

Using Enquiry-Based Learning (EBL) to Prepare Students for Group Work: Lessons from successive implementations

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Abstract

This paper reports on three successive implementations of a second-year Enquiry-Based Learning (EBL) activity, run in the first semester, designed to prepare students for a group project in the second semester.

EBL is a student-centred, collaborative approach to learning, which allows the student to investigate discipline knowledge, whilst developing personal, professional and other transferable skills. It has been applied successfully in many contexts; there are many examples in the University of Manchester and this School. However, this example of EBL has received very mixed reactions from the students and staff, ranging from very enthusiastic to extremely negative. As a response to these reactions the EBL activity has been adapted in each of the three years of its delivery.

This paper describes the cycles of implementation, feedback and subsequent reimplementations, to understand the specific structural challenges to this particular example and also draw out some broader lessons concerning the development of EBL activities.

It draws on a variety of sources of information including direct observation, student evaluation through questionnaires and focus groups, and discussions with members of staff. An action research methodology is used, focusing and reflecting on students' perceptions of the activity gathered through critical incidents.

What emerges is the importance of: the students' perceptions of the activity; engaging and maintaining the students' motivation; and how embedded the activity is in the curriculum.

Introduction

A survey of employers, conducted by the Institution of Engineering and Technology (IET), highlighted a mismatch between the skills required by electronic engineers and the skills that graduates possessed. This finding is in line with those of similar studies and engineering educational reviews in both America and Australia (Mills and Treagust, 2003). These studies emphasise a lack of teamwork and communication skills. There has been debate about the most appropriate method of embedding these skills into the engineering curricula, whether Problem-Based Learning (PBL) or project-based learning approaches are more suitable (Perrenet *et al.*, 2000; Mills and

Treagust, 2003). This paper describes a development where these approaches are used to complement each other. PBL is used to provide a structured approach and framework to prepare students for project-based learning.

Background

This development takes place against a background of increased interest in Enquiry-Based Learning (EBL) of which PBL and project-based learning are examples (Kahn and O'Rourke, 2005).

The University of Manchester was awarded a CETL (Centre of Excellence in Teaching and Learning) by HEFCE (Higher Education Funding Council for England). CEEBL (Centre for Excellence in Enquiry-Based Learning, 2008) supports a number of projects across the University.

The University of Manchester has worked in collaboration with University College London and the University of Bristol on the implementation of PBL into electrical engineering degree programmes. In Manchester, PBL has been introduced into three the areas of VLSI design (Powell *et al.*, 2006b), Optoelectronics (Powell *et al.*, 2007a) and Robotics (Powell *et al.*, 2007b).

Rationale

To prepare students for a 10-credit team-project, the Embedded Systems Project (ESP), in the second semester of the second year (Barnes *et al.*, 2006), a team-based activity was accommodated into the first semester of the tutorial system (Powell *et al.*, 2006a). It provides an opportunity for students to develop and practise their teamwork, project and presentation skills in the supportive environment of the tutorial before employing them in the higher stakes environment of the team-project. It was anticipated that they would be able to engage with the team-project more effectively and earlier after this preparation. Consequently, this activity was modelled on the team-project, reflecting its subject matter and its assessment, but the level of activity was proportionately smaller.

During the first year of this activity, the delivery ran relatively smoothly eliciting positive feedback from staff and students. However, the decline in attendance and by implication in engagement became an increasing concern. This concern has driven a critical review of the activity and its development over subsequent years of its delivery. This paper describes *implementation* of and *feedback* from this activity over three *cycles of delivery* and then provides a summary of the *attendance*.

Methodology

An action research methodology (Zuber-Skerritt, 1992) is used, where the focus of the research is change made to a system. Through observing and reflecting on the effects of these changes, a better understanding of the system is gained.

Emphasis is on the qualitative sources of evidence, particularly observations, focus groups, student questionnaires, staff perspectives and the extreme cases, as in critical incident analysis:

- Different tutorial groups were observed at different stages of the project, providing cross-sectional and longitudinal perspectives.
- Four focus groups were held at different points during the first cycle. Voluntary focus groups are prone to attracting students motivated to have something to say about the activity, whether positive or negative. At the end of the third cycle, an impromptu focus group was conducted with a selected group, which was considered a more representative sample.
- An open, goal-free (Scriven, 1973) questionnaire was administered towards the end of each cycle. This solicited 34, 45 and 17 responses for the three cycles, representing 26%, 31% and 13% of the cohorts respectively.

- The opinions of the tutors were solicited through a review meeting after the first cycle and e-mail in all cycles.
- Critical incident analysis is a mode of reflection where unexpected reactions are used as the starting point of the enquiry (Cowan, 2004). Consequently, some of the evidence has arisen out of unanticipated situations. These situations and the views expressed may not necessarily be representative; however, they may be illuminative.

There is emphasis on the interpretive, particularly being sensitive to how students perceive the activity.

Table 1: Significant changes over cycles of delivery

Feature	Cycle 1	Cycle 2	Cycle 3
<i>Credit for Activity</i>	0	1	1
<i>Format</i>	5 linked problems	1 project	1 project
<i>Teamwork Workshop</i>	End of Semester	Beginning of Semester	None
<i>Ask the Consultant</i>	No	Yes	No
<i>Reflective Report</i>	No	Yes	No
<i>Timescale</i>	Weeks 1-12, Fortnightly	Weeks 1-12, Fortnightly	Weeks 3-8, Weekly
<i>Distribute Guides</i>	Yes	Yes	<i>Manchester Steps Only</i>
<i>Distribute Components</i>	Yes	Yes	No

Cycles of Delivery

This activity has been delivered over three years with slight modifications made each time in response to the feedback of staff and students from the previous delivery. By linking the delivery and feedback from different groups, issues that emerge in such a development will be drawn out.

The cohort sizes were equivalent:

- 2005-06: 131 students in 24 groups of 4-6;
- 2006-07: 145 students in 29 groups of 4-7;
- 2007-08: 130 students in 24 groups of 5-7.

The significant changes to the activity over the cycles of delivery are summarised in Table 1. The nature, motivation and consequences of these changes will be unpacked in the subsequent sections.

First Cycle (2005-06)

Implementation

Students were asked to design a sensor system, based on the microcontroller processor board that they would use in the team-project, to capture the temperature profile of a commercial decorative tile kiln. This was seen as a suitably authentic task that employed electronic engineering in the context of providing a service to another industrial process.

The project was broken down into five linked problems:

- 1) Design a Circuit: to interface a thermistor with their microcontroller board;
- 2) Choose a Sensor: to replace thermistor, which it was revealed would not measure the kiln temperatures required;
- 3) Plan a Project: to revise an existing plan to compensate for the slippage caused by the initial error in sensor selection;
- 4) Practical Implementation: of the circuit for the new temperature sensor;
- 5) Group Presentation: of the previous activity.

Problems were presented at the fortnightly tutorial, where the group reported the progress that they had made on the previous problem and planned how to address the new problem. The groups were expected to meet independently between tutorials. The transferable skills were supported by a series of lectures and student guides (Powell, 2006), covering teamwork, project planning, searching for information and group presentation. Student contribution was continuously assessed at the tutorials and the presentation was assessed, but the marks were used for formative purposes only.

Feedback

Positive

The activity challenged students ideas of where the responsibility for learning lay. For example, one student opined that:

I have learnt from the second year that if you want to learn something, then if you arrange some lecturers that explain it, for example ... then you have a better chance of understanding it.

It was evident that the shift from tutor-driven to student-driven activities was a significant transition. However, it is exactly this transition that the activity was providing students an opportunity to negotiate.

Some groups found it challenging:

We were up in arms, didn't have a clue what we were going to do, all stressing out and getting dead worried. We thought that we were never going to do this. But we persevered, we learnt about thermocouples, we learnt about thermistors and that and came up with a circuit we needed three weeks down the line ...

This was an exceptionally good group, but it does show the problem working well: triggering initial difficulties that the group can work through and transcend, ultimately exceeding expectations and growing in confidence from the experience.

Students and staff that engaged in the activity appreciated that it was good preparation for the team-project and that they were gaining appropriate skills from the activity:

*Yes, it did get us going to the library and things, even teamwork and things, getting us to meet and organise meetings was a good idea. ...
Doing the presentation did help me. I was the last to present in my group, but I do not think that I would have had the confidence to stand up in front of a room full of people if I had not had the practice in the first semester. It is a good idea.*

This was also evidenced by increases in the confidence logs for those skills and in student learning reported in the questionnaire.

Negative

The attendance for this activity was a concern. However, some tutors did reflect that it provided a sustained focus for the tutorial that it previously lacked and attendance had improved. Others reported that their groups felt embarrassed about not working on the project, so stopped attending.

Concern was expressed that, since the activity was not assessed, it was given lower priority than activities that did carry credit. For the same reason it was also difficult to engage teammates in the activity. Less motivated students, reportedly, found the activity 'easy to ignore'. There was strong demand for credit to be associated with the activity. One student explained:

Good idea, couple of marks to make it a bit more workable. Part of the ESP, you know that it is going to count towards the degree. It would be great if everyone realised that it was going to benefit you. Some people realised that and some people didn't. ... In some cases you just have to force students into something to get them to benefit. Sometimes students don't realise what is going to benefit them.

Some students felt that the hypothetical project planning exercise was too involved and too distant from their experience. They considered that a smaller plan based on their actual activities would be more beneficial.

Many of the team-working experiences were negative, perhaps not unsurprisingly given the poor engagement of their peers. One tutor quipped:
Some of them didn't seem to learn. They seem to go through first semester and have some bad team-working experiences. Then go on to the second semester and have some more.

It was considered that team working still required some attention.

A workshop was planned at the end of the semester, to provide students with an opportunity to reflect on their first semester's performance and plan for the second semester. This was so poorly attended that only one out of the three planned deliveries was made. It was well received by those present: the facilitator received a round of applause at the end. Students seemed unsure how this workshop fitted into the rest of their course, particularly as it was not on a technical topic. Being in the last week of the semester, many students were fatigued with the recent round of coursework and looking forward to their vacation.

Second Cycle (2006-07)

Implementation

One unit of credit from the team-project module was requisitioned for this activity to indicate that the School valued it.

To provide a more authentic project planning activity, the five problems were integrated into a single over-arching project with the initial misdirection removed. This allowed the students to plan their activities over the semester and manage that plan, moving the activity even closer to the form of the team-project.

The workshop planned at the end of the semester was moved to the beginning and more closely linked to the activity, providing an introduction to teamwork. A reflective report on the team-working aspect of the project, which became part of the assessment, was linked to the workshop.

To provide support for students who were finding the tasks too difficult, in a responsive manner compatible with EBL, *Ask the Consultant* sessions were held. Questions were solicited from the groups prior to the sessions via e-mail, which were addressed at the beginning of the session. Further questions were dealt with as they arose.

Feedback

The addition of credit seemed to have the desired effect: attendance improved; more groups completed the project and presented their work; reflective reports were written, some showing real insight and genuine reflection. The desired skills were being attained, as evidenced in statistically significant improvements in confidence and reported on the questionnaire. However, all was not well ...

Responses from a proportion of the questionnaires were surprisingly negative: some described it as *'useless, a complete waste of time'*. It seems that the additional credit did improve conformance to the activity, but it was reluctant conformance from some: *'worth just enough so that you can't ignore it'*. Part of the problem was *'there was a lot of work for very little credit'*. Many students readily articulated the relationship of 1 credit representing 10 hours work. The argument that the activity would enable them to perform better in the remaining 9 credits of the unit did not seem to be heeded.

Similar concerns about the level of credit were voiced by the tutors, for example: *... the students thought there was scant reward for the effort which can make it difficult to keep them engaged, ... However my group did an excellent job throughout, really worked well as a team and I was disappointed they couldn't get more reward for their efforts.*

A related problem was that deliverables clashed with other coursework at the end of the semester. This was seen as a distraction from their 'real' work, which carried more credit.

The workshop, despite having been successfully used in other parts of the University, engendered a negative response from a particularly vocal student. He considered that *'teamwork could not be theorised; they already knew how to work in teams and that anyone who did not was a lost cause and should not be at University'*. He thought that the School did not endorse the workshop, since a lecturer was present for only a portion of the time. In fact, the lecturer was moving between different parallel sessions and was very complimentary about them.

For a number of students, the workshop had started the semester on a wrong note and undermined their confidence in the tutorial system before it had begun. Part of the problem seemed to be that the range of students' experience was very broad: some from very traditionally delivered education and others with experience of running their own companies. The workshop was targeted at those new to teamwork and inevitably disenfranchised those with more experience.

The e-mail component of the *Ask the Consultant* sessions was more successful than the contact component. The majority of questions received concerned the problem specification. The nature of some of the questions suggested that some groups took the problem seriously and were developing sophisticated solutions. The e-mail interaction was valued by some groups and requested by some after the third cycle. Interaction in the lecture theatre was limited. Few students were willing to volunteer questions in an open forum. The rest of the session was given as an opportunity for group work. Most groups were content to work on the problem without additional input. However, some were not able to work, as there were not sufficient members of the group present. The sessions were also used to gain some impromptu evaluation of the groups' teamwork, technical and other progress.

Feedback indicated that all groups had made reasonable progress and some were engaged with the more difficult aspects of the problem. A few groups were experiencing some problems engaging all their team members. Two groups submitted damning critiques of the activity itself. These were followed up.

One group expressed their dislike of the teamwork workshop, described above. They also did not understand the value of the activity since *'little information was actually being taught'*. The teamwork component they found redundant, since there were other teamwork activities in the programme with substantially more technical contents and credit.

The other group seemed disenfranchised, because the project was not substantial enough. This was a particularly experienced group, one of whom had previously worked with thermocouples. They thought that authenticity of the problem was challenged, since in industry an off-the-shelf circuit would be used not one designed in-house, even though groups were free to follow either route. They identified a structural problem, that the *Ask the Consultant* activity, which ended up addressing questions about specification, was too late in the lifetime in the project. They also perceived the absence of the lecturer, who was unavoidably delayed, as a lack of endorsement by the School.

Some tutors were concerned that there was too much '*paperwork*', with evaluation questionnaires and student guides, focusing on '*soft-skills*', which '*students quickly consigned to the dustbin*'. Others were concerned about the lack of technical content and there was an equal spread of opinion about whether the problem was too hard, too easy or just right.

One component that had caused confusion over both the preceding cycles was part of the *practical implementation* phase. This was introduced to address some of the practical problems that students were having in the team-project. As a stimulus for discussion, electronic components and a circuit diagram for a sample operational amplifier circuit were issued. A sample circuit was used since there was no way of knowing the details of the circuits that students were designing. Tutors discussed the markings and placement of components in preparation for groups to plan the layout of their circuit on stripboard.

Many groups confused the circuits given with those they were designing. Some groups tried to reverse-engineer their circuits to fit the components provided. Other groups thought that their circuit '*had been rubbished*' and replaced by the sample circuit. Students perceived this activity as compromising the integrity of the project.

Third Cycle (2007-08) Implementation

The activity was compressed into weeks 3-8, to avoid clashing with other coursework deadlines and to provide a more concentrated activity. In response to the level of credit and some of the negative feedback the activity was stripped back to its essential components, dropping the workshop, *Ask the Consultant* sessions, reflective report and the distribution of components.

It was decided to issue only one of the guides at the beginning of the semester: the *Manchester Steps*, which takes the steps associated with PBL (Boud and Feletti, 1997) and fits them to the acronym of MANCHESTER (Allan and Powell, 2007). The other guides were still available on the School server for students to consult.

Feedback

All but one group engaged with the project and produced a solution and final presentation. This group simply did not engage with the activity despite the tutor's best efforts. These were '*weak*' students and the tutor identified

the real need here is to try to balance the strength of the tutorial groups from the first into the second year. ... Mixing and surrounding these weaker students with stronger ones could help motivate them to engage more fully with the project.

The response rate from the questionnaire was low, but responses were positive, showing the desired set of skills being gained. Comments included:
Overall good practice for next semester

Overall this was a great experience and was placed at a good time in the semester as it would really overcome my presentation weaknesses before more serious presentations such as for placement opportunities, and it has really helped in boosting my confidence.

Overall, an excellent exercise giving a good introduction to the team skills needed for the ESP project including experience of potential pitfalls and problems.

To triangulate these results with a more representative sample, an impromptu focus group was held at the beginning of a laboratory. Some students did not like the activity, desiring a more practical component. They also found it redundant, since there were other teamwork activities in the programme. However, others rearticulated the positive comments above and differentiated the activity from other teamwork tasks because it was more open, had a real-world aspect and a greater variety of different components for the group to engage in.

Further Cycles

The details of the next iteration are still under negotiation. It will be repeated in some form in the next academic year. One component that is likely to be implemented in future cycles is the incentive of a prize. A sponsor has been identified who will supply some hardware for the winning group. To implement this, a mechanism for unbiased judging of the solutions across all the groups is required. The addition of a short technical report would provide an objective point of reference for adjudication.

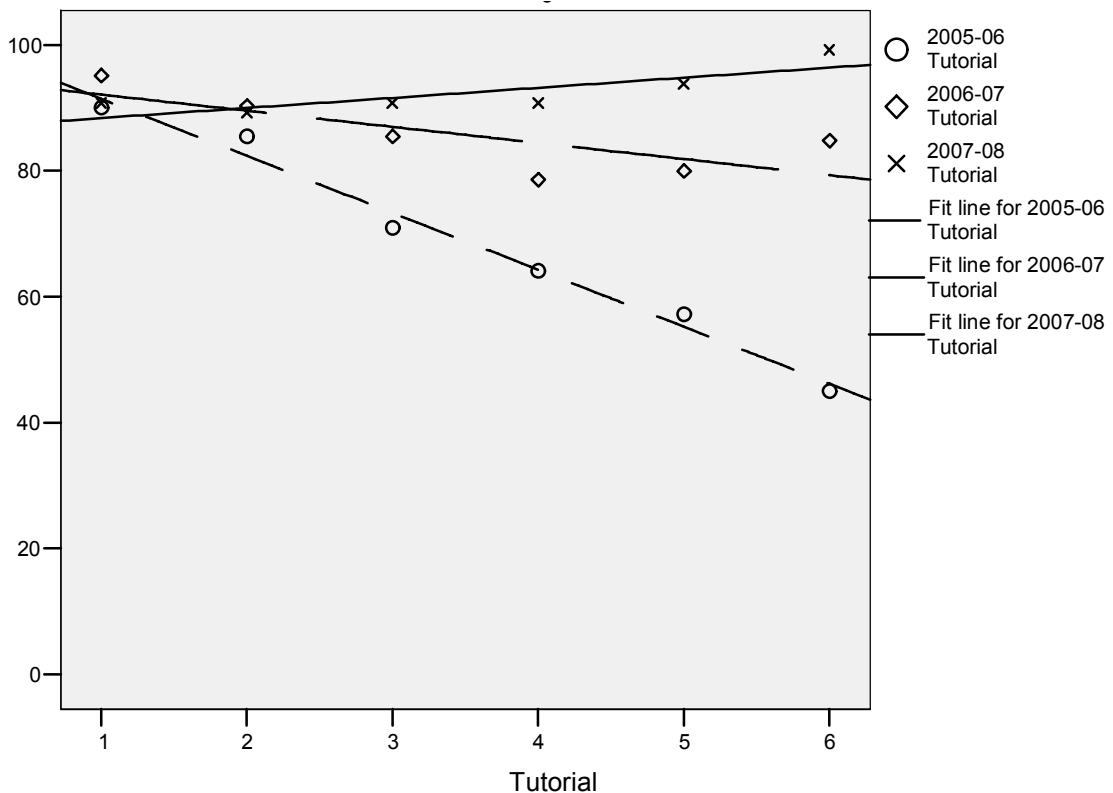


Figure 1: Attendance of Tutorials as Percentage of Cohort

Attendance

During the first cycle the level of attendance at the tutorials became an increasing concern and therefore a critical measure in future cycles. Whilst a crude measure of engagement, because students who are present are not necessarily engaged, it is a necessary pre-condition for engagement.

A summary of attendance at the tutorials over the three cycles is shown in Figure 1, below. The first cycle (2005-06) shows a significant ($p < 0.001$) linear decline in attendance over the activity of approximately 12 students a week. The second cycle (2006-07) shows a dip in attendance for tutorials 5 and 6, rather than a linear trend. The linear component shows a decline of approximately 4 students per tutorial. However, this is not significant ($p = 0.078$). The third cycle (2007-08) shows a significant ($p = 0.045$) increase in attendance of approximately 2 students per tutorial.

These results suggest that attendance and hence engagement with the activity have improved over the three cycles of delivery. This triangulates well with the other evidence suggesting that the students found the activity more engaging in the later implementations.

Discussion

The nature of this activity, inviting the whole cohort to engage in a project, makes it vulnerable to students who do not attend, or show low levels of commitment when they do attend. This affects the experience of the whole group. Whilst negative experiences can result in much learning about teamwork, it is not our intention to create a problematic team-working environment. Further, we intend that the benefits of engaging with a positive team-working experience are gained by the majority of the cohort. Also there is a danger that students who did not engage with this preparatory exercise may conclude that they need not engage in the main team-project.

For these reasons it is important that the activity is designed in a way that involves the majority of students. This can be done by appealing to students' intrinsic motivations, such as natural interest in the subject or belief that engaging in the activity itself will benefit them. There are extrinsic motivations that can be used, such as rewarding the activity with credit or offering a prize to the best solution. The introduction of extrinsic rewards can have a negative impact on the intrinsic motivation (Deci *et al.*, 2001) and this effect may have been part of the negative reaction experienced in the second cycle.

This activity does contain a level of intrinsic motivation. Some tutorial groups found that the scenario was interesting and did engage with the activity during the first year of its delivery. However, this intrinsic motivation was not sufficient to encourage the majority of students to engage with the activity to completion as it was implemented in the first cycle. Since for the activity to be successful there needs to be engagement from the whole cohort, more extrinsic motivations are required despite the acknowledged negative impact on intrinsic motivation.

The inclusion of credit in second cycle was partially successful, in that it changed the activity from being '*easy to ignore*' to being '*hard to ignore*'. However, it emphasised structural problems with the activity and consequently engendered resentment:

- it was a small activity stretched over an entire semester, meaning that students engaged with it infrequently and at a low level;
- the level of activity did not match the credit award. Our students are conscious that 1 credit represents 10 hours of input and this activity exceeded this;
- the presentation and report coming at the end of the semester clashed with a series of other coursework deadlines.
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Stripping back the activity and condensing it into the first part of the semester do seem to have mitigated some of these problems.

There are a number of ways that indicate how embedded an activity is in the curriculum. Credit is an obvious one. Other ways are having a regular timetabled slot, involvement of members of staff, and association with other modules. Some students seemed sensitive to the level of endorsement that the School placed on activities. The absence of a lecturer was interpreted as a lack of endorsement.

Conclusions

The success of new activity is dependent on: the perceptions the students have of that activity; students' intrinsic and extrinsic motivation to engage in that activity; and, related to this, how well the activity is embedded in the surrounding curriculum.

The activity described did achieve a measure of success, as evidenced by the comments of some of the staff and students that have engaged with the activity and the increased level of attendance.

Further Work

This paper has focused on the delivery, and student perceptions and experiences during the activity. Another aspect, which has not been covered in this paper, is whether or not the activity actually achieves its objective, i.e. preparing students for the team-project in the second semester. This will be the focus of a future paper.

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