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PHYSICS CONCEPTS: ENGINEERING PBL AT USQ

J. Sabburg[A], P. Fahey[B] and L. Brodie[C]
[A] Department of Biological & Physical Sciences, USQ, Toowoomba, Australia.
[B] Department of Mathematics & Computing, USQ, Toowoomba, Australia.
[C] Faculty of Engineering & Surveying, USQ, Toowoomba, Australia.

Abstract
Problem based learning (PBL) has been incorporated into the curriculum of programs offered by the Faculty of Engineering and Surveying at the University of Southern Queensland (USQ) since 2001. This paper examines student learning in a team-based PBL course offered in 2006. The study checks students' understanding of 10 fundamental physics concepts using computer administered quizzes conducted at the beginning and end of the semester. Pre-course results indicate that there is no difference in students' general understanding of physics concepts between those entering PBL and those entering the more traditional physics course. Neither was there a difference based on the type of physics curriculum they had undertaken at secondary level. It was found that this PBL course is 'pitched' at the physics concepts in which students have the greatest prior knowledge. At the completion of the course only one question resulted in greater than 50% incorrect answers by those who had not previously studied physics, with the same question also being the least correctly answered by those that had previously studied physics. Further, students with less than 1 year of physics in year 11 and 12 are benefiting most from the physics content of this PBL course.

Introduction
USQ is a regional university and its award programs are offered in on-campus, distance and online modes. The Faculty of Engineering and Surveying (FoES) offers programs in 9 major discipline areas. This Faculty has an integrated structure (no departments) which encourages team teaching, particularly in the lower levels of its programs. Teaching teams often use service teaching from other faculties largely for the areas of mathematics and physics. Specialist teaching is also a requirement of Engineers Australia.

Recent reports from major engineering accreditation and professional bodies (IEAUST 1999; IEEE 2002; ABET 2003; EC 2003) have highly prioritized the need for problem-solving skills, teamwork (in multidisciplinary teams) and communication skills. Engineers Australia (2005) summarises professional competencies as "apply knowledge of mathematics, science [and] engineering fundamentals … to engineering models". Engineering studies need to focus on the *application* of mathematics and physics to substantiate conclusions and solve complex engineering problems. Surveys of physics graduates in the workplace also showed conclusively that problem solving skills and communication skills rank higher in importance than specific knowledge, whereas the emphasis of most curricula has been often the reverse (Mills and Sharma 2005). In 2000, in response to new accreditation requirements from Engineers Australia, FoES decided to replace four traditionally taught, content based courses (including a course called Physics and Instrumentation), with a strand of four new courses using PBL. It was believed that experience in team-based problem solving would help graduates apply their knowledge in an engineering context. This approach to learning is also discussed in Mendez et al. (2005), along with issues such as service teaching, context centred teaching, distance learning and team work, from various Universities in Australia.

In semester 1, 2001, the first PBL course, Engineering Problem Solving 1 (EPS1), was offered to both on-campus and distance students in their first year of study. Teams of up to 8 students were randomly formed and allocated a USQ academic as a facilitator. On-campus teams met regularly with the facilitator, whilst the distance teams worked in a 'virtual' mode communicating via electronic methods. These included internet 'chat', electronic discussion boards and email. Facilitators regularly checked emails and discussion boards, answered student questions, helped resolve team conflicts and facilitated student learning. To enhance service teaching of physics to engineering and spatial sciences, an effective inter-faculty teaching liaison group had already been set up, in line with recommendations of "Physics Education for Australia" (Pollard et al. 2005).The team problems were carefully crafted by this group to incorporate key aspects of physics as the learning objectives (e.g. Wee et al. 2005). The actual physics concepts to be included in the course objectives were identified through much debate between the different disciplines of the Faculty.

The four main disciplines in FoES are: Agricultural, Civil and Environmental; Electrical and Electronic; Mechanical and Mechatronic; and Spatial Science including Surveying. No specific physics content was found to be core to all four disciplines. In the end it was agreed that EPS1 would cover the key physics concepts of fluid flow, heat, temperature, force (mass and weight), pressure and SI units, with a very strong focus on the practical application of these concepts in engineering and surveying. The objective of this paper is to review the physics topics covered in EPS1, trying to determine the impact and appropriateness of this content for engineering and surveying students.

Materials and Methods

All 244 students in EPS1 and 72 students in the equivalent traditional physics course were requested to complete short quizzes at the beginning and end of semester. The quizzes were computer administered using the University's web-based teaching platforms. Quiz questions were chosen based on the learning objectives of the two courses, as well as the core physics concepts outlined in a discussion paper in relation to the trial of the new contextual based physics curriculum in Queensland schools (Ridd et al. 2002). In all, there were 10 multiple choice questions, with 4 options for the students to choose from. Specifically, the questions asked about: mass and weight; Newton's 2nd law; pressure; kinetic energy; potential energy; the Celsius scale; specific heat; latent heat; convection and conduction. It should be noted that the traditional physics course included all these topics in its curricula, as the students undertaking this course came from a diversity of backgrounds, including those enrolled in physics and biomedical majors. One example quiz question is: Which of the following options best describes the following process, "heat travels along a metal object"? a) Convection; b) Conduction; c) Radiation; d) Evaporation. The students were also asked if they had undertaken and passed at least 1 year of physics in grades 11/12 at High School, as well as what physics curriculum they undertook.

EPS1 students completing the quiz at the beginning of semester were told which questions they got wrong and what the correct answers should have been. No feedback at all was provided to those in the more traditional physics course. The order of 10 questions and the order of the four answer choices on each question were randomised and the same quizzes were issued at the end of the two courses, this time with full student feedback for incorrect answers, for both courses. Unfortunately, none of the students in the traditional physics course completed the second quiz, despite several reminders. Analyses were conducted using paired and independent sample Chi-Square tests as well as 95% confidence intervals. As findings were consistent across the various analyses, only 95% confidence intervals are presented here.

Results and Discussion

Completion of the quiz was not an assessment requirement of the courses, so we were unable to achieve complete data. EPS1 students were required to use computer-based communication much more regularly than those in the more traditional physics course and so were much more compliant with the computer-administered quizzes. Results were obtained from, 198 EPS1 students at the beginning of semester and 184 at the end of semester (including 140 students who answered at both the beginning and end of semester). Only twenty students from the more traditional physics course completed the quiz at the beginning of semester. It was found that 83% of EPS1 students had completed at least one year of year 11 and 12 physics at high school, compared to only 55% of students in the traditional physics course.

At the beginning of semester there were no statistically significant difference in quiz results between students entering EPS1 (mean score 7.12) and students entering the more traditional physics course (mean score 7.55). Neither was there a difference based on the physics curriculum they had undertaken in high school (thus, not considered further in this study). Two questions, relating to energy, had greater than or equal to 50% incorrect answers. All questions, except the Celsius scale (which nearly everyone got correct), convection and conduction, were answered significantly better by those who had previously studied physics at high school.

Performance of EPS1 students improved from the beginning to end of the semester. At the beginning of the semester the mean score on the 10 point scale was 7.12 out of 10 (95% confidence interval 6.81 to 7.43). At the end of semester, the mean score was 8.23 (95% confidence interval 8.02 to 8.44). Figure 1 shows student performance for each question at the beginning and end of the semester. The proportion of students answering the questions correctly, improved during the semester on all questions except the Celsius scale (which nearly all students answered correctly).

The topic areas specifically addressed in EPS1 are marked by asterixis on the horizontal axis labels (only fluid flow was not directly assessed). The topics targeted by EPS1 tended to be the areas which most students could already answer correctly: the percentage ranged from 71.2% for convection to 98.5% for the question on the Celsius scale.

Figure 2 shows quiz scores out of 10 at the beginning and end of semester, according to whether students completed at least a year of high-school physics or not. Students without high-school physics made greater gains over the semester.

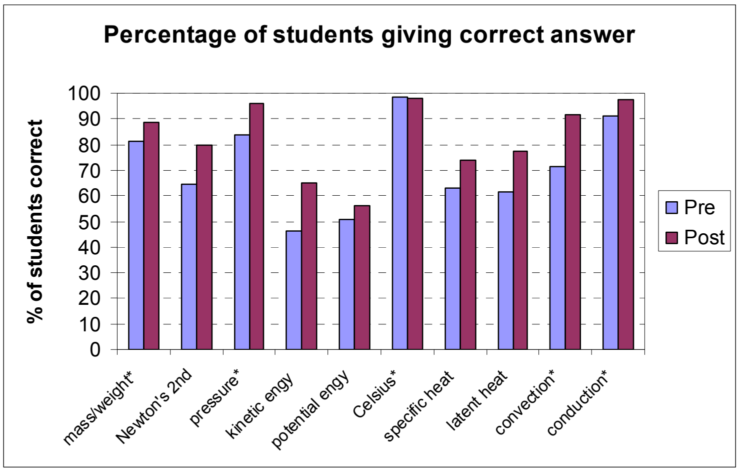

Figure 1: Percentage of EPS1 students giving correct answer on each question at the beginning and end of semester

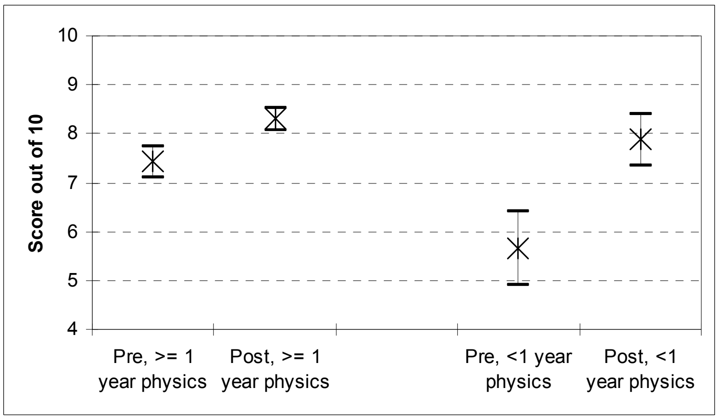

Figure 2: Mean scores for students with and without 1 year of year 11 and 12 physics at beginning and end of semester

Figure 3 shows separate graphs of the change in success rate per question, for students with some year 11 and 12 physics and for students with little year 11 and 12 physics. Statistically significant improvements in performance were noted for all topic areas except the Celsius scale and conduction (where most knew the answer at the beginning of semester, leaving little room for improvement) and potential energy.

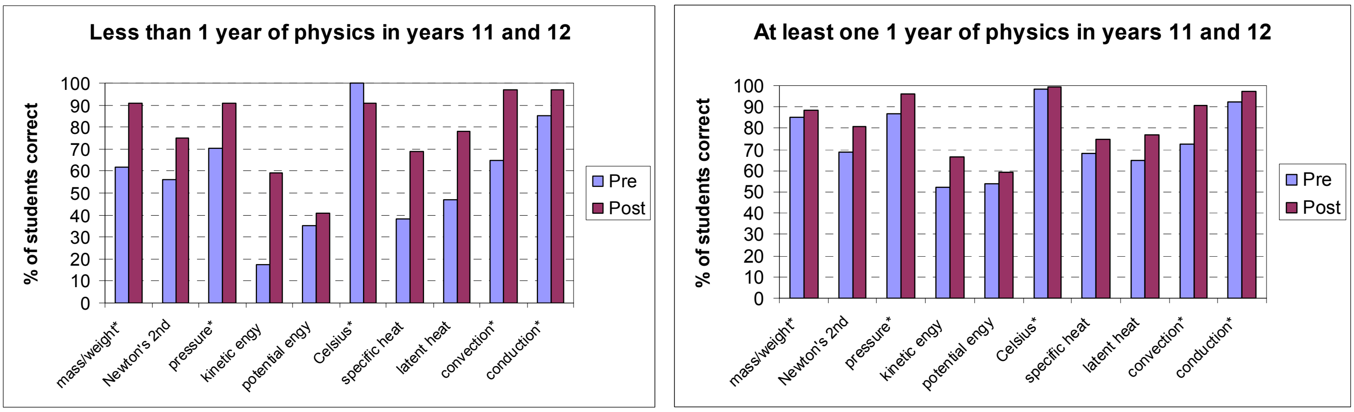

Figure 3: Change in performance on each question for students with and without 1 year of year 11 and 12 physics

Written feedback from EPS1 students was generally positive (except maybe for the grammar in some cases). For example: a) An email quote, **"**"Technicialy i have learnt quite alot i havnt studied physics in 9 years and has given me the oppertunity to renew some forgoten physic principles and fundementals", b) A student reflection, "During this report my technical knowledge regarding heat transfer methods, convection, radiation and conduction improved. I must say I did not really have a great theoretical base on heat transfer methods previously.", and c) The course evaluation, "The course improved my ability to learn and apply aspects of physics". From a total number of 190 students the responses were: Strongly agree (5%), Agree (48%), No opinion (24%), Disagree (16%), Strongly disagree (4%) and No answer (3%).

Conclusions

This study is relatively modest in its design and objectives. Its importance is that it represents the level of quality assurance / performance evaluation which is achievable by a teaching team using their own resources in their own classroom. The results have provided us with some very useful confirmation and insights into the success of our teaching program. Pre-course quiz results indicate that there is no difference in students' general understanding of physics concepts between those enrolled in a PBL course, and those enrolled in a traditional physics course. Neither was there a difference based on the type of physics curriculum they had undertaken at secondary level. However, most questions were answered significantly better by those who had previously studied physics at secondary level.

Secondly, this study has shown that the problem solving course is 'pitched' at the physics concepts in which students have the greatest prior knowledge. This may be appropriate because, a) we're dealing with students very early in their university course, and b) it provides the majority of students with the opportunity to concentrate on learning about team problem solving methods, rather than being under pressure to learn the more difficult physics concepts. If we did wish to have slightly more ambitious content in EPS1, we now know we can safely drop the Celsius scale, which all the students know already, and pick up an area like potential energy, where students are currently making no real progress during the semester. It should be noted that the three other subjects studied by most students during S1, 2006 were, Foundation Maths, Communication and Case Studies, and Engineering Materials, none of which had any specific physics learning objectives. Also, in hindsight, maybe the correct answers should not have been issued to the EPS1 students completing the quiz at the beginning of semester, but it is hoped that they would have done their own research to find out any incorrect answers. However, it is concluded that the gain in the students learning resulted from what they had experienced in the EPS1 course.

Thirdly, we see that students with less than 1 year of physics in year 11 and 12 are benefiting most from the physics content of EPS1. EPS1 is providing these students with an opportunity to catch up with their peers. Students who have already done a year of physics in high school are recording much less improvement. Presumably these students are free to concentrate on the team work and problem solving skills being taught in EPS1. We conclude that learning of physics concepts in a non-traditional setting can occur, but our modest study was not able to resolve whether this learning is more or less effective than by traditional methods.

Acknowledgements

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References

ABET, (2003), Engineering Criteria, Accreditation Board for Engineering and Technology, www.abet.org
Engineering Council UK (EC UK), (2003), Regulating the Profession, www.engc.org.uk
Engineers Australia, (2005), IEM Graduate Attributes and Professional Competency Profiles - Working paper for IEM 2005 Ver 1-13 May 2005, http://www.ieagreements.com/IEM_Grad_AttrProf_Competencies_v11(2).pdf
The Institution of Engineers, Australia (IEAUST) (1999), Manual for the Accreditation of Professional Engineering
IEEE (2002), Attributes of the 21st Century Engineer, www.cseg.inaoep.mx/~jmc/21st.html
Mendez, A., S. Feteris, L. Kirkup, M. Livett, D. Low, A. Merchant, D. Mills, J. Pollard, A. Rayner, M. Sharma, G. Swan. K. Wilson and M. Zadnik (2005), Snapshots - Good Learning and Teaching in Physics in Australian Universities, *Carrick Institute for Learning and Teaching in Higher Education*, 1-28.
Mills, D. and Sharma, M. (2005), Learning Outcomes and Curriculum Development in Physics Project, Final Report, *Carrick Institute for Learning and Teaching in Higher Education*, 1-9.
Pollard, J., Sharma, M.D., Mills, D., Swan, G, and Mendez, A. (2006), Physics Education for Australia, *Australian Physics*, **43**(1), 20-26.
Ridd, P., Wegener, M., Gray, E. and Cornish, B. (2002), Assistance to Schools Preparing Work Programmes for the Queensland Trial Pilot Physics Syllabus, http://www.mbc.qld.edu.au/physics/uni_physics.html
Wee, K-N L., Keki, Y.C.M.A. and Sim, H.C.M., (2002), Crafting Effective Problems for Problem-Based Learning, *Temasek Centre for Problem Based Learning*, Polytechnic Singapore, 1-19.