Applying Learning Design concepts to problem-based learning

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Problem-Based Learning (PBL) seeks to produce learners who not only remember the theory, they know how and when to apply it. However, providing a problem to a group of students is not a guarantee that they will be able to solve it. Even more uncertain is whether the solution the students offer and the journey they undertook to arrive at it resulted in them learning the intended underlying concepts and theories. As students become increasingly time poor, they are less inclined towards a learning approach which requires them to be self-directed and motivated. This paper reports on a learning design which seeks to scaffold and accelerate the PBL process by providing a balance of facts and concepts to be remembered and tested via an online quiz, followed by an activity-based tutorial session that focussed on the application of those concepts to new problems in conjunction with the use of resource material and memory aids.

Keywords: Problem-Based Learning, LAMS sequences, MOODLE, activities

Introduction

Learning Design for the higher education environment is a complex task, especially in light of the increasing diversity of the student body. Learning materials need to be re-designed to take advantage of different student ability levels, learning approaches & media, and curriculum re-developed to support a huge variety of outcomes that are often discipline specific. The central ideas behind Learning Design represent new possibilities for increasing the quality and variety of teaching and learning within a learning context (Britain, 2004). Learning Design encourages the analysis of the process of designing learning activities by providing a framework for academics. This enables them to reflect in a deeper and more creative way about how they design and structure activities for different students or groups of students. Designs that prove to be effective may then be communicated and shared between teaching staff or retained for re-use on future occasions (Britain, 2004).

One well tested Learning Design, Problem-Based Learning, provides students with the opportunity to gain theory, content knowledge and comprehension in a more authentic way (Major & Palmer, 2001). In addition, this approach helps students develop advanced cognitive abilities such as critical thinking, problem solving, and communication skills (Barr & Tagg, 1995). However, PBL involves a change in focus from teacher delivered solutions to student acquired problem-solving skills requiring a fundamental change to the design and delivery of course materials and learning and teaching methods.

In this paper we propose a learning design for PBL which is currently being utilised in a second year undergraduate IT analysis and modelling unit that is a core subject to all of our degrees. Problem-solving is the key learning outcome in this unit. The first half of the unit is specifically focussed on gathering requirements and modelling the problem using the Unified Modelling Language (UML). The second half of the unit is concerned with designing a computer-based solution to the problem identified. Despite the centrality of problems to this unit, this semester is the first time in which PBL has been applied.

Learning Design Concepts

Any learning design comprises three key elements: the content or resources learners interact with, the tasks or activities learners are required to perform, and the support mechanisms provided to assist learners to engage with the tasks and resources. This unit sought to provide students with high quality authentic learning activities or problems in an attempt to provide an environment which encourages them to seek understanding rather than memorisation and which encourages the development of lifelong learning skills. Students were provided with scaffolded learning activities to assist them as they developed their own knowledge and skills. Many of these supports were gradually reduced as the unit progressed to the point where the students developed their own capacity to solve problems individually and collaboratively with their peers. To aid students' efforts in collaborative problem-solving there has been an intentional shift in this unit to create situations where the lecturers offer just-in-time advice. Group work, sharing of ideas and peer comment were also employed in line with the view that PBL is a process in which real world problems are used to help and motivate students to identify, apply, collaborate and communicate their knowledge effectively (Savery, 1994).

With the effective implementation of PBL, evidence of the principles of Behaviourist, Cognitivist and Constructivist Schools of thought can be found. Behaviourist Learning Theory states that learning is a change in observable behaviour caused by external stimuli in the environment (Skinner, 1974 as quoted by Ally, 2004). In the PBL tutorial sessions, described in more detail below, we provided problem notes, handouts and text-based activities whose sequenced use was teacher-directed. Prior to the tutorial session a mandatory weekly online quiz was set. The quiz is an example of drill and practice testing providing immediate feedback of factual knowledge that would later be (re)used in the tutorial for problem solving.

Cognitive Learning Theorists claim that learning is an internal process that involves the use of memory, motivation and thinking and that reflection plays an important part in learning. A variety of content was provided by the teacher via a Learning Management System (LMS) and hand-outs from a range of sources based, in part, on the needs of the problem (Smissen & Sims, 2002). Information was chunked to prevent overload during processing in working memory as is suggested by Miller, (1956) (as quoted in Ally, 2004). An overview of the lesson was provided to provide a framework for learning and students and tutors produced a summary activity after the lesson (Bonk & Reynolds, 1997, as quoted in Ally, 2004).

Constructivist theorists believe that learning is an active process of construction of knowledge rather than its acquisition. Teaching is therefore a process of supporting that construction rather than transmission of information (Duffy and Cunningham as quoted in Lefoe, 1998). Constructivist teaching tends to be more holistic, more collaborative in method and more encouraging and accepting of student initiative, and often provides freedom and variety in assignments and assessments (Henriques, 1997 as quoted in Fahy, 2004).

The use of PBL in this unit supported a Constructivist environment by:

- Involving students with real-world problems and situations.
- Modelling the analytical and thinking skills of the teacher and other experts, which students then can apply, with appropriate feedback, to their own problems and constructs.
- Work with authentic problems that reflect real contexts and characteristics.

(Adapted from Jonassen, 1999)

In the PBL ideal, students will learn the theory by seeking out ways in which a problem can be solved. However, time and resources are finite. The amount of content to be learnt and the time available in which to learn the content compete with one another. Furthermore, for many undergraduate students, an open-ended problem which relies on their own motivation and ability to explore the literature themselves is beyond them. An alternative is to provide concepts and theoretical knowledge in the more traditional style of teaching which are motivated and practiced within the context of real problems.

This paper describes a learning design based around PBL which seeks to balance and ground theory with practice. In the next section we introduce the learning design we used, followed by a description of a Learning Management Systems we considered and another

which was actually used together with the non-computer based components of our approach. We conclude with some discussion and an outline of our proposed evaluation at the end of the current semester.

The Design of Learning and Learning Theory

Preparation and sequencing of activities, organization of content and consideration of the roles adopted by students and teacher are central elements of planning for learning. It was a vital element in this unit as the PBL methodology and delivery of each tutorial had to be communicated between staff members (for a partial example of one of the learning designs used, see Fig. 1). The concept of creating a learning design is familiar to all teachers (Britain, 2004): it is what teachers do each time they prepare for a class. They design the learning that will take place in a given time frame. Lesson plans or learning designs are patterns for action: a sequence of activities, incorporating resources and tasks. Learning design patterns should embody "educational values and vision" (Goodyear, 2005, p.82). These patterns can provide a reproducible and sharable template. However, the reusability of the PBL problems provided to students in this unit is unlikely as students having to repeat the unit will already have seen the problems in the previous year. A rotation of problems over a 3 year cycle is possible, though many questions will need revision/updating due to changes in technology and the methodologies used.

Tutorial for Week 1
Activity 1 – Getting to know each other (25 minutes)
1.1. Introduction by tutor – how the tutorials will run, when tutor is available, quiz needs to be done each week before Monday 5:30pm, available after the Thursday night lecture the week before. Worth half mark, need to attend to get other half mark.
1.2 students in pairs speak to each other for 5 minutes to find out the other person's name, degree and some other facts about the other person. Each person gives a 30 second introduction to the class about the other person.
Activity 4: Group activities (Up to 6 groups), 20 minutes
Each group will be given an equal number (2-3) of sample SDLCs found on the internet (Note I've got 4 copies (2versions) of RUP). The group will have 5 minutes to consider how they fit with the SDLC phases from the text book shown on the whiteboard. They should compare the different phases and activities. They should look at the diagrams to see what additional information they convey thinking about the relationship between phases, the role of the SDLC within an product's life and within an organisations business activities.
After approx. 5 minutes all groups will be asked to swap their cards with another group and do the exercise again adding to what they thought about with the previous set of cards. Swap around three times.

Figure 1: Extracts from the learning design for the tutorial in the first week.

The learning design for the weekly 2-hour tutorial was first created by the lecturer and then discussed with the tutor. Some practical issues sometimes arose via the discussion as consideration was given to the room layout, number of people, equipment, the knowledge and behaviour/attitudes of the students and so on. For example, for some questions we had wanted groups to share their solutions with other groups. The room we were using was a computer lab. While the room had a computer for each student and a projector connected to one central machine, it did not have an overhead projector, a visualiser or photocopier to allow us to share/view one another's outputs. Therefore, in some exercises we asked students to reproduce their solution (i.e. write it down twice on paper) so that they could keep one copy and share the other.

Following the discussion with the tutor prior to the first tutorial for the week, the lecturer would finalise the design and email it to the tutor and produce or assemble any handouts/resources to be used in the activities. Seven tutorials were conducted each week. After the first tutorial on Monday the tutor would contact the lecturer to report back what had worked and what hadn't. Small redesigns were made to ensure quality and consistency across all the seven tutorials. If there had been more than one tutor, the weekly meeting would have been with the

lecturer and all tutors, with each tutor reporting back after their tutorial session. However, it would have been more difficult to manage any small redesigns. More problematic would have been ensuring that tutors acted as facilitators allowing the students to discover solutions for themselves as this requires an understanding and buy-in of PBL goals and methods.

As a key concern was managing the learning activities to provide an appropriate balance and flow between theory and practice we sought a tool that would support sequencing of activities. The first LMS we considered for this purpose was the Learning Activity Management System (LAMS).

A LAMS sequence to manage PBL

In general, each week there was a sequence of activities aimed at providing a combination of theory and experience. The students could hear about the key concepts with worked through examples via the 3-hour face-to-face lecture or iLecture. Students could read about the same concepts and examples in the lecture material, textbook and additional readings. The optimal sequence was for students to complete the readings before the lecture so that any gaps could be filled in by the lecturer. However, it is unlikely that many students organised their study in this way. Immediately following the lecture, an online quiz became available to allow the student to consolidate their understanding from the lectures and readings regarding the terms, concepts and theories presented. The quiz was worth 0.5% each week and had to be completed by Monday of the following week before the first tutorial class. With the theory fresh in their minds, students then attended the two-hour tutorial class introduced in the previous section.

Some of the class time, up to half an hour, was devoted to learning how to use a Computer Aided Software Engineering (CASE) tool. This year we used Enterprise Architect by SPARX for UML modelling. However, most weeks the full two hours were devoted to individual, group and class activities focused around problems given during the tutorial session. The two-hour session is conducted in a computer laboratory with wide aisles and chairs with wheels, allowing students to work in front of a computer, away from the computer, individually and in groups. The only preparation for the tutorial required by the students was the online quiz (which was based on the lecture and reading materials). Problems were not provided to the students before the class. In contrast to traditional tutorials, the focus was not on providing the answers, but rather on how to understand the problem, the problem-solving process and evaluation of the range of solutions. The activities performed within the tutorial sessions will be discussed later as part of the non-technology based part of the approach.

A more specific sequence of activities is shown in the LAMS sequence in Fig. 2. The first icon shows two optional sequences: a “noticeboard” and “chat and scribe”. The sequence shown is a template that can be reused weekly. The initial activity is an optional sequence to allow in some weeks topics/issues to be raised for discussion which people could chat and write about. The next activity is a multiple choice quiz. As previously described, this activity is a quiz designed to ensure that students engage with the content including the terms, definitions, theories and concepts in the lectures and reading material. The following activity involves an off-line Q&A session. This is in fact the in-class tutorial session. As part of the tutorial session, students discuss the questions and answers (shown by the off-line “chat” activity). As part of the activities, individuals or the group scribe enter their thoughts and solutions online.

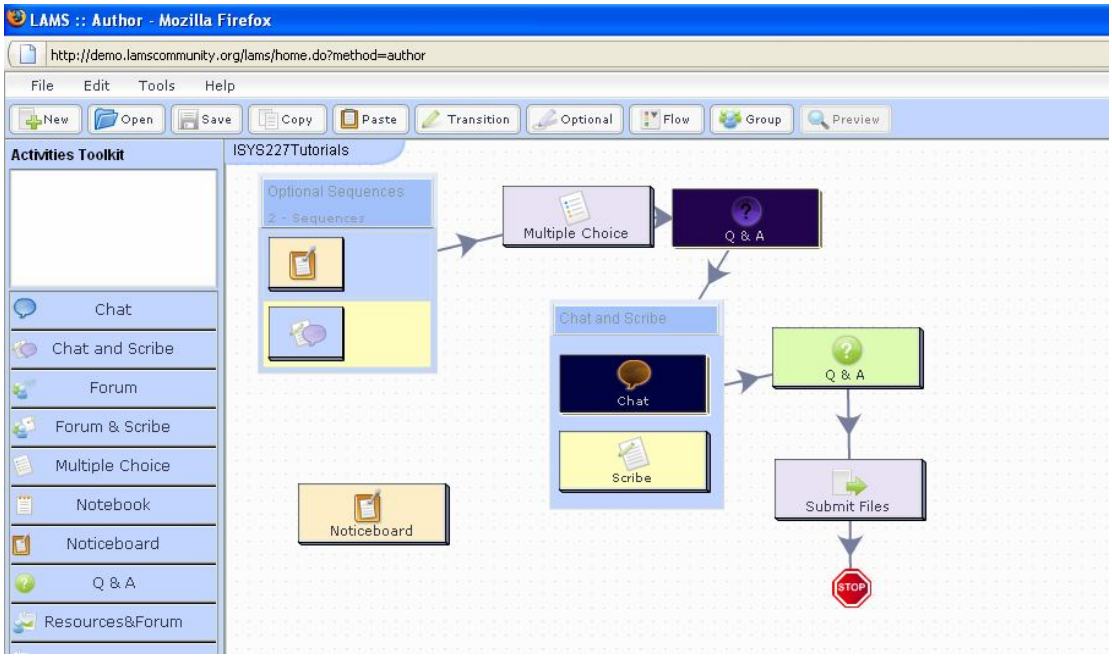
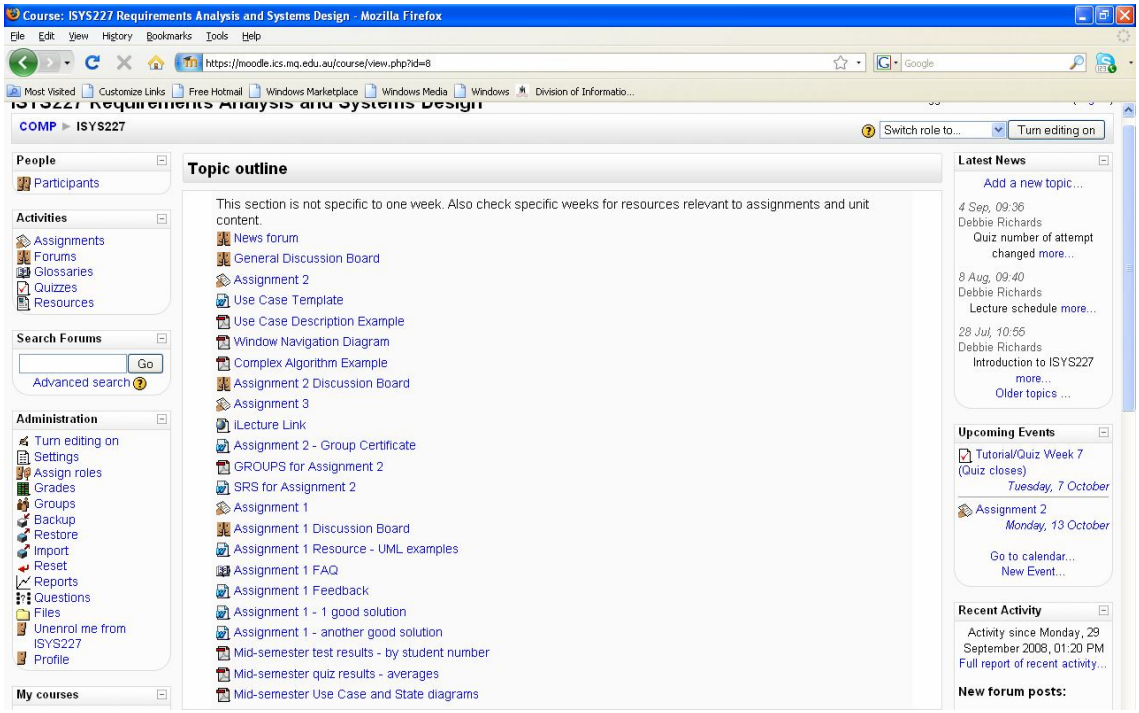


Figure 2: The LAMS sequence to guide the PBL and supporting activities

Following the tutorial, students are required to answer a few short questions individually to ensure they reflect on the learning from the tutorial activity. The reflections/answers are submitted and awarded a mark out of 0.5, providing an overall weekly mark for the quiz, tutorial and reflection of one (1), representing 12% of the total unit marks. A stop gate is shown at the end of the sequence to indicate that the activities are completed for that week. This sequence is repeated each week. A noticeboard has been included to keep students informed of any news or information relevant to the unit for that week. It is not connected to the LAMS sequence as it is not specific to any step in the sequence.



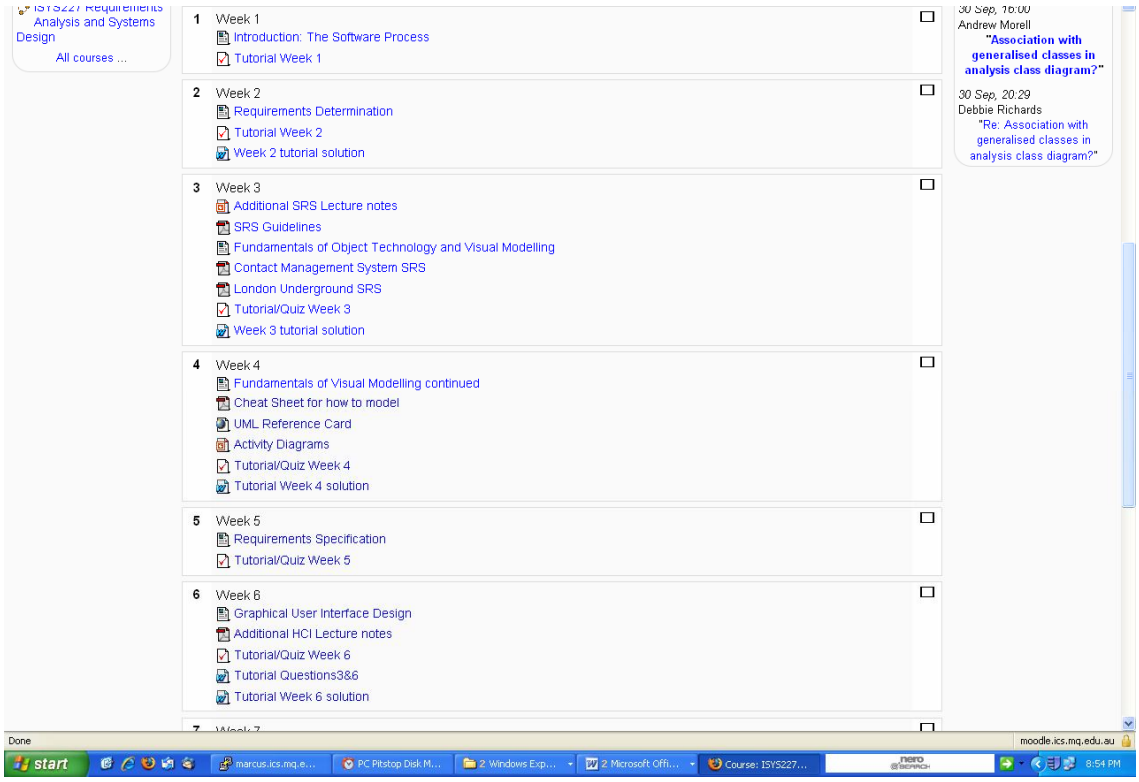


Figure 3: The main MOODLE page for the Analysis and Design unit.

The learning design presented was created to be incorporated into the Blackboard LMS used at our university. However, the sequence was not implemented because some technical issues (network speed and access) raised concerns as to whether the system would be seamless and response times acceptable. Also, the semester was rapidly approaching and it was unclear if the issues could be resolved before the start of semester. Students were already being asked to use a number of new software tools in this unit. For example, a product known as TRAC was being introduced to support project management and version control of files, an automated response systems (aka keypads/clickers) were used for in-class feedback and for assessment in the mid-semester quiz. Additionally it was decided within the department to trial the replacement of BlackBoard with MOODLE. Under these circumstances, we decided not to additionally require students and teachers to learn LAMS, but to use any features available in the technologies we had already chosen to include in the unit (such as forums and quizzes) and to handle some of the activities and the flows manually. As MOODLE provided the learning platform for the redesigned unit, we describe it next. The main screen can be seen in Fig. 3.

Implementing our learning design with the aid of MOODLE

MOODLE provides a central and shared repository which structures and provides access to numerous learning objects and activities for the students which have been created by the teacher and sometimes by the students (as in discussion board questions and answers) (see Fig. 3). However, the site is more than an archive, it is a meeting place.

From a number of possible options we chose to organise the learning resources mostly by the week in which they were needed/provided (though we took the topic option to achieve this). The teaching staff and our students have found this much more transparent, intuitive and usable as compared to the structure of the unit when using Blackboard. MOODLE offers a large range of features including forums, resources, quizzes, group and individual assessment management. We have been using all of these features to our satisfaction (with the exception of the use of a drop down list for entering grades which needed to be accurate to two/three decimal points). In particular we have found the quiz facility very flexible and

integral to the implementation and management of our scaffolded PBL design. As shown in Fig. 4, each week immediately following the lecture, a quiz with 10-16 questions was made available to students. A mixture of multiple-choice, true and false, matching, embedded answers (cloze) and short answer questions were used. The ability to time, randomly order, automatically mark, provide feedback, monitor and graph the results for each question and quiz was very useful to both the students and the teacher.

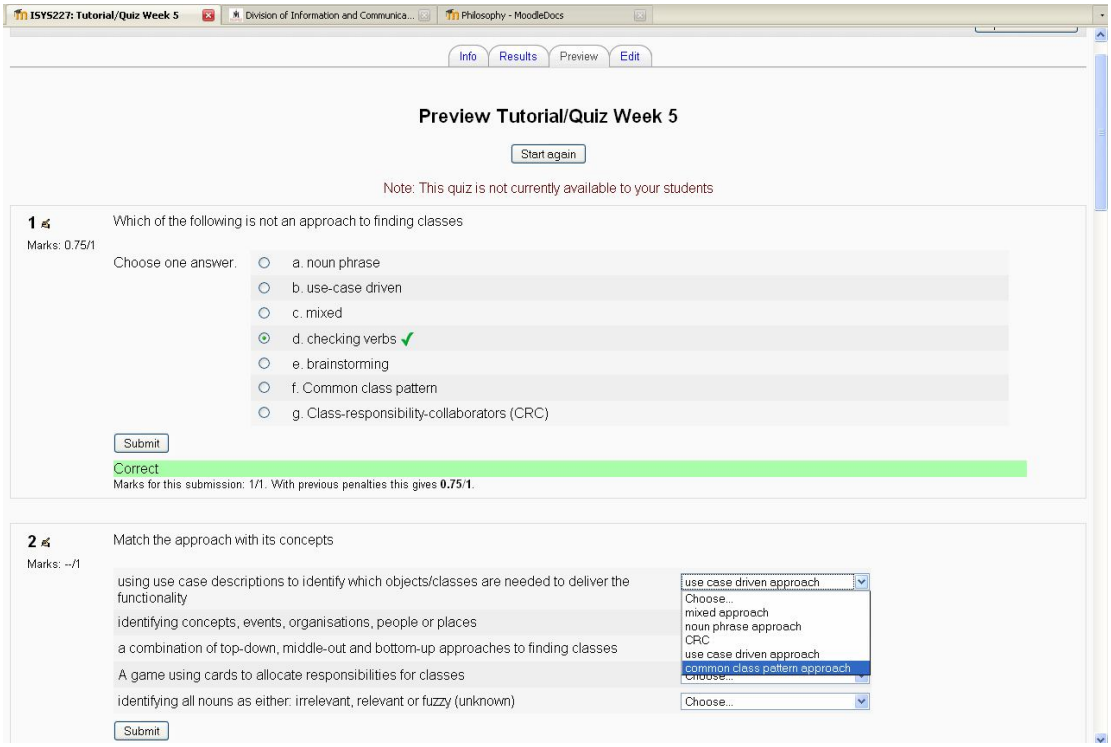


Figure 4: A snapshot of the quiz for week 5.

The quiz served the purpose of priming the students with the key concepts, terms and theories that would be relevant for the PBL experience in their weekly tutorial class. It was a quick, and some students have said enjoyable, way of reminding students about the reading material and the lecture they had just attended. Some students used the quiz to test what they understood and remembered. Many others used the quiz to guide and focus their readings of the textbook, lecture overheads and additional lecture material. From an analysis of the student activity logs provided by MOODLE, it was apparent that the quizzes for weeks 1-6 were revisited by most of the students in the week prior to the mid-semester test (though they couldn't resubmit their answers) for the purpose of revision. It is expected that the quizzes will be used again for revision before the final exam.

Non-Computer based Activities

Some of the learning activities shown in the LAMS sequence in Fig. 2 were conducted offline. This includes the two-hour weekly PBL-based tutorial session. As described above, the weekly quiz consolidating the lecture and reading content was designed to scaffold and expedite the discovery of the learning concepts during the PBL activities in the tutorial. Also, within the tutorial session we provided a number of resources to further scaffold students. Each week there were handouts and laminated "flash cards" containing examples, models, key terms and techniques to assist students with the problem solving activity. The learning design as presented earlier (see Fig. 1) acted as a "run sheet" including activities, questions, problems and possible solutions for the tutor. As a further example to the run sheet/learning design given in Fig. 1, Fig. 5 provides a snippet demonstrating the use of visual material to reinforce concepts and to understand relationships between concepts instruction.

Activity 5: Whole class activity – bringing all the ideas together this week. 10 minutes
Students will have seen that other activities and issues are part of building software and that some of the SDLC were in fact process models such as RUP. How do the different standards (COBIT, CMM, ITIL, ISO), process models (RUP, agile, aspect, spiral, MDA), systems planning tools fit together (BPR, VCM, SWOT, ISA) relate to each other?
Stick all the other slides on the board and ask where they should go – how do they fit? After they think for about 30 seconds or someone suggests what type of thing it is (eg RUP is a process model) then put up the three headings – 1. process models, 2. standards, 3. systems planning to get them started and ask them to consider where about they belong in relation to the SDLC. Then ask where each of the individual things go i.e. are they system planning, process standard or process model?
Layout something like this – but think what makes most sense and you might change it depending on what each groups thinks.

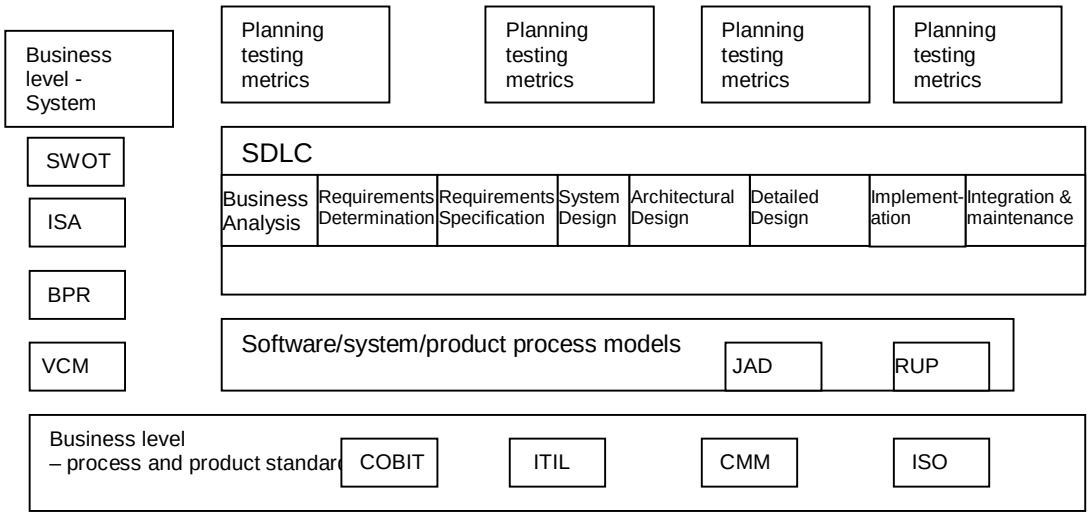


Figure 5: Example of the use of visual material and mind/concept mapping within the tutorials.

The Tutor's View of PBL

PBL proposes student-centred and self-directed learning conducted in small groups facilitated by teachers in which problems are used to focus and motivate learning (Barrows, 1996). To achieve this, tutors need to be trained, monitored and continuously supported in their roles as PBL facilitators. Otherwise, tutors faced with guiding students in PBL sessions may revert back to providing mini-lectures or the solutions as they can find the open-endedness and breadth of content covered during PBL sessions somewhat overwhelming (Vernon & Blake, 1993).

In our unit, we have been fortunate to be able to employ one tutor who recognised the potential of using PBL to run all of the tutorial sessions. This has allowed uniformity across classes, but more importantly it has been possible to discuss how the tutorial should be conducted in detail prior to the tutorials and throughout the week as the sessions occur. The tutor commented about her experience:

> "PBL is ideal for working in groups and I think this can benefit the students as they are more likely to brainstorm and come up with ideas and thoughts before they reach a conclusion/ possible solution. PBL and working in groups also takes the pressure off each individual to come up with the "correct" or "only" answer to a given problem/question."

The tutor contrasted this situation with traditional learning where the students are given a set of questions, where each question has one answer:

> "The students are more likely to try to memorize the answer in a traditional approach as opposed to understand it. In PBL they have to understand the underlying

> principles before they can come up with a solution, which ultimately forces the students to become more involved in the learning process."

She did have some reservations regarding collaborative learning within PBL however:

> "The downside to working in groups is that some students take a much more relaxed approach to participating and end up not doing or learning much, if anything."

The Students' View of PBL

To add to the tutors reservations can be resistance from students to PBL. As many higher education teachers are too aware, students are becoming increasingly time poor, due to part or full-time employment needed to fund their lifestyles, and non-study focused. Hence students are often unwilling to be self-directed learners. Many students are not only unwilling to take responsibility for their own learning but they may also complain that tutors/teachers are shirking their responsibilities when they will not provide mini-lectures or the answers (Schmidt and de Varies, 1992).

At the end of the semester we will survey students (using a survey similar to that used by Ahlfeldt, Mehta and Sellnow, 2005) regarding how they have found the PBL sessions and the quizzes to determine whether the two have been found to be useful learning vehicles independently and also as a learning sequence. We also intend to conduct interviews with some students and the tutor to determine their experiences, attitudes and suggestions.

Conclusion

The benefits of replacing a one hour traditional computer laboratory-based practical and one hour class room-based tutorial with a two-hour PBL session are yet to be determined for this unit. We are currently in week 11 of the semester and the students and staff will be interviewed at the completion of the unit. Our motivation for introducing PBL was a failure rate of around 40% in the final exam for this unit in the previous year, so we will be interested to see whether this cohort of students achieve greater success in the final exam at the end of this year. Further, we had observed over the past three years the inability of many students in their third year project unit to apply the knowledge and skills they should have acquired from this second year unit. We will also assess whether these students exhibit better skills transfer in their third year project in 2009.

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