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Software Quality: from Theory to Practice

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Abstract— **For over ten years, the first author of this paper (IR) has been teaching Software Quality in the traditional fashion where students are presented with materials through lecture and tutorial format. Her experience has been that concepts are difficult to convey, particularly if the students do not have prior industrial experience. Additionally, standards are topics which can become very boring to teach and learn. These difficulties have resulted in an uninteresting learning environment where it is hard to gauge what learning, if any, has been undertaken by the students. Therefore, in conjunction with the second author (YD), a problem-based learning practitioner and researcher, we investigated what other teaching methodologies could be used to improve the situation. This has resulted in IR implementing a problem-based learning instructional approach in the classroom during academic year 2009-2010. Through focusing on software systems within hospitals, students within a software quality class have developed a software quality plan supported by an academic paper.**

Analysing the implementation of PBL in the class, we demonstrate that students have developed a greater understanding of software quality concepts and standards. consistent with the findings of Hmelo-Silver [1], **it has also resulted in students experiencing and learning competencies such as team working, presentation and discussion, which are required in an industrial environment.**

Keywords-problem-based learning, PBL, software quality, competencies, software quality plan.

I. INTRODUCTION

One of the authors (IR) has taught software quality for the past 10 years. While there is much research available on software quality and the concepts, it is often difficult to deliver these concepts to students. The requirement is that students who complete the class can understand the concepts, resulting in their implementation in their professional lives, and the Learning Outcomes for the Software Engineering Quality module which is discussed in this paper reflects this:

1. Devise a set of test cases to verify a set of functional and non-functional requirements.
2. Analyse various software development processes (examples include project management, risk management, reviews, configuration management).
3. Prescribe various mechanisms that promote the institutionalization of processes within a software development organization.
4. Investigate how the results of a software process assessment may be used.
5. Describe one software process model and the process categories within that model (e.g. Software Process Improvement and Capability determination Model, ISO 15504).
6. Define the concepts of product and process quality.

However, imparting this information to groups of students is not always easy, becoming more difficult as diversity between students increases. To overcome these difficulties IR implemented the problem-based learning teaching methodology in her software quality class. She designed and developed a curriculum which is benefitting the students.

II. PROBLEM-BASED LEARNING

A. *History of Problem-Based Learning*

Problem-based learning (PBL), as it is known today, began with the Faculty of Medicine at McMaster University in Canada in the mid 1960's when they introduced the tutorial process as central to its entire curriculum development [2]. The McMaster philosophy led to other medical schools, for example, the University of Limburg at Maastricht in the Netherlands, the University of Newcastle in Australia, and the University of New Mexico in the United States, to adapt the McMaster model of problem-based learning and develop their own elements to influence to PBL as we know it today. PBL is an approach to structuring the curriculum that involves confronting students with problems from practice which provide a stimulus for learning [3]. This is further reiterated by Barrows [4],[5],[6] when he states that "PBL is characterized as an approach to learning in which students are given more control over their learning than a traditional approach, and asked to work in small groups, and most importantly acquire new knowledge only as a necessary step in solving authentic, ill-structured, and cross-disciplinary problems representative of professional practice".

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There is so much that is different about a PBL curriculum as contrasted with the traditional curriculum model of the previous decades that any real movement to PBL would have to be considered a "paradigm shift", implying a very different way of providing medical education. Barrows, one of the major contributors to the development of PBL defines it as "The learning which results from the process of working towards the understanding of, or resolution of a problem" [2]. While PBL originated in and had been refined by medical education, it has spread to other professional disciplines in higher education such as engineering and science.

B. Expectations from Problem-Based Learning

Schmidt [7],[8] and Coles [9],[10] stress the importance of linking theory with practice and the importance of asking students to expand on the new knowledge. The concept of making connections brings things together, linking prior knowledge or learning with new knowledge. For example, they suggest participating in private study, group problem solving, preparing and presenting papers or cases, concepts maps development, posing and answering questions, taking notes, peers tutoring and reflection. PBL presents several critical shifts from traditional educational models [11].

The PBL goal is long-term learning that results in behavioral change and not just conceptual mastery [12]. The growing number of institutions that have successfully incorporated PBL into their management curriculum supports the argument that we may well be dramatically changing the next generation of business leaders [13],[14].

A major study undertaken by Walker & Leary [15] represents the first full synthesis to examine the impact of PBL. It concluded that PBL students either did as well as, or better than, their lecture-based counterparts. Students tended to do better when the subject matter was outside medical education. As PBL becomes more mainstream [16], this analysis indicates that PBL students are not being disadvantaged by the implementation of a new process. It is agreed that PBL will undoubtedly change in its development and implementation in the 21st century. This is not unique and change will be needed to cope with the ever changing environment that we come across. However, the preparation of students through PBL for the environment that they are facing will go on.

The need to prepare graduates for professional life is reviewed in Armarego [17]. The development of new technologies and the increasing rates of changes in levels of complexity has resulted in organisations requiring multi-faceted employees. PBL holds great promise for preparing students to operate in such an environment. It does this through its collaborative self-directed, authentic learning, characterised by problem-finding, problem-solving, reiteration and self-evaluation. It is this process that Barrows says what distinguishes *true* PBL from "same-name" methods that use a problem of *any sort* somewhere in the teaching/learning sequence. With this insight, students are better able to develop competencies in the often neglected, affective learning dimension and they gain a more balanced understanding of complex situations. Furthermore, affective learning serves as a critical link between cognitive and behavioural learning that motivates students and enhances educational outcomes.

III. RESEARCH METHODOLOGY

This paper presents a study of the implementation of PBL within a software quality module[1]. Within the class, only one of the students has participated in a PBL environment prior to attending this module. A lecturer's reflective journal which is written up within 24 hours of holding the class each week is maintained. Each of the students participating in the module also keeps a reflective journal which is assessed. For this research, about 70% of the way through the module, each student was surveyed via e-mail asking them to discuss the positive and negative experiences from their attendance. Implementation of PBL within the class was observed, the lecturer was interviewed and her reflective journal was analysed. A presentation to a peer group and participation in discussion about the module were also analysed.

IV. CASE STUDY

A. Module Description

PBL was implemented in the Software Engineering Quality module within the M.Sc. in Software Engineering at the University of Limerick, Ireland. Fourteen students participated in the module. These students come from a variety of backgrounds, which can cause problems when teaching the module. They include full-time and part-time students. Some of them have industry experience and others are recent graduates. In addition, of the 14 students, 6 are from Asia and are not native speakers. The remainder of the students are from English-speaking countries.

A. What happened before?

The module was previously run through holding a double lecture weekly in standard classroom format (see Figure 1) – the lecturer talking through a pre-prepared lecture which was presented on MS powerpoint slides. Students were given a coffee break after one lecture, in the expectation that this break would support their learning when they listened for the second lecture. This style resulted in the lecturer doing the majority of talking. While, at times, the lecturer did pose some questions

[1] A module is a 12 week course with a minimum of 24 lectures, each 50 minutes long, normally run with 2 lectures per week.

to the class, or involved them in interactive activities, overall, throughout the semester, there was little interaction between the students and the lecturer and even less between students themselves. Once or twice during the semester, a guest lecturer would normally present for one hour, followed by a second lecture from the module lecturer. Students read a limited number of assigned papers. Overall, this teaching resulted in uninteresting classes for the students and the lecturer. Little or no feedback in either direction was given. Additionally, students found it difficult to learn software quality concepts.

Assessment for the module was divided between a team project and final exam, worth approximately 40% and 60% respectively. The project involved self-selected groups working together outside of class time, and presenting a final paper at the end of semester. The project was not discussed in class, and any learning which a group had done was not shared within the class. There was no record of individual involvement in the project. In addition, the project usually took the format of a case study which required the students to 'figure out' a domain in which they may not have had any specific interest. The final exam was used to examine concepts which had been presented in class, and while those that did reading outside of class performed well in the exams, there was no real incentive for students to research topics on their own.

Figure 1. Classroom layout for traditional lecture

While there is normally an interesting mix of students in the class with a variety of backgrounds and experience, no advantage was taken of this. For example, students with industrial experience were not given the opportunity to share these experiences. In addition, international student diversity is not appreciated in the traditional classroom. (In fact, when starting the PBL class, international students introduced themselves to their classmates, even though this was the second semester in which they were in class together).

A. *What happens now?*

This year, the class were introduced to PBL learning techniques. Recognising that a good problem (the trigger) is critical to the success of the course, the lecturer designed a problem based on the following criteria: it would be engaging and interesting to the students, it would motivate them to look for a clear and deep understanding of the concepts presented and that it would relate to a situation with which they were familiar. The trigger in Figure 2 was presented to the students during the second week of the module.

TRIGGER

Students viewed a video (accessed April 2010):
http://www.youtube.com/watch?v=-xrrk-XhgVc
and were then asked to:
Develop and write the software quality plan for a hospital.

Figure 2. Problem presented to the students

As with previously, the class is run over a double lecture. However, the traditional lecturing format is no longer used. At the start of the semester, the students were split into groups of five/four by the lecturer, ensuring that each team had at least 2 Asian (Chinese, Japanese, India, Pakistani) students. At the start of each lecture, students join their groups immediately and work on the problem. The lecturer circulates between the groups as a facilitator, discussing any issues that may arise, and ensuring that all groups are working towards a relevant software quality plan. She will sometimes give them pointers as to where to find further information, and, when required, she will give a short 10-15 minute lecture. This ensures that all groups are benefitting from her knowledge and are steered in a particular direction. For example, one lecture was held to ensure that students understood the breakdown of processes into Organisation, Management, Engineering, Customer-Supplier and Maintenance processes, thus removing exclusive focus on Engineering processes. Additionally, at the end of class, the day's work is summarised during a short 5-10 minute discussion to all students.

Figure 3. Monitoring within a Hospital

To ensure an understanding of the requirement, and also, to give students an insight into the hospital quality system, a subject-matter expert visited the class after they had researched the problem for 4 weeks. She gave a very short presentation,

and then students questioned her for 90 minutes about software processes and data quality within the hospital. This input was invaluable in allowing the students to understand the strengths and weaknesses of the quality systems within the hospital. In particular, as seen in Figure 3, students now understand that, because of electronic monitors within hospitals, software has become increasingly important for the treatment of patients.

The module is continually assessed with no final exam. Each group prepares a paper which is worth 25% of the module. Additionally, they present their work to the class – once half-way through and once at the end of the module. These presentations are worth a total of 25%, with 50% of this allocated to the individual for presentation skills. Ten percent is allocated to participation within their group during class time and 10% to four individual oral exams. They also produce an individual portfolio, worth 30%, which includes summaries of papers they have read, a reflective journal, minutes of meetings and an outline of their participation in the project. In addition, the lecturer keeps a reflective journal which is completed within 24 hours of class each week.

Figure 4. PBL discussion group

During group discussion, the students identify roles for each meeting – discussion leader, recorder, observer and team members. They are expected to keep minutes of their meetings and review these minutes each week. At the previous meeting, it is normal that each student has been tasked with some action items and these are discussed. During the meetings, students have access to papers which have been identified by the group. They also have internet access, so they can view any papers or other information they require. Some of the groups move to the adjacent café to hold their meetings and discussions (illustrated in Figure 4).

V. ANALYSIS

B. Student/Lecturer Perspective: What has worked?

The Software Quality module has moved from being a traditional lecture where there was little or no interaction within the classroom to a very interactive situation where there is input from students and lecturer alike. This has resulted in a situation where previous industrial experience, medical experiences and international experiences all have inputs to the discussion and learning by the students and has been described as *a very interesting and innovative way to learn*[2]. From the mid-semester presentations, it is obvious that student knowledge has increased, as they demonstrated an understanding of material which had not been observed when this module had been taught previously. Students themselves recognize this: *Personally, I believe that I have learnt more through PBL in the first 8 weeks than I would have in a standard classroom environment*. They also notice that *..the things you learn through …stay with you longer.* Both students and lecturer are enjoying the classes, and they have given the students *…an opportunity to get to know the rest of my classmates better...* In addition, students belong to a more interactive environment, actively participating in the meetings, and providing new knowledge which has been learned between meetings. This has given them *a real sense of solving a problem*, and they are learning *from each other in a "Student" way.* This is in the knowledge that they …. *have put in more work….* Student attendance has improved, and students are very conscious of disrupting their group if they are unable to attend for a particular reason. This usually results in an e-mail being sent to the group and to the lecturer explaining their absence. Students work consistently, and each week it is noticeable that the groups are progressing with their software quality plans. Students have been reviewing academic papers, which is a requirement for this level, but something which has not obviously been undertaken in the past. In addition, the students are given regular feedback, both through discussion with the lecturer and through assessment results being made available soon after class. Many organizations require that they acquire soft skills. PBL provides an opportunity for them to learn these. Students themselves note that they have.*learned a lot about team work* and see that the PBL experience will be *beneficial in industry as we are expected to work on our own, look at the problem and provide solutions for it.* Students' feedback also indicates that *PBL has been a success thus far.*

A. Student/Lecturer Perspective: What has not worked?

Initially it was difficult to get students into process at first as they had not previously experienced PBL. They had to understand their role within the group, which varied from week to week. However, this caused problems and *maybe if they retained the role for a longer time period there could be some continuity and people could get immersed in the given role. As it is I believe the roles are not paid any great attention and it is the individuals' personalities which determine their role.* There is also recognition that their active participation in the

[2] Direct quotes from student and lecturer feedback is presented in italics within the text.

problem was the key to their learning and when there people did not become involved *sharing of the knowledge is reduced*. Participation needs to be controlled - *at times ….we had a lack of direction, although that was almost always solved quickly by guidance and talking as a group.* When students came into class without work completed, *members of a team may not participate,* it was particularly obvious to both the rest of the group and to the lecturer and it became a point of frustration … *some team members do not contribute or fail to do the work that they are assigned to do and that becomes hard on the other team members,*. However, once they realized that lack of participation caused significant problems, their work rate improved and consequently their progress in the module improved.

Additionally, there was a requirement to carry out assessments throughout the semester. This consisted mainly of oral examination and observation of the students in their work. As this was not the normal way of assessment, this proved quite difficult for the lecturer.

Another concern was whether this concept suited all those involved in the class. We recognize that the same learning technique many not be universally successful, and this was also noted by the students: *I don't think it suits some people in my group.*

C. Comparison with PBL research

PBL can work well if a good problem is presented and the basic structure of the 8-step approach is followed. In this case, there was an excellent problem depicting a patient arriving at an Accident and Emergency unit surrounded by an array of electronic equipment. The problem could be played from a YouTube video clip many times until students grasped the underlying concept of what was required of them in solving the problem. It was not unusual that the students were puzzled and may even have been bewildered in trying to come to grips with was required of them from this new process.

PBL could be considered a threshold concept, a troublesome space [21] but once you come to understand that there is a framework to follow - albeit not the traditional framework - things settle down and the real learning begins. The manner in which novices address problems is different to experts. Gijselaers and Woltjer [22] agree that "novices tend to organize their knowledge representations around the specifics of the problem, whereas experts move to the more abstract level to see the general principles". The manner in how this group of novices operated would support this theory. The students requested more direction and perhaps the identification of the learning outcomes. While it is difficult for a lecturer (now facilitator to do this), providing the students with information other than that which is critical to get them moving should be avoided. With a well-structured problem they will reach their learning outcomes independently.

The tutorial process in this case was followed with a mixture of PBL group work and the use of the lecturer as an independent resource. The lecturer designed and developed a module that was assessed through a range of innovative assignments.

The importance of the role allocation, and its importance to the PBL process, generally tends to be overlooked in the PBL literature. While there is a strong focus on problem type and facilitator training, very little attention is paid in the literature to role development in PBL. Quite apart from the improved operation of the PBL process, the skills developed in the managing of a PBL tutorial are invaluable. The Discussion Leader's management of the opening and closing discussion, the feedback from the Observer and the collation of the tutorial memo from the Recorder can be taken to the workplace. In this particular case, the roles were seen as an inconvenience rather than an opportunity to develop further skills and therefore, this opportunity was lost.

When implementing PBL within the software quality class, improvements in preparing students for the workplace and the demands that will be placed on them are obvious. Students have gained confidence and skills that they were unlikely to develop through the traditional method of course delivery.

It is recognized that it can be difficult to assess students during the PBL group work. This is not unusual, as support is needed if all the elements of PBL are to be implemented.

To have universities working in isolation without a strong industrial link is not good practice, regardless of the methodologies used. Garrick, Chan & Lai [18] suggest that workplaces are now the real place of learning as they have the most up-to-date technology, computerized systems and sophisticated networks, and that workplace learning poses a real threat to universities. It identifies a range of challenges for the universities of the twenty-first century to overcome if they are to retain their place as a vital part of the social fabric. In this module, a first step was taken which involved a subject-matter expert meeting with the students.

VI. SUGGESTED IMPROVEMENTS

When students provided us with their positive and negative comments they included suggestions as to how the module could be improved. What was interesting about this was that, unlike previously, feedback was now being given in both directions.

Some students were looking for more structure to the module where the lecturer *could ask the group for a table of contents (before we start writing)* …. They also suggested *having more milestones and a clear work breakdown structure* …. One of

the students considered the module within the course of study: *If in a previous module such as … software design, the students were tasked to design [and implement] a solution. If then … the Software Quality module looked at the project … and devised a software quality plan for it. Once a software quality plan was drawn up the students would be tasked with comparing their ad-hoc design and development process with the processes in their software quality plan*. Additionally, students have recognized the need for more time to enhance their presentation skills, and this may be a means to support the assessment process. The improvements suggested to the operation of the PBL in this software engineering classroom have been noted.

VII. CONCLUSION

Problem-based learning has been a positive experience for both the students and the lecturer involved. From the lecturing perspective, it has provided a different method of teaching which is interactive and interesting. It has provided students with the experience of solving a real-world problem and the opportunity for them to understand and absorb the topic. Students who complete this module will achieve the learning outcomes which have been defined as well as having gained other soft skills which have not been exclusively listed.

One question which concerns us is whether it is possible to roll out PBL concepts to a work based environment and consequently increase software quality knowledge? Joham [19] argues that problem-based learning is an effective learning strategy in a management discipline. However, we need to identify the different factors that can effect PBL, and the factors that can help how students experience the PBL context, student perceptions of PBL assessments and what type of learning arises from PBL assessments. Additional research should be carried out to understand the effectiveness of PBL in achieving desired knowledge acquisition and problem-solving skills and outcomes for Software Engineers.

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