provide students the space to explore the topic more deeply at the expense of a narrowing of the topic.

It is of concern that during the PBL exercise and in their reports, the students avoided making numerical comparisons between specifications of the different technologies, falling back on vaguer more descriptive statements. When tables of comparisons were reported, they were frequently quoted completely from their sources. Considering the students’ discipline it is important that they are able to approach new knowledge and make quantitative comparisons. Emphasising this aspect will be a focus of future years.

One of the issues that it was anticipated that PBL would address was the motivation and engagement of the students. This was not the principal motivation for applying PBL in this particular context, but was considered to be a potentially beneficial ‘side-effect’ in the PBL project as a whole. The active nature of PBL, requiring that students engage in the process for there to be any learning at all, and the additional motivation from authentic problems suggest a priori that PBL would improve the students’ motivation.

Our experience here would suggest that, for the students already engaged and committed to the learning process, it did provide an engaging and rewarding learning experience. However, it did not seem to affect the attendance patterns of those less committed. It may be hoped that, for students whose engagement is in the balance, the PBL exercise would be an engaging influence; however, it is not clear if this occurred in this context.

There are a number of influences on attendance in this context: being at the beginning of an optional module, students are still deciding which modules to select; this is also a peak time for recruitment interviews; students faced with a coursework deadline may miss lectures to meet the deadline; and the learning culture of the cohort. It may be more productive to try to influence the learning culture earlier in students’ academic careers, before expectations are set that lectures are optional and notes can be picked up after the event.

The lower risk approach to assessment reduced dependence on the coherence of the group. In this context, this was an advantage. However, it could be argued that it avoids the issue and a more team-based product might increase commitment to the team, or at least bring this issue of team commitment to the forefront.

CONCLUSIONS

This paper describes the implementation of PBL, a form of EBL, into a third-year, Optoelectronics module.

The experiences and reactions of the three groups involved, captured through participant observation and focus groups, were presented, drawing out principal differences in their experiences.

A number of issues that arose from this experience were briefly discussed, including: the different reactions of the students to the PBL process; a reduction in the breadth of coverage; a tendency for students to avoid quantitative comparisons; and student motivation and attendance.

We would like to conclude that introducing EBL into this module was a very worthwhile activity, which does bring with it its own challenges and issues.

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