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Introducing PBL into Civil and Structural Engineering

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Abstract
The benefits of problem based learning for students are a deeper understanding of lecture material, and the development of problem solving and collaboration skills which will greatly enhance their educational experience. This approach has been successful in other programmes as it departs from the traditional '*what I am told I need to know*' to '*what I need to know to solve the problem*' promoting self-directed learning. Lecturers in turn transition from the giver of information to the facilitator of learning through support, guidance and monitoring. This project introduced an active learning element into two concrete technology modules by replacing traditional laboratory exercises with a project requiring students to design, test and report on a series of concrete mixes and aggregate samples in the context of a real life assignment. Previously, the details to conduct the laboratory were provided to the students. This project, carried out in groups, required students to apply the theoretical knowledge from lectures thereby increasing their understanding of the material, developing their learning and teamwork skills and appreciating the context in which engineers work.

Keywords: Problem-based learning; research; activity; graduate attributes

Introduction

First introduced in the 1960s, Problem Based Learning (PBL) is an established pedagogy that involves learning through activity. Typically, a problem is introduced early in the semester which provides the context and motivation for the student's learning. PBL has been shown to provide a deeper understanding of lecture material by students while promoting problem solving and improving collaboration skills. Lecturers move from the giver of information to the facilitator of learning with a polar shift in students attitude where the traditional '*I am told what I have to do*' changes to '*what do I do to solve the problem'*. This in turn promotes self-directed learning, a lifelong skill in itself. Several studies have been carried out using PBL in a civil engineering context and results have indicated success in increasing the technical knowledge of lecture material. Results have also demonstrated increased engagement from students and evidence of critical thinking and deeper learning.

Here, a PBL project was carried out as part of two second year concrete technology modules in an ordinary (DT004/2) and Honours (DT024/2) degree programme. While the project concluded that PBL was effective in encouraging deep learning of the subject it also provided an insight into potential problems for the students in terms of adjusting to this new way of learning. It also notes the difficulty in scheduling sufficient time for students to prepare for and carry out the laboratory testing. The importance of smaller group sizes and using an appropriate marking scheme to assess the whole process are also highlighted.

A review of graduate attributes following the exercise was also undertaken. Graduate attributes include soft, key, employability, generic, non-technical and transferable skills. [2-3, 5-19] and are often interchanged. The Institute of Engineers of Ireland (IEI) regard graduate attributes to include the ability to

> extract, through literature search or experiment, information pertinent to an unfamiliar problem that is within the current boundaries of the field; design and conduct experiments and, under guidance in a peer or team relationship, to analyse and interpret data; write technical papers and reports, and synthesise their own and their team's work in abstracts and executive summaries.
>
> (Engineers Ireland 2015: 16)

These attributes have been developed in consultation with employers and should also form the backbone of engineering education. The results show, following surveys, that students felt these attributes did improve during this project.

Project Outline

Current third year students from the DT004/3 and DT024/3 who had previously completed the laboratory element of the two modules in their 2nd year participated in a focus group where a questionnaire was presented and completed. Students were encouraged to reflect on what they enjoyed within the laboratory sessions and asked if they felt the proposal would be of interest and/or benefit. The main outcomes of the two focus group sessions showed that:

- students enjoyed the practical aspect of the laboratory;
- individual reports for each experiment were repetitive and unnecessary with group work preferred;
- the need for peer assessment was highlighted to ensure marks were attributed fairly amongst the group;
- an example of a professional report would be of benefit;
- there was disagreement on the attitude towards independent research with students still preferring detailed instructions;
- the introduction of a real life scenario would help bridge the gap between theory and practice;
- several students thought PBL would involve more work on their part.

The results from the focus group were used to design the intervention, particularly in relation to the extent of background information provided and the marking scheme.

Design of the Intervention

The PBL approach was implemented into the two modules, one in each semester, over a 12 week period. The DT004 and DT024 class had 30 and 16 students respectively and split into groups. The DT024 class were split into four groups of four. However, due to timetabling issues, the DT004 class were split into three groups of ten. Each group was given their assignment in week 1 with different criteria for the concrete mix design.

Students were presented with two scenarios to mimic tasks comparable to those they may attempt in employment as a graduate engineer.

Scenario One:

'A new quarry has just opened near to the location of a proposed motorway project. Your employer has been engaged to assess the quality of the aggregates contained within. You will be supplied with a sample of aggregate from the quarry and the following tests should be carried out in accordance with appropriate standards:

- Specific gravity;
- Particle size distribution of the quarries fine (<5mm) and coarse aggregate;
- Flakiness index;
- Elongation index.

Structural properties should also be assessed, namely the:

- Aggregate impact value;
- Aggregate crushing value;
- 10% fines'.

Scenario Two:

'Your employer has been engaged as the structural design engineer for a new concrete multi-storey car-park. Your concrete mix design (using justified assumptions) should satisfy the recommendations in EN206 and BS 8500 for concrete in a car-park environment. To provide confidence, the unreinforced compressive and tensile strengths should be determined using at least two methods and the results compared. The results from the compressive strength results should be assessed using an appropriate method to determine if the concrete is acceptable. All tests should be carried out in accordance with appropriate standards to satisfy the following criteria:

- Cube compressive strength;
- Flexural strength;
- Slump test;
- Compaction factor;
- Ultrasonic Pulse Velocity;
- Schmidt hammer strength;
- Indirect flexural strength'

Students were provided with material during lectures preceding the laboratory on the types of tests that can be carried out on aggregate samples and hardened concrete, but the specific details of each test were not covered. Students were also given an example of how a concrete mix design was carried out.

The work consisted of three laboratory sessions per group. Students in each group were expected to come to the laboratory session prepared with detailed information on how to carry out the tests in accordance with relevant national standards and present to the lecturer. The aggregate tests were completed first and the results were used as inputs for the concrete mix design. Students designed, cast and made samples for testing in the next session.

During this time, the tutors in the laboratory provided guidance but re-asserted that the research and preparation for the laboratory tests needed to be completed by the students themselves. Students were asked to keep a blog of their experiences of the laboratory session on Webcourses which provided good feedback for making changes to the second cycle of this project.

The culmination of the project was the production of a professional report and a presentation to the class and tutors on the methodology of the testing regime, but most importantly the reasoning behind the group's decision on whether to accept the aggregate supply or the concrete mix. This closely mirrors what a graduate engineer would be expected to do in a design office; research the task, make an assessment and decision and provide backup evidence on whether a supplier product is acceptable or not. Both scenarios were presented in one final report at the end of the semester.

Data collection

Before the exercise started, students were surveyed to determine their perception of particular skills and abilities on a scale of 1-10 under the headings below. With the exception of technical knowledge, are desirable as graduates attributes identified in the literature:

- Technical knowledge of concrete
- Independent research
- Teamwork
- Time management
- Self-directed learning
- Team communication
- Problem solving
- Report writing
- Presentations
- Self–confidence
- Pro-activeness
- Innovation

- Articulation
- Personal effectiveness

The survey was re-taken by the students after the laboratories and the data used to assess the improvement in the range of skills outlined above.

Findings

The findings from the two surveys before and after the project are reflected in two spider diagrams.

Figures 4.1 and 4.2 show the results from the Level 8 Honours degree class (DT024/2). As may be seen, all areas do show an improvement in ability but the extent of which are minor with the highest improvement in personal effectiveness. While these results are disappointing, this exercise was undertaken as a trial in Semester 1 so the findings could be reflected upon and fully implemented into DT004/2 in Semester 2. Feedback from the blogs confirmed that this was the first opportunity the students had had to carry out independent research. As second year students, this is perhaps a little unsurprising but highlights the importance of providing opportunities to develop these skills in the first year programme design. An increase in their ability to carry out independent research has also been identified as a benefit of PBL which noted an increase in both research and reading outside of the course.

Personal effectiveness and proactivity also shows an increase. This data is also backed up by one on one discussion's with the students and blog responses. The students felt that the group size of four was optimal as everyone was expected to contribute and they enjoyed the practical aspect of the laboratory sessions. Students were also asked to peer-review each other as part of the marking scheme and these results also show evidence that, in general, team members contributed equally. It is well known that students do not always engage in an honest appraisal of each other's work, but it was observed that peer assessment was closely aligned with the activity of particular group members. This is perhaps due to the overall mark for the laboratory part of the module worth only 20% and did not contribute towards a final year mark. The issue of grading is a recurring problem identified previously but has not been raised as an issue by students within this study.

The aim of the project was to identify areas where this approach did not enhance development of graduate attributes. The results show no particular areas where this is true. Students also noted in blogs that they felt they had run out of time as the reports and presentations were due on the last week of the semester, clashing with other deadlines. There was a very poor standard of presentations from all groups. They did not come well prepared and were significantly lacking in presentation skills.

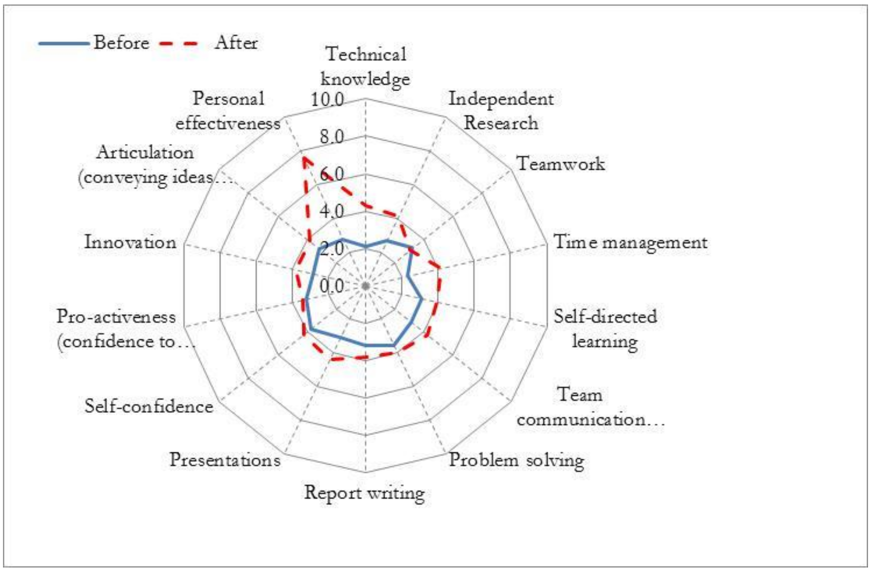

Figure 4.1: DT024/2 Spider diagram of graduate attributes before and after

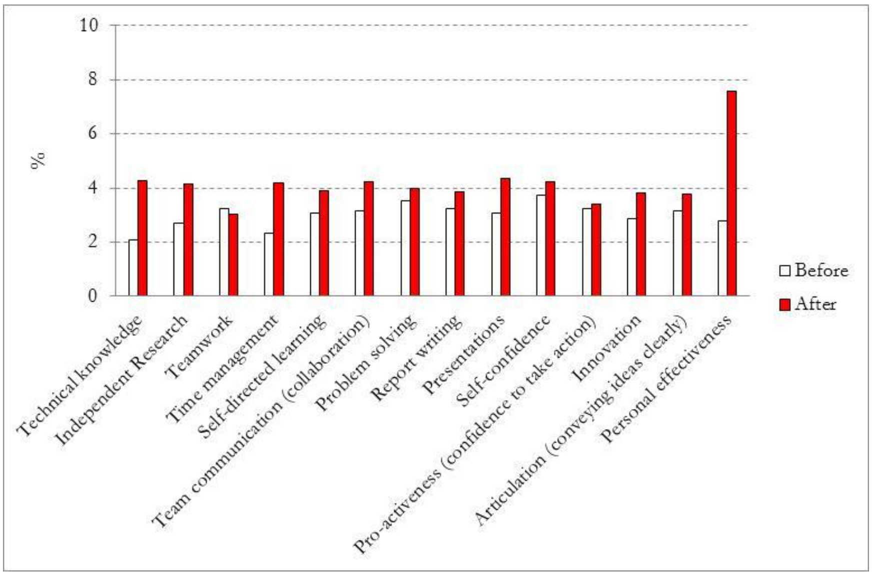

Figure 4.2: DT024/2 Improvements in graduate attributes before and after

Figures 4.3 and 4.4 show the improvements in graduate attributes before and after the exercise was introduced into the DT004/2 class. As shown, there is significant improvement in students' perceptions of these abilities in all areas. The best improvement is in technical knowledge of concrete which is particularly pleasing and demonstrates that PBL was effective in improving concrete technology understanding from lectures.

From a purely academic point of view, it is pleasing to observe the largest increase in student abilities was in their technical knowledge of concrete technology. The results show an increase in students' attributes in all areas and more so than for the DT024 class. This is due to the feedback received from DT024 following the trial implemented for DT004. Issues highlighted in terms of better referencing supplied to students, more in-depth presentations by the lecturer of what was required and strict adherence to having material ready before the laboratory began.

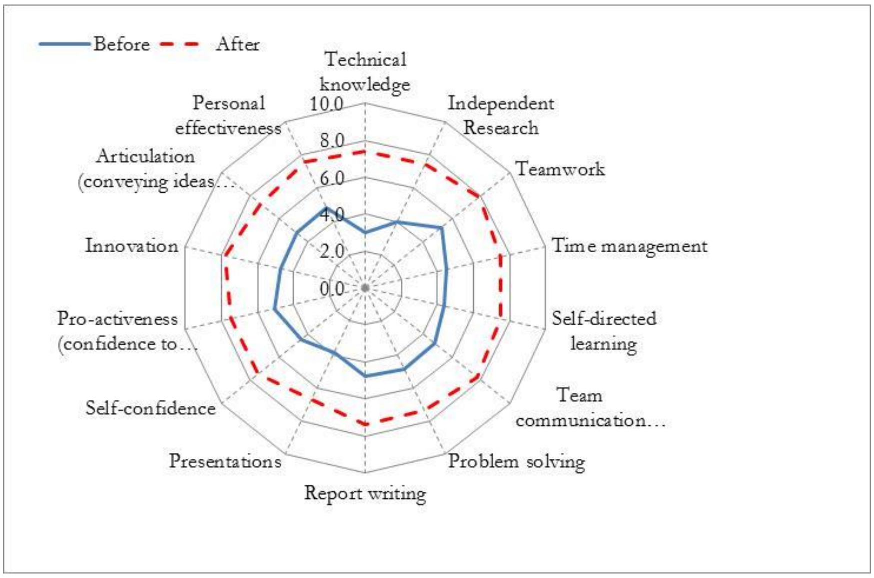

Figure 4.3: DT004/2 Spider diagram of graduate attributes before and after

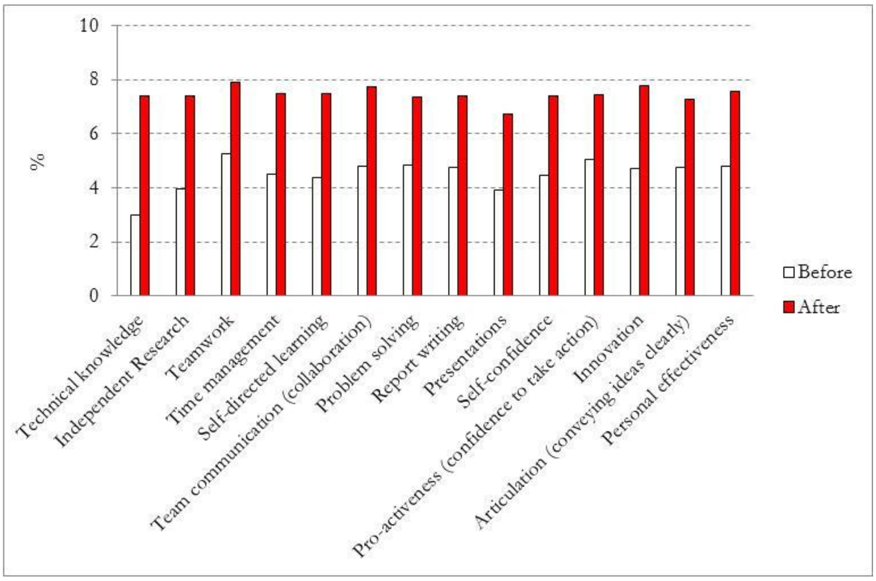

Figure 4.4: DT004/2 Improvements in graduate attributes before and after

Evaluation and Conclusions

Overall, this first attempt to introduce PBL formally into two undergraduate programmes was well received by the students involved. They enjoyed the activity, the practical aspect of the tests and the fact that it was their designed concrete mix they were testing, not just some pre-determined recipe. Several students noted the obvious link between theory and practice.

It is clear that PBL is an effective teaching pedagogy to enhance deep learning of a subject, but unless the PBL project is designed with specific graduate attributes in mind, it can be lack opportunities to develop deep learning including soft skills such as time management and report writing.

This was the first cycle of this project and changes will be made to further cycles in line with the recommendations. This is with a view to creating a PBL project which is focussed on proving opportunities for students to develop graduate attributes. It is intended that a longitudinal study is carried out to enhance this module over the course of several years.

Recommendations to DIT

Below are the recommendations from this work.

- Groups should be asked to provide a five minute presentation at the beginning of each laboratory session identifying the research they have carried out beforehand. This will aid their presentation skills while enforcing the requirement to come prepared.
- A basic reading list should be provided to assist students in finding relevant information both for the testing regime but more importantly for the discussion of results.
- Students should be required to attend a library information session to assist in their independent learning.
- The project should be split into two, with each scenario requiring a separate report and presentation. Whilst this may result in more work for the students, feedback has suggested that this would help significantly with time management. It would also allow the tutors an opportunity to give feedback on report layout and presentation style half way through the semester.
- Groups should be required to produce a Gantt Chart at the start of the project, identifying each task and the deadline for each group member to have completed his/her task. This will expose students to aspects of forward planning, programming and project management.

Future work

The authors are working within their School to formally implement PBL activities in undergraduate and postgraduate programmes. It is hoped, following consultation with colleagues that it be introduced into two modules per semester.

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