

Skills Audit and Competency Assessment for Engineering Problem Solving Courses

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ABSTRACT

This paper describes a strategy for auditing existing skill levels, and assessing achievement of course objectives, by students enrolled in Engineering Problem Based Learning (PBL) courses.

Our method involves initial auditing of existing skills and competence of each student, and continual assessment to monitor progress. The initial skill assessment will facilitate the effective allocation of students with different levels of skill in various discipline areas, into well balanced teams. This balance will facilitate effective mentoring within the teams and, because improvement by individuals and the team collectively will be formally assessed, mentoring within the teams will be encouraged.

The formal assessment of objectives will be tailored to individual student's existing skill levels. The emphasis will be on advancement of skills and competence rather than simply achieving a minimum standard. This novel strategy will provide the flexibility for equitable assessment of students with different initial skill and competency levels; particularly relevant to students studying in the distance mode who may have considerable professional experience and advanced skills and competence.

By tracking progress towards the achievement of objectives, students can be provided with an individual portfolio of achievements through the suite of PBL courses.

INTRODUCTION AND BACKGROUND

The University of Southern Queensland (USQ) has developed an international reputation for offering high quality academic programmes in the on-campus (internal), off-campus (distance), and on-line delivery modes. The university's principal campus is situated at Toowoomba, approximately 130 kilometres west of, Brisbane, Australia.

The Faculty of Engineering and Surveying (FoES) is one of five Faculties at the University. In 2002 FoES introduced a problem-based learning (PBL) approach for several courses to ensure that graduates develop problem-solving skills and the ability to work effectively in multidisciplinary teams. This was consistent with the university's vision and the faculty's philosophy that engineers and surveyors (spatial scientists) are predominantly problem solvers. They must be able to use the latest technology to find creative solutions to multidisciplinary problems throughout their professional lives. It was considered that PBL would be a preferred strategy to achieve this since it purposefully creates situations from which learners broaden their perspectives and acquire new skills (1).

The use of PBL provided a mechanism to demonstrate that participants had developed the necessary professional skills required by professional accreditation bodies (2,3,4). It was also an opportunity to establish an innovative teaching practice in Engineering education at USQ that was outside the dominant transmission model normally used in universities (5), and that recognised that learning may be more effective when undertaken in groups (6).

The PBL strand consists of a series of four consecutive courses, with an additional final year research project seen as the capstone of the strand. The main objectives of the first two PBL courses, which are compulsory for all students in the Faculty, are to develop the fundamental skills needed by students for participating effectively in multi-disciplinary teams, and to expose students to a wide range of problem-solving tools and skills. The subsequent problem-solving courses are designed, in terms of structure, content and pedagogy, to expand and improve these skills, and to impart fundamental technical content in several discipline areas. In all problem-solving courses student teams are presented with open-ended technical problems for which they must

develop, justify and present solutions. The problems are developed to construct technical knowledge and skills as required by the course specifications.

Students enrolled in the initial PBL course are placed into teams of eight members. Current practice is to randomly allocate students to teams, but it is recognised that a better system would be to balance members' existing skills within the teams. Furthermore, each team is allocated a staff member to act as a facilitator. The role of the facilitator is explained in Gibbings & Morgan (7). An examiner is also appointed to the course who has overall responsibility for administration and assessment of the course, and staff training and coordination.

At USQ, students may elect to study in the on-campus (internal) or off-campus (distance) modes. Distance students study from various geographic locations around the world, which enriches the learning experience due to the cultural diversity, but also creates its own set of logistical problems. These problems are further complicated in the problem solving courses by the fact that students in the same team may be studying at Associate Degree (two year degree), Bachelor of Technology (three year degree), or Bachelor (four year degree) levels. Students enrolled in the PBL courses may also be studying any of the 9 majors offered in the faculty - Agricultural, Civil, Environmental, Electrical and Electronic, Computer Systems, Mechanical, Mechatronic Engineering or Surveying and Land Information. Because of this diversity (different disciplines, different study modes, and different programs), existing knowledge, expectations, level of interest, and other cultural and personal differences, the difference in learning objectives of each individual student can be profound. It is interesting to note that most of these elements were also identified as core principles that need to be considered when designing education for adult learners (8).

Most students studying in distance mode do so because they are already employed in some capacity in industry and the distance mode allows them to study and work at the same time. Because they are already in the workforce, many have different skill levels and personal competency attributes compared to internal students. In addition, an increasing number of internal students do not come directly from school and do not have the traditional

prerequisite studies usually associated with undertaking technical university courses. School leavers do not necessarily possess the maturity levels and skills to be independent learners.

It is clear that during the setting of objectives and assessments, especially for the first two PBL courses, there needs to be some recognition of prior learning or skill. It seems logical that the assessments should be individualised for each student, and at the same time peer assisted learning within and between teams must be encouraged and rewarded – but the current assessment strategy does not achieve this.

At present the assessment strategy varies slightly for each of the four PBL courses. Formal course evaluations by students, quality audits and reviews by staff, and anecdotal evidence from stakeholders have recently identified some deficiencies with the existing assessment strategies. Some shortcomings identified with the current assessment in the first PBL course are that:

- some students want to do all of the work themselves. The most common reason is that 'high achievers' don't want to rely on others to carry out tasks that could ultimately affect their 'marks'.
- some students are not motivated and contribute very little to the team effort. Thus the assessment strategy must ensure that the individual only, and not the team, is disadvantaged – this may not be the case under the present assessment scheme.
- there is no real incentive for students to learn new skills. For example, under the current system, those who are proficient or excel at a particular skill (for example, report writing) will tend to adopt this role in all projects because this gives the team its best chance of receiving a 'good mark' for the projects.
- there is little or no *incentive* for mentoring within the teams. Assessment should require that teams provide evidence of mentoring - if it is important and in accordance with learning goals, then it should be assessed (9,10).
- greater incentive must be provided to individuals to encourage the assessment of other teams' proposals (mentoring between teams) and to provide constructive feedback. Evidence must also be provided by teams of action taken as a result of this feedback.
- more personal reflection should be encouraged and better direction should be

provided to students on the requirements of the individual portfolio (used as part of the assessment). At present too much emphasis is placed on the team mark for the projects and on the project solution, rather than on what the individual has learned and how and why the individuals' skill and competence levels have increased.

This paper outlines a revised assessment strategy for the first PBL course to overcome some of these shortcomings, and to effectively assess achievement and advancement of skills and competence, in a way that recognises diversity and prior skill and learning, and that does this in an equitable manner. This assessment strategy will address the course objectives and ensure that minimum standards are met. It will also provide students with guidance and encouragement to:

- take responsibility for their own learning: this is generally referred to as 'constructive alignment' (11,12), or 'constructivism' (13),
- identify their own individual learning objectives that allow them to extend and build on existing skill and competence,
- develop suitable strategies to achieve these individual learning objectives,
- provide a mechanism for students to monitor their own progress throughout the strand of PBL courses

This strategy is entirely in accordance with the 'constructivist paradigm' (13), since PBL is much more facilitative in nature than prescriptive, and 'collaborative learning' (14,1).

METHOD

Initial Skills Audit

A strategy was devised for the development and validation of a method of auditing initial skill levels. This will allow the continuous assessment of students against course objectives as they progress through the PBL strand of courses in both the on campus and distance modes.

The first part of the method involves the initial auditing of existing skills and competencies of each student, while the second part involves continual skill assessment to map student's progress throughout the full suite of PBL courses. The skill assessment will be used to allocate students with different levels of skill in various fields into well balanced teams. This will encourage mentoring within the teams.

Individual students will be able to use their skill assessment as an introduction to other team members, and provide facilitators with a standard of comparison against which later skill levels can be assessed to monitor both student and team progress.

Although the initial skills audit will not form part of the formal assessment, it will be the starting point for the student's individual portfolio of skill achievement. It will assist with developing the overall assessment strategy and individual learning goals. The results of the skills audit will be available in digital form to course facilitators and the individual student. It will be the student's responsibility to make this document available to other interested parties, including members of their allocated project team.

Formal Assessment of Skills – Portfolio

Assessment will depend more on the process, reflection, and self-evaluation rather than on specific quantitative criteria (13) and the emphasis will be on advancement of skills and learning new skills, rather than simply achieving a minimum standard. This will be achieved by each student individually negotiating and being assessed on, objectives and goals for each project within the PBL courses. The direction will be determined by the learner within the constraints of the problem to be solved, which is seen as desirable for adult learning (13). Students will have to negotiate suitable roles within their team for each project. This is in accordance with research that suggests that adult learners want control over learning based on personal goals, and that learning and better outcomes will increase as a result (8). There is convincing evidence that those who take some initiative and become involved with their own learning in this way will learn more than those who take a more passive approach (15).

Teams will be required to submit a plan, similar to the system noted in Isaacs (16) for the project incorporating each team member's individual learning objectives. These must be agreed by team members, must be consistent with course objectives (and graduate attributes), and be aligned to areas in which the student requires improvement rather than an area of existing high level skill and competence. This will encourage development of new skills since the students will be assessed on these negotiated objectives alone – teams whose plans demonstrate the development of new skills by its members will potentially receive higher marks. By tracking

progress in the achievement of objectives, the students can maintain an individual portfolio of achievements throughout the suite of PBL courses. This improvement by individuals and the team collectively will be formally assessed, and mentoring will be improved. This will lessen the reliance on a 'team project mark' and allow for more individual assessment than currently occurs.

This strategy for formal assessment of objectives will provide documentary evidence that each student has achieved the minimum standard expected of a graduate as dictated by PBL course objectives, program attributes, accreditation bodies, professional associations, and defined graduate attributes.

The novel assessment approach, involving tailoring to individual student's existing skill and competence levels, will also provide the flexibility for equitable assessment of students with skill levels that are already well above the required minimum standard. Students who may have highly developed skills in some areas, as is often the case with mature age distance students, can now be assessed on an equitable basis with students who may not have the same starting level of skill. Students will basically be assessed on rates of improvement rather than final achievement level.

In essence, students will develop an individual log to record their progress in skill and competence achievement. This approach is similar to what has been adopted by several professional associations in Australia that have the responsibility, often under legislation, of assessing individual members against national competency standards before granting professional registration with their associations. It has also been successfully used in various forms in education for example Albert and Morrison (18, p.292), and (19), although it is not common in engineering or technical education. The log or portfolio will provide a structured record, in condensed but specific form, of the student's progress in the skills development through the student, facilitator, and examiner signing off on milestones as they are reached.

Formal Assessment of Team Projects

Each team will be required to prepare a plan that will include an individual's role and responsibility within the team and their learning objectives. This approach recognises that not all students will have the same learning objectives, nor will

they be faced with the same issues (particularly considering the student diversity), so it is necessary to be flexible (17). It also recognises that true 'engagement' can come from students negotiating their own learning objectives and constructing them within their own context. This may also lead to a sense of 'ownership' and enhanced motivation (17).

Teams will be required to publish preliminary project reports on a web site by a designated date. Teams will be awarded marks for work done to date. Facilitators and other teams will have the opportunity to provide feedback on what has been submitted. Individuals will be given formal credit for this activity based on their participation as assessed by the facilitator. Teams will then have the opportunity to alter their submissions in light of the feedback and resubmit the final project report, which will again be assessed. This final submission must provide evidence of changes or actions subsequent to the feedback, and outline how and why the initial report was improved as a result. This reflection and collaboration within the team are seen as critical to the learning process (16). In this way, the assessment will become an integral part of the learning process. The system will also encourage students to engage in the learning tasks associated with the problem solution, which is one of the most fundamental tasks of education (18).

This process also acts as a quality audit and review for facilitators. It provides an early opportunity for troubleshooting any possible problems within teams and to provide pastoral care. It also provides valuable insights into the instructional design of the course, how well the general pedagogy is working with respect to course learning objectives, and if changes are needed to the project/problem design.

RESULTS, ANALYSIS AND DISCUSSION

The primary outputs from this strategy will be the initial skills and competency assessment and the strategy for the design of the skills and competency portfolio.

Initial Skills Audit

The skills audit will be an online self-assessment carried out by the student personally. This will involve subjectively answering a set of questions regarding team work, problem solving, and other technical skills. Questions will be written in easy

to understand language to overcome potential problems with cultural diversity, and expressed in terms of how well the student believes they can perform certain defined activities.

These initial skill audit questions will also be linked to the course objectives wherever possible. For example, suppose a course objective was: 'Communicate information in a professional manner'. A corresponding task that describes one of the skills that students are expected to achieve might be: 'Prepare a professionally written technical report in English on a word processor'. The corresponding questions that would appear in the initial skill audit might be:

1. How would you rate your ability to use a word processor?
2. How would you rate your English expression, grammar and spelling?
3. How familiar are you with standard referencing styles?

Students will grade their performance of each of these activities by checking a box against a five point scale where one denotes little or no knowledge and five denotes experienced and expert in all or most aspects.

There is a possibility that some students may either under or over estimate their skill levels. Students are advised that:

- the audit is not part of a formal assessment,
- all students will ultimately have to prove their skills, so there is no benefit in under or over estimating skills,
- if students underestimate skills, they may be placed in a team with someone who is supposedly strong in this same area and may be charged with the responsibility of mentoring them in this skill. This will be ineffective and inefficient, and their team will be disadvantaged due to not having well balanced skills.
- if they overestimate skills, then they may be asked to mentor a team member in this area. In this case mentoring won't be effective and they and the team will consequently be penalised.

Formal Assessment of Skills – Portfolio

Most skills and competencies that will be assessed in the portfolio will be directly linked to course objectives and graduate attributes. They will be subdivided similarly to the initial skills audit, into the general fields of: team skills, problem solving skills, and technical skills. Most

skills will also have a level of achievement attached to them. This portfolio of skills will essentially be a professional development audit and will provide a status report of the students' progress at any particular time.

Following on from the earlier examples of course objective, task statement and skill audit questions, the corresponding competency/skill assessment questions might be:

1. Professionally structured report
2. Consistent and appropriate format of report on word processor
3. Spelling, grammar, and punctuation
4. English expression, syntax, vocabulary, sentence structure
5. Illustrations, figures, and graphs used appropriately in text
6. All information correctly referenced
7. Harvard referencing style and Bibliography used correctly (including electronic sources)

Students will again grade their performance in each of these activities by checking a box against a 5 point scale (starting or default level will be zero where no skill level has yet been demonstrated). They will be able to judge how well they have performed in these areas after receiving feedback on their initial team reports. They will also be provided with guidelines on how to self-assess their performance.

Students will first nominate objectives (and skills/competencies) for each assessment project after negotiating their individual roles and responsibilities within their teams. After the final project report is submitted they will request, and provide documentary evidence in their individual portfolios for, certain levels for the competency or skill addressed.

The skills portfolio will demonstrate and formally record the practical realisation and advancement of skills and competencies. Despite the initial skills assessment and negotiating project objectives based on existing skills and competencies, the default position for *formal assessment* of all students entering the PBL strand is that they have not met any skills or competencies until this has been 'demonstrated'. Each individual student must formally demonstrate the achievement of the skills and this must be verified by their peers, facilitator and the course examiner. Evidence of achievement of skills and competence is presented and assessed in the student's individual portfolio. There are several ways that

students can demonstrate the achievement of a particular skill level:

- Peer assessment/agreement and documentation of performance during team projects (in accordance with the peer agreed team roles and predetermined individual learning objectives),
- Evidence of effective mentoring within the team in these skills,
- Individual requests supported with documentary evidence of conduct during the project (this should not occur often as this is not peer assessed), and
- Exemptions for students who have enrolled with advanced standing and have been granted exemptions.

The student will only be recognised as having met the standard if the facilitator and examiner are satisfied the student is competent and has the capacity to maintain a high level of performance in all aspects at the requested level of the skill being assessed.

This process records the achievement of the skills and competencies and tracks the student's competency in the identified skill areas. The portfolio will provide formal recognition of the status of individual skill achievement, and will be available to course facilitators and examiner. Like the initial skills audit, this individual portfolio will be disclosed to other students at the individual's discretion. However, it will be prepared by the individual with supporting documentation, peer assessed by other members of the project team, assessed/checked by the team's allocated facilitator, and finally moderated by the examiner to ensure consistency and as a final 'due diligence' quality check.

This process allows facilitators to recognise existing areas of specialisation but still provide documentary evidence of the students' achievement of all skills and competencies. It also allows the examiner to identify areas of specialisation where a student has achieved higher than minimum levels of skills, knowledge and competency, since the process provides a mechanism whereby achievement above the minimum required can be recognised, assessed and credited. This encourages students to attain skills and competencies in excess of the mandatory requirements for graduation.

The formal assessment strategy will also encourage students to develop new skills in

areas in which they have previously identified a weakness. The opportunity for feedback and mentoring within and between teams will be enhanced. Formal credit will be given to individuals for providing feedback to other teams' work (although this will be assessed on participation rather than quality). Both inter and intra team mentoring will be assessed in the individual portfolios. It is believed that this increased mentoring will have the added advantage of encouraging better intra-team communication and should therefore foster better teamwork.

This strategy provides a mechanism to separate individual and team assessment. It also provides the flexibility to equitably assess the attainment of skills and competencies at a higher level than the minimum requirements because the assessment is concerned with the attainment and advancement of skill level, rather than assessment against some predetermined minimum criteria.

Consistency of assessment between facilitators is achieved by staff training and documentation of requirements in a course facilitator's guide (7). The examiner performs a moderation role to further promote consistency between facilitators and to ensure due diligence has been applied to crediting individual skills and competence.

Detailed information on how to complete the log and address the documentation of skills and competencies will be provided to students. An up to date copy of the full skills portfolio will be kept by both USQ and the student, but the system will be largely self-managed by the students as there is no advantage to be gained from 'cheating'. Operational details of how the system is administered are beyond the scope of this paper. It is recognised that the system will be trialled with a pilot study. It is also accepted that existing facilities and infrastructure will have to be utilised as much as possible to minimise extra staff time needed to execute the revised assessment strategy. It will then be implemented, monitored and reviewed, and the results will be reported in subsequent publications.

CONCLUSION

The strategy of an initial skill and competency audit for students offers several major benefits. It allows the tailoring of assessment to individual

needs and will cater for prior learning and existing skills. This will enable more effective use of student diversity and encourage mentoring. The portfolio will encourage an *increase* in skill levels rather than just meeting a minimum standard. It will provide a continuous assessment strategy throughout the 4 courses, allowing the student to demonstrate, not only the achievement of graduate attributes, but progression and final competence level. Self directed learning and life long learning skills will be fostered; these in themselves are desired graduate attributes.

A skills audit and assessment package will significantly increase the ability of students to direct study and energy into self identified areas which will most benefit their future careers.

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