USING PROJECTS INSTEAD OF PRACS FOR HANDS ON LEARNING

Geoff Walker

School of Computer Science and Electrical Engineering
University of Queensland

Abstract

In 1999, power electronics laboratory practicals were isolated two-hour sessions with only nominal assessment. Students were unmotivated, and didn't prepare for or subsequently review these sessions. The pracs were rushed, and students' actions task oriented. Learning was shallow at best. In 2000, the practical component was changed to two projects, each spanning four weeks. The projects were larger, linked, real world problems, tackled by groups of three students. Assessment was via individual workbooks kept during the project, a group demonstration of the working project by all members, and a subsequent written report. These projects were highly successful in motivating the students, and achieved the transfer of the theory presented in lectures into personal practical understanding of that material. These outcomes were judged by observations of the class, project and exam marks, and responses to a questionnaire given at the conclusion of the semester.

1. A PROBLEM WITH PRACTICALS

In 1999, the power electronics subject at The University of Queensland included five self-contained two-hour pracs, one per fortnight. The prac topics were aligned to the material presented in the lectures for that fortnight. Students worked in pairs.

The pracs were focused on observing in practice the theory presented in lectures. The short, self-contained format dictated that each prac was a set of specific tasks designed to reinforce a single concept. Students found this an unmotivating "academic" experience.

Further, the set-up and tidy-up time in the prac environment was a significant fraction of the two hour period. There was no scope for faulty equipment, unfamiliarity with equipment, lack of preparation, lack of understanding, or disorganisation of any kind.

Assessment was qualitative rather than quantitative, with marks being assigned for "Attendance, Ability and Attitude". Most students found getting the full 4 marks for 4 percent easy. Many students showed very poor preparation and limited enthusiasm as a result of the nominal rather than rigorous assessment.

Together, these problems compounded. Pracs became short, isolated sessions in the laboratory. Poor preparation and accountability through nominal assessment had additionally unmotivated students. Pracs were not helping students learn.

The educational intervention, designed to address these problems, was to base the practical component of the subject around projects. The contact time was still a two-hour session in the electronics laboratory. However, a number of these sessions were grouped together over a several weeks to form a project.

This work was undertaken as an action-learning project for the Graduate Certificate in Education Course (GCEd), undertaken by the author in 2000. This paper is a summary of the final report for this course [6]. It describes the process and outcomes of replacing short pracs with longer projects for the laboratory component of the power electronics subject.

2. LITERATURE REVIEW

2.1 Problem Based Learning

An excellent paper offering an introduction to the concept of student centred learning is "What the Student Does: teaching for enhanced learning" [2]. John Biggs offers two examples of students at different ends of the learning scale. Susan spontaneously adopts a deep approach to learning, since she is bright and motivated. Robert adopts a shallow learning approach, desiring only to expend sufficient effort to pass. Biggs emphasizes that their respective approaches are choices they adopt, and not innate to whom they are. Robert can be encouraged to change his style of learning to be closer to that of Susan by the use of different methods of teaching.

Traditional transmissive teaching techniques allow students like Robert to be passive, or unengaged, in their learning. Susan is active or engaged of her own choice, despite the teaching technique used. Using an active teaching method forces Robert to be involved or engaged in the subject matter.

Biggs argues that successful learning is a result of what the students do. The task of teaching is to organise student-learning activities that promote understanding of the material. Learning outcomes are measured not in terms of knowledge gained, but rather understanding demonstrated.

The objective should be to solve problems that will be met in the student's subsequent professional career; the assessment is the success of their solution. By careful selection of problems (projects), all the important material as well as its application will be covered.

This paper suggests the practical component of the power electronics subject should be reformatted to address real world problems. The technical content of the problem should align with material presented in lectures and tutorials. Assessment should be criteria based, focusing on demonstrated understanding of the material.

Abernethy, Dalmau et al. [1] discuss the re-creation of a first level subject as a deep-learning environment using problem-based learning. Prior to the changes, students were noted to exit a university with only surface-learning strategies, hence poor problem solving abilities, and "an inability to reconcile theory and practice".

According to Gibbs [3] to whom these authors refer, deep learning is occurring (note active, present tense) when students can show their understanding of material by being able to verbally explain that material, generate questions and answers, and solve problems using that material. Deep learning requires the student to have intrinsic motivation, and use appropriate learning techniques. For this subject, the team identified three demands which when placed on a learner would precipitate deep learning:

- Integrate (bring together) and reflect upon knowledge, skills and experiences as they are brought to bear on an issue or problem.
- Use a variety of perspectives when viewing an issue or problem
- Effectively communicate their response to an issue or problem using a combination of spoken, written or physical actions.

The first two action points can be encouraged in my students when they undertake pracs by choosing a real world problem of significant size and depth so as to be challenging and motivational rather than trivial. It will be important not to solve the problem for the students, but rather to leave the problem "open" for a number of weeks. Enacting the third point will depend on a mixture of modes of assessment of the practicals backed up by descriptive criteria.

Student motivation to apply a deep learning strategy is also clearly important [1]. The student's choice of learning strategy is driven by a number of factors, and can be changed. Three motivations targeted by the subject creators were an appeal to a conscious decision ("deep learning is very beneficial – you should adopt it"), contingency (assessment favours those who adopt a deep learning approach) and a longer term approach of giving the subject a reputation of excellence ("this subject is excellent – you'll enjoy every aspect of it – including the way it is taught and assessed").

Reeves and Laffey [5] also describe the design and evaluation of a new introductory engineering subject introduced to replace a traditional first year subject. The new subject used problem based learning to teach higher order engineering problem solving skills such as problem specification, communication techniques, creativity, and conceptualisation.

Assessment was a critical element in the subject redesign, because the institution (a military academy) relied heavily on GPA (i.e. cumulative course marks) for student awards and privileges.

The original subject was a traditional knowledge and process-based course with specific curricula. Such a course can be assessed by an appropriate exam to generate a well-defined normal spread of marks, with fine granularity. Although these marks may not actually show any correlation to student understanding, everyone (staff and students) is comfortable.

In contrast, the marks generated by criterion referenced assessment in a course with general rather than specific goals are better presented in the form of the occupancy of a band (strata) of competence, and marks will usually be far less spread. While this approach will say more about the students' actual learning outcome and techniques used, to the outside observer, it may appear to require more effort and produce a less satisfying result – if the result desired is a nicely spread normal distribution.

The new subject used criterion-based assessment. In the end of semester review, this new assessment was the greatest single source of dissatisfaction for both students and academics. Despite this, an evaluation taken both before and after the subject by participants of both the old and new subjects showed that only the graduates of the new subject had significantly improved in the key area of higher order problem solving.

David Kolb [4] defines the process of experiential learning, based on the work of three famous researchers in this area, Lewin, Dewey and Piaget.

Kolb summarizes his perspective on experiential learning with the following three propositions that I quote verbatim:

- Learning is best conceived as a process, not in terms of outcomes.
- Learning is a continuous process grounded in experience.
- The process of learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world.

2.2 In conclusion

Our traditional modes of education can view the process of learning as merely transferring knowledge for later recall using, for example, lectures and examinations. This transmissive mode of teaching does not necessarily demand the involvement of students, which leads to shallow learning and a lack of true understanding. Even if the learner does seek to understand the material, this process of learning most realistically occurs during revision for the examination, and not at either the lecture or the examination. This opportunity for deep learning occurs under unfavourable conditions: the student is forced to seek comprehension in an abstract world of concepts, under stressful conditions, and often without the presence of lecturers or tutors, or other forms of feedback to measure their success.

The use of projects should address many of these problems. Learning should occur during several unstressed sessions in the guiding and challenging presence of mentors and peers. Problems can be set in the physical world and be naturally motivating. Each problem can run over a number of weeks, with opportunities for reflection, and more than one project used, allowing for at least one major “forced” reflective period.

3. PROJECT DESIGN

To ensure the projects were as effective as possible, considerable thought was given to their design and implementation.

3.1 Project Size

Three four-week projects were planned for twelve useful teaching weeks in the semester. Due to external pressures on both students and staff, the third project was subsequently dropped.

Because of the nature of projects, a minimum amount of time was required to allow them to function as hoped. At the beginning, time was required for defining the nature, scope and goals of the specific project topic. For pedagogical and practical reasons, these issues were discussed and negotiated with the class. There was also some teaching at the outset to establish the connection of the project to the subject content. I also desired the students to undertake some research into their approach to the problem to allow creativity and ownership.

Sufficient time was required at the conclusion of the project for presentation and marking. In fact, these aspects proved to be a substantial workload for both staff and students and three projects would have represented too great a burden.

A single large project spanning all lecture content was not chosen for several reasons. The links between lecture content become hard to draw and maintain. Students can become overwhelmed with the magnitude of the task, and might be required to draw more heavily on project management skills that are not the focus of this subject. They are likely to procrastinate without intermediate checkpoints, and don’t receive the feedback these would provide. Further, assessment becomes a large task all at the end of semester.

3.2 Project format

Each project consisted of four, weekly, two-hour laboratory sessions. Linking these was a weekly one-hour tutorial specifically for the discussion of the lab work between the students themselves, the lecturer and tutor. In the first week, the problem was outlined, along with a suggested course of investigation, and a number of expected learning outcomes. After this, as lecturer I attempted to minimise my interference in the solving of the problem by the groups.

3.3 Project topics

The three projects were based around fitting a bright headlight and electric motor to a scooter.

1. A mains powered battery charger.
2. A power electronic converter to best match the battery to the headlight.
3. A power electronic converter to drive the motor that will be installed in the rear wheel of the scooter. (Not undertaken)

These projects were linked together by a common, real world problem or task. Each of the tasks was increasingly complex, and matched the progression of material presented in the lectures. The detailed descriptions of the current year’s projects can be found on the subject webpage [7].

3.4 Project teams

Students worked in self-assigned groups of three. This allowed a distribution of the workload, a mixture of past experience and skills, and the opportunity to share ideas and work creatively and critically. Individual assessment components were used to force equal load sharing to some degree.

3.5 Project Assessment

Assessment occurred in the final week of each project. It included both individual and group assessable components to help ensure even participation by group members.

Assessment via different modes of delivery was used to achieve a greater likelihood of deep learning on the part of the learner, and better evaluation of depth of understanding by the assessor. Presenting in different ways hopefully stimulated students who learn using senses other than the written (visual) medium.

The assessment included three modes of presentation:

- A physical artefact (the product)
- An oral presentation (demonstration / defence).
- A written report (the detailed design and evaluation of the project).

Additionally, each student's workbook was marked with emphasis on regular, thoughtful entries that demonstrated thinking and learning, rather than strictly correct entries.

The oral presentations were performed as a group at the time of the product demonstration. Individual members explained different aspects of the project and answered questions independently for separate oral marks. The written reports were submitted either individually or as a larger joint report by the team.

Assessing a significant body of work rather than a superficial examination of a small amount each week allowed a more accurate final picture of student success. The students prepared well, and took the assessment seriously, unlike the previous year.

The overall assessment of the Power Electronics subject in 2000 was as follows:

- Projects 15% each, × 2 = 30%
- Tutorials 6.7% each, × 3 = 20%
- Mid Semester Exam 20%
- End of Semester Exam 30%

4. EVALUATION

4.1 Project Marks and Exam Marks

The projects were marked against criteria which value understanding. Thus the marks students received for the projects were a reflection of their understanding of the material covered by the projects. Most students did well, and in this sense the projects were a success.

Further, since the exams were written to primarily examine deep learning, the effectiveness of the projects in enhancing deep learning should also be evident in the exam marks. In the complete report prepared for the GCEd, an attempt was made to evaluate the effectiveness of projects by their effect on the students' marks. However, without statistical techniques such as a control group, it is very difficult to justify that such an improvement is a direct result of the projects. A much better source of validation is feedback directly from the students.

4.2 Student Questionnaire

An email questionnaire with several open-ended questions was emailed to the whole class directly following the final exam. Despite the lateness of the questionnaire, the response was excellent. Slightly over half the class (16 from 29) replied. Students took the questionnaire seriously, investing both time and thought in their replies.

A copy of the email questionnaire and collated responses is in the complete GCEd report [6]. A summary of the key findings of the questionnaire follows under subheadings that reflect the questions.

4.2.1 Overall response – are Projects better than Pracs?

The first question asked, *"Do you prefer the use of projects to pracs? Why / Why not?"*

Most students responded with a clear yes, with a couple offering an enthusiastic *"Definitely!"* and *"Absolutely."* Generally each student offered a number of reasons, and often a common reason was given by a number of students. It is exciting that these reasons invariably align with the pedagogical goals that were fundamental to initiating the intervention. Equally exciting is that often the students had the maturity to consciously recognise these underlying pedagogical drivers and also had the correct attitudes and motivation and so supported them.

In summary, students reported that …

- Project work caused thinking, and students were compelled to understand to complete the task.
- Projects helped them see the interconnectedness of knowledge
- Projects turn theory into practice, and they gained personal practical knowledge.
- Larger problems (such as projects) better reflect real-life situations they will encounter.
- They had been given the goal, but not the process. They were in part responsible for the process of achieving the goal, that is, the problem was a design activity.

- The problem was not neatly specified. There were many possible solutions, and this encouraged creativity and self-expression.
- Projects were fun, interesting, and involving.
- They were time consuming, but this time commitment was more flexible.
- There was a compulsion to get it to work, both intrinsic and extrinsic.
- The use of projects enhanced lecture material, and allowed students to interact better with the lecturer. In short, it was a better learning environment

One student stated *"I have no preferences otherwise it would be no"*. This student indicated that the project approach was a bit too daunting for him and he felt out of his depth. Two other students also offered some negative reactions to the projects:

- Projects were too unstructured, and students had to work out the learning goals for themselves.
- They were more time consuming than pracs.
- Assessment was not well defined.

When asked to rate the use of projects on a scale of 1-7, most students gave them a 6, with some 5's and 7's. The most critical respondent gave 4.5, *"mainly due to the projects being too open ended, and the assessment […] not being tightly defined. The concept is very good, though."*

4.2.2 Project length, complexity and design freedom.

The majority of respondents were happy with the number and length of the projects. Five students felt that two longer projects would have been better, but one student warned *"Projects that drag on too long result in reduced interest from participants"*. Two students also noted that more time should be allocated for later projects as their complexity increases.

Students again realised that the complexity of the projects was a vital key in making them useful learning tools – *"I think they certainly help in understanding the lectures better"*, *"[The difficulty of the projects]…made me realise I have to certainly understand the theory before you can make something work"*, *"It is what would be expected in the real world"*.

The best student suggested *"If three projects were to be completed, they would definitely need to be a bit easier, which would ultimately make them less satisfying. I'd go for two projects and make them a bit harder instead"*.

Only one student found the projects were too complex. Most students felt the complexity was about right, but many did suggest more guidance or direction early in the project would help.

When asked, *"Should I have constrained you more? Or did you like doing the research required and making the design decisions required for a more open design specification?"* most students clearly indicated a preference for an open design specification and the minimal constraints imposed. The key reasons offered were the opportunity it offered to demonstrate creativity and individuality, and to make decisions as would be required in a real engineering environment.

Carrying out the required research was variously reported as time consuming, enjoyable, slow moving, or even daunting. More guidance in the form of hints, pointers or boundaries was suggested.

4.2.3 Project Assessment

Most students had no problem with the method of assessment using workbooks, a demonstration, and a final report.

There was some disagreement about the value of assessing the workbook. Two students could not see the point of the workbook when the material was assessed by a demo and report anyway. Equally two others felt that if workbooks were assessed, the report should be dropped, or much reduced in both size and weighting. I feel this indicates that I should more clearly explain the different purposes of these documents, both verbally and in the marking criteria.

Initially the weighting for workbooks, demonstration and report was 20%, 40% and 40% respectively, but then was later changed to 20%, 20% and 60%. I suggested the change, which was accepted by the class, when I observed that students were investing far more time into the reports than the demos, and I wished to reflect that in the marking weighting. In the questionnaire, generally students were either happy with the weighting, or suggested that the marking scheme move marks away from the report as per the original weighting.

The contribution of the project marks to the overall subject mark of 30% was judged about right by most students. A couple actually suggested weighting them even more heavily since this better reflected the time invested in them. This is an encouraging result as it demonstrates the students believe the projects are worthwhile, and the project mark is a genuine reflection of their ability.

4.2.4 Working with others

Two of my questions asked about interacting with others in the project tutorials, and working together to write joint reports.

Students offered valid preferences and objections for both joint and individual reports. The most commonly cited problem of joint reports is the extra time and effort required to work with each other and co-ordinate the writing. Some indicated that they learnt more by doing the entire report themselves, while others indicated that working (writing) with the group helped them learn more. This was usually a reflection of peoples' personalities. Everyone agreed that having the choice was a great option.

Some of the reasons offered for a lack of participation in the project tutorials were

- Fear of criticism from lecturer and other students.
- Fear of being copied, or loosing a competitive edge.
- Laziness. As one student said *"we were waiting for you to tell us what to do"*.
- Self-confidence.
- Lack of time.

The suggestions given to improve the lack of sharing included making the project tutorial sessions compulsory, setting questions that had to be answered on the board, and organis ing compulsory sharing which rotated from group to group.

5. CONCLUSIONS DRAWN AND ACTIONS FOR 2001

The replacement of pracs with projects in the power electronics subject appears to have achieved its goals. Most students readily accepted, benefited from, and enjoyed the new approach to practical learning. One student's concluding questionnaire comment was *"Can you convince all lecturers to do the switch?"*

The use of projects will be retained in the power electronics subject in 2001, and has now also been successfully tried in the third year electronics subject. A few details require fine-tuning, and some aspects simply require better preparation. Specifically

- Plan the number and duration (scope) of projects with greater recognition of the external pressures on both the staff and students at various points in the semester.
- More detailed marking criteria should be created. These should clearly explain what is required for each type of assessment (workbook, demonstration, or report), and what standard should be demonstrated to achieve a given grade.

  It is also important to explain the motivation and goals behind the use of that mode of assessment, as this motivates the students, and helps them achieve better overall outcomes.
- Plan better (perhaps more formal) modes of demonstration presentation to
  - generate more motivation,
  - allow students to benefit from one another,
  - allow better feedback from students and staff,
  - achieve greater transparency and accountability in the marking process.
- Plan more deliberate use of contact time, especially the project tutorials, to help facilitate the sharing of information and creation of ideas.

6. REFERENCES

[1] Abernethy, P., Dalmau, A, et al., "Creating a Deep Learning Environment: Motivation, Pedagogy and Organisation.", Action Learning, Experience and Promise, pp 107-121.

[2] Biggs, J.B. "What the Student Does: teaching for enhanced learning", Higher Education Research & Development, Vol. 18 No. 1, 1999, pp 57-75

[3] Gibbs, G. "Lecturing to More Students" No.2, Teaching more students project, Oxford, The Polytechnics and College Funding Council.

[4] Kolb, D.A., "Experiential Learning". Prentice Hall, Sydney, 1984.

[5] Reeves, T.C., and Laffey, J.M. "Design, Assessment, and Evaluation of a Problem-based Learning Environment in Undergraduate Engineering." Higher Education Research & Development, Vol. 18 No. 2, 1999, pp 219-232

[6] Walker, G.R., "Using Projects instead of Pracs for Hands on Learning", Final report for the Graduate Certificate in Education, UQ, 2000. Available from http://www.csee.uq.edu.au/~walkerg/

[7] Walker, G.R., "ELEC4400: Advanced Electronics and Power Electronics Design", Course outline, http://www.csee.uq.edu.au/~elec4400/

7. BIOGRAPHY

Dr Geoff Walker is a lecturer at The University of Queensland School of Computer Science and Electrical Engineering. He lectures undergraduate electronics and power electronics courses. His research interests of power electronics and embedded electronics are applied in areas including Electric and Hybrid Electric Vehicles, renewable energy, and energy efficiency.