Beyond PBL: Preparing Graduates for Professional Practice

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Abstract

An analysis of practitioner studies concludes that a gap exists between industry expectations of IT graduates and formal education, in particular in non-technical skills and knowledge. This paper reports on the final cycle of an Action Research project to examine and implement alternative learning environments for Software Engineering. A model based on reflective practice, founded on the evaluation of previous cycles applying Cognitive Apprenticeship and Problem-based Learning, was developed and implemented. This study looked at the alignment between student approaches to learning and the environment developed, in particular student disposition towards deep or surface learning. Although evaluation shows the student cohort achieved significantly higher scores in their assessment that those of previous offerings, it was notable that students who reported themselves as adopting surface approaches were less comfortable with the environment. However, they still exhibited deep learning characteristics when observed in a subsequent course.

While an understanding of student learning is fundamental in developing learning environments, alignment between discipline and learning is also critical in educating competent practitioners. Results of this study show that students placed in an environment that enables them to model professional practice, and reflect on that modelling, should be much better prepared for the workplace.

1. Introduction

Previous papers [1-3] have described the stages of a gradual shift from more traditional engineering learning in an attempt, within the School of Engineering Science at Murdoch University, to address characteristics specific to Software Engineering (SE). The learning environment has undergone several iterations. This paper discussed the final outcome – a learning model based on reflective practice.

A lack of alignment between professional practice and education has triggered the move to alternative educational models. Numerous studies in IS [4-6] and CS/Engineering [7-9] indicate that industry requires professionals who can work within an organisational structure,. They need skills and analytical techniques that allow them to learn, evaluate and apply emerging technologies in a collaborative environment.

Formal education has been slow to engage with these needs. Bach [10] stated that one reason software engineering is not more seriously studied is the common industry belief that most of the books and classes that teach it are “impractical”. Others have explored the inadequate training software professionals receive [9, 11]. The suggestion [6] is that tradition and inertia act as significant barriers to substantial revisions to curricula in line with the findings of practitioner-based studies.

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2. Previous work – a *CreativePBL* approach

The learning environment the SE students experienced within this School was developed to enhance divergent thinking and creative potential [3]. The objective was to address claims that creativity and innovation in engineering is poorly understood and not adequately fostered in undergraduate teaching [12]. In addition, the explicit development of metacognitive strategies, and the ability to reflect *in* as well as *on* action [13] enables students to use past experience on a general level, while still being able to deal with each new problem situation in its own terms [14] – necessary skills for a rapidly changing profession. Glass [15] also suggests that discipline (imposed by methodology, for example) is necessary for the creative design of software systems.

This environment, based on Problem-based Learning (PBL), therefore, focussed on *metacognitive* strategies and *reflection* to assist students to transfer the skills and knowledge learnt to other contexts. *Creativity*-enhancing activities were incorporated within the curriculum, while strategies for divergent as well as convergent thinking were made explicit to foster *adaptability* in students.

Evaluation of the model as implemented during 2003 indicated that student perception of their learning within the environment was mixed: comments on a lack of *mastery* of subjects; of only *focusing on components* addressed by the project work, on *delegating* and *relying* on others for concepts, indicate less content learning. However, these were balanced by student perception that they learnt more in the areas of *research*, *communications*, *team* and *negotiation skills*. A sense of ownership of the learning was also exhibited "*there were ample resources & up to us to take it"*.

Table 1. ASI scales for Reproduction and Meaning Orientation [16]

Scale	Meaning
Meaning Orientation	
Deep Approach	active questioning in learning
Use of evidence	relating evidence to conclusions
Interrelating ideas	relating to other parts of the course
Comprehension learning	readiness to map out subject area and think divergently
Reproduction Orientation	
Surface approach	pre occupation with memorisation
Syllabus-boundness	relying on staff to define learning tasks
Improvidence	over-cautious reliance on details
Fear of failure	pessimism and anxiety about academic outcomes

Despite the measure of success of this *CreativePBL* model, the learning diagnostics results indicated at least as strong a bias to surface learning as there was to deep learning in the class (the student cohort). The Approaches to Study Inventory (ASI) [17] showed that students were very much sitting on the fence between learning for meaning (MO) (mean 2.53, standard deviation 0.43) and learning for reproduction (RO) (mean 2.56, standard deviation 0.41). Table 1 gives a description of the scales applied and Figure 1 the ASI results for this group (many of the students show similar scores for MO and RO (eg Student 9). Students who learn not just to pass exams score higher on MO). This confirmed the analysis of student comments provided through School-based feedback mechanisms (eg Year Survey) and reflective comments included in assessment elements.

In effect, meaning-oriented students were more likely to see their learning environment in positive terms while reproduction orientation was associated with the

view that the learning environment was difficult. This supports the work of Entwistle & Tait [18, 19]

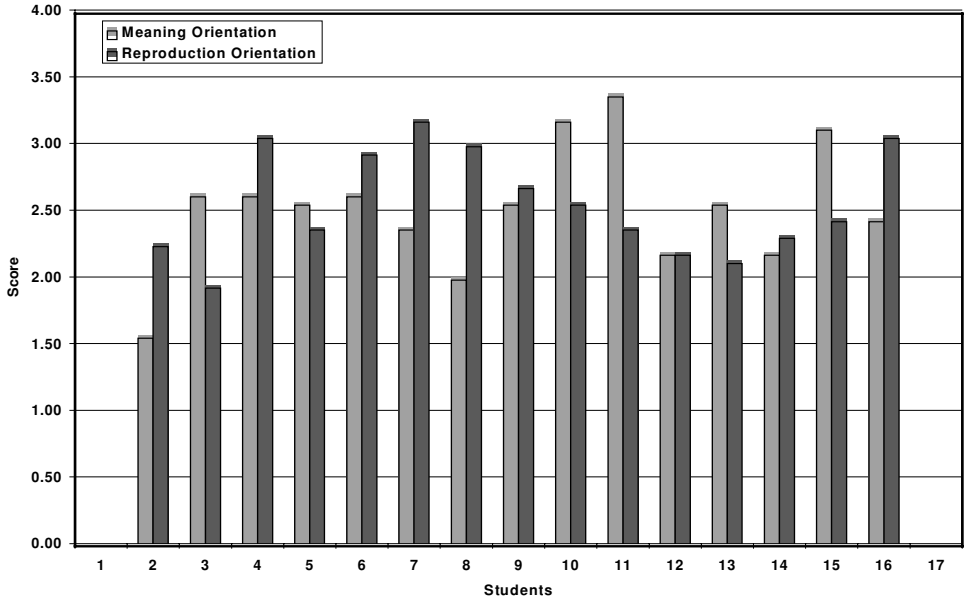

Figure 1. ASI results for 2003 student cohort taking a course based on the *CreativePBL model*

3. Learning for professional practice

3.1. Issues with PBL

The *CreativePBL* environment has gone some way to addressing the issue of preparing students for situations that are highly variable and novel [20]:

- it shifts the focus from teaching to learning: the environment is student-centred and minimises 'teaching'
- it concentrates on developing (generic) capabilities and on student learning outcomes
- it enables moves from highly differentiated and fragmented curricula to integrated learning programmes.

Ultimately, however, the *CreativePBL* model is a process-oriented approach (implying process is of greater importance then the product [21]). This meant the students were spending too much time applying and monitoring the process, at the expense of their engagement with the learning environment. While practitioners acknowledge opportunism and heuristic insight are important in design, the PBL process was seen as an inhibitor – it did not satisfy the need for contingency measures to be available in the creative nature of design, where the unexpected is expected [22].

3.2. Reflective learning in studios

Cowan [23] notes that there is as yet no authoritative educational explanation of teaching and learning centred on reflection. However, there are models of learning that describe reflection as part of the process (eg [24, 25]). Reflection centres on identifying discrepancies between beliefs and actions. Interest in reflective practice dates back to Dewey [26] and his work with experiential learning theories.

The ideas discussed in the work of Argyris and Schön [27] and the many writings of Schön (eg [13, 25, 28, 29]) have triggered a rethinking about professional education. Although weaknesses and inconsistencies have been identified in the approach (eg [30]), both practitioners and educators recognise that programmes for the professions need to provide opportunities for students to develop 'soft' skills, embedded as a normal part of formal education [8, 31]. Practitioner studies have also indicated the importance of graduates' ability to keep up with changes in knowledge and information requirements. Therefore a further issue to be tackled in our context was to provide strategies for life-long learning.

What is needed, then, is a model of education that adds, to the positive aspects of both PBL and the reflective studios advocated by Schön, strategies to integrate the evaluation of 'practical' outcomes of the problem with the creative process. Aspects of Laurillard's learning discourse [32], with teachback [33], and self-explanation [34] are also seen as key phenomena in learning. These ideas form the basis for the *Studio Learning* model introduced in the SE programme (and indeed, in all engineering specialisations) during 2005.

3.3. Implementing *Studio Learning*

The SE curriculum was defined as three Design Studios, taken over the last two years of the Engineering programme. Rather than time set aside for lectures, tutorials and labs, Studios work in a block-teaching framework – each Studio is allocated 10 hours of class contact (teacher present) and another 10 hours of additional class time. Therefore students were expected to spend a minimum of two days a week on each Studio plus any additional time required by individual study habits.

All 3rd and 4th year students spent Week 1 of semester in an orientation programme. This ensured a common base of understanding and some exposure to issues surrounding such a different mode of learning. Students demonstrated their engagement with this learning model: the quality of the final presentations and diversity of solutions emphasised their ability to be self motivated independent learners, with appropriate processes (eg PBL and group process) established. Significantly, initial observation indicated that students who were at Murdoch Engineering prior to this 'Design Week' were better able to make the shift to Studio Learning - understandable since it is preempted in several courses already running. However, student feedback showed that articulation students and (international) students joining the School on exchange programmes initially found the learning environment disorienting and confronting (the Design Week is discussed in [35]).

Both qualitative and quantitative data was collected from SE students undertaking successive Design Studios – activity logs, reflective journals, critiques of the learning environment and of their performance in groups were all incorporated within the formal assessment structure.

3.4. What actually happened

The students appeared comfortable with the class environment, and were able to work towards the milestones set. Minutes of meetings indicated reasonable work breakdown, while activity logs showed most students were willing to spend time outside of class to achieve the objectives they had set through the PBL process. Comments from the Year Survey in week 4 of semester support this perceptions – only one negative comment was recorded (*heavy workload, takes up a lot of time*) while the

majority of comments were positive ([good]*lecturers/facilitators; lots of learning to do; seems well structured*). The comment from the Year 3 co-ordinator confirms this (one academic oversees each year group of students and deals with issues which go beyond individual courses):

> *the first assessments reflect the novelty of the Design approach to learning for the students. Adjusting to the expectations of the studio format seems to be the greatest issue. … I expect that by the second round of surveys many of these issues, especially related to workloads will have been addressed as the students will have spent more time in the Design Studios.*

Students also noted that with all their studies undertaken within a Studio environment, they felt they were much more in control of their efforts. A focus group to probe this concept resulted in the following:

- students felt academic staff were more tolerant of the needs of other Studios
- with a full-time load of only two Studios student time was not as fragmented across different areas
- except for the (negotiated) compulsory attendance, students could vary the time they spent on each Studio in response to their total learning context. It was the team's role to ensure tasks were on schedule. They concluded that this flexibility reduced stress and allowed them to focus on the learning they needed to achieve for the task.

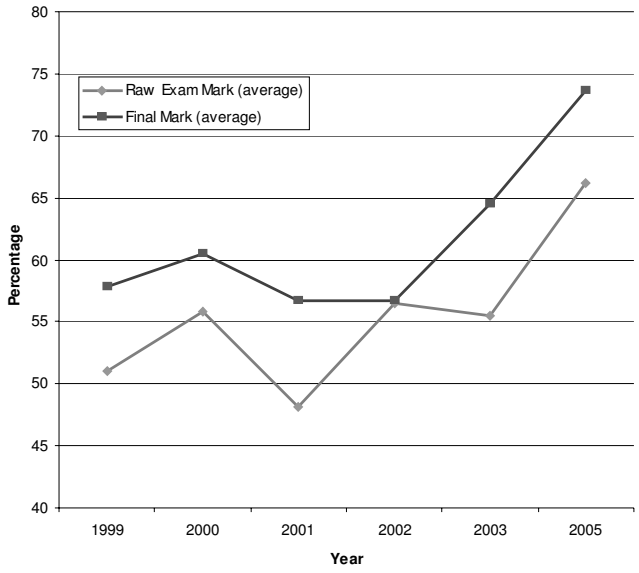

Figure 2. Raw and final exam marks for SE Studio 1

These perceptions were confirmed in student comments in the end-of-semester University survey referring specifically to the first SE Studio:

Student A *This unit teaches a process that is built on knowledge but more importantly that knowledge is converted to a skill via practice on the problem. I don't believe this is achieved by the other style of teaching e.g. lectures and exercise type assignments*

Student B *These design studios are a formalisation of what is occurring naturally i.e. we learn from and work with each other already*

Student C *This method of teaching has provided me with a frame work that I can use to identify future problems and develop solutions.*

The cohort undertook the unit successfully: although there was a reduction in the importance of the final exam, a statistically significant increase in marks across all components was noted, with the exam modelling previous offerings intentionally. The means for both the raw exam marks and the final mark showed a marked improvement, as indicated in Figure 2. This chart is based on the courses with the same content as the Studio. This could be seen to indicate the exam fulfilled its role by *not* measuring how much low-level information the student can reproduce – if that was the case Woods [36]

suggests the end result is poorer performance when compared with students who experience more traditional teaching.

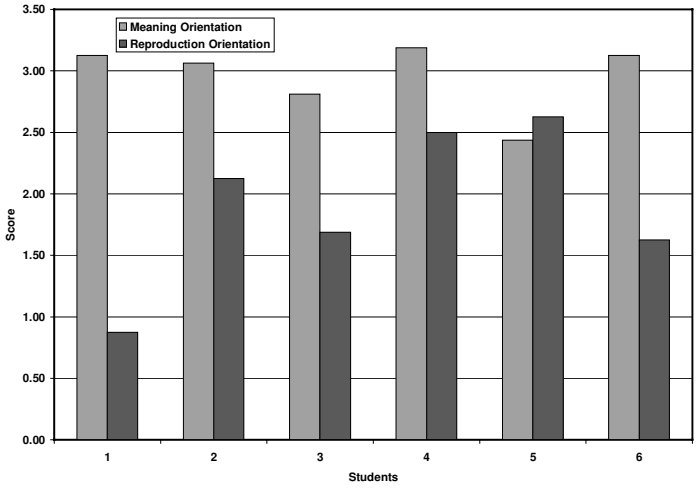

Figure 3. ASI results for students undertaking SE Studio 1 in 2005

What is important to note is that students who reported themselves as adopting surface approaches to learning preferred teaching and assessment procedures supporting that approach, whereas students reporting deep approaches preferred courses which were intellectually challenging and assessment procedures which allowed them to demonstrate understanding. In this context student 5 (in Figure 3)'s comments are pertinent:

> **Student 5** *I personally feel I learn less, I guess this is not my style of learning. It is as good as me taking a unit externally and just staying at home and teaching my self, and if I have problems asking a friend, or researching further. I guess however teaching yourself things you do tend to understand concepts better. However I feel that I am an audiovisual learner, thus listening to someone explaining the concepts, PowerPoint's and teaching it to us makes life easier for me. I believe I gain a better understanding in this way*

These contrast markedly with other students in the cohort, for example:

> **Student 6** *Seriously I feel I have learnt a lot more useful things in this unit compared to most of the other units I have taken at this University -- I am learning more, much more for reasons that include: […] This method of teaching has provided me with a framework that I can use to identify future problems and develop solutions. I have noticed that the design studios require a lot more work from me than if I was working alone. For example I have to spend more time working on problems because of the extra overhead of working in a team (meetings and social interaction). There is also the need to do extra research to gain information that is normally just handed out in a lecture. However I don't mind putting in the extra effort because I feel the extra effort is worth it because I feel more confident that I do know the material (not an impostor) and can apply it to future situation.*

3.5. Advanced learning

The context of the second SE Studio is that students work, in teams, to specify, design and develop a system for an external client. As well as satisfying all the criteria for Studio Learning (including sufficient complexity to permit an evolving design space; multiple acceptable solutions, etc) the problem had sufficient 'length' to require good project management. Interaction with clients was also a feature, and the problem chosen was outside the student or teacher's expertise. This meant students could not rely on the teacher to solve application domain issues, but required them to either consult with the client (who was only minimally available) or find out for themselves.

From the perspective of the cohort undertaking this unit, the learning environment was familiar – the work environment, location, teacher and learning model were all based on SE Studio 1. Students were required to undertake reflective activity logs, minute meetings and rotate the role of project manager (who both set the milestones and scheduled the work for that milestone). It was the cohort's decision whether a final exam would be scheduled – it depended on their ability to present and demonstrate a product by the exam period, with a decision required by Week 10 of semester. An exam has not been set since this choice has been provided to students – it indicates (and the activity logs confirm) strong intrinsic motivation.

In order to monitor class interaction, an independent observer was engaged over several sessions to log the nature of transactions undertaken within the class. Although interaction schedules were only used sparsely due to a resource hunger, they provided significant insight of performance during each learning session: a willingness on the part of the students to vary their behaviour based on the specific needs of the learning situation, calling on the teacher only as required. However, the value of this instrument would be enhanced if the granularity were finer (eg identifying individual group members and their specific interaction patterns). Within the context of this study ethics approval did not allow for video capture of any sessions.

Table 2. Summary of Interaction Schedules for SE Studio 2

Interaction	Percentages		
	Session 1	Session 2	Session 3
Teacher explaining	3.4	13.6	17.2
Teacher demonstrating	2.2	4.5	0
Teacher questioning	2.2	3.1	5.2
Teacher checking	5.5	1.5	9.5
Students discussing with teacher	8.8	6	18.1
Students working individually	48.3	7.6	23.3
Students discussing together	16.5	39.4	4.3
Students questioning	4.3	10.6	16.4
Students explaining	8.8	10.6	5.2
Taking a break		3.1	

The first session logged has team members constructing their understanding of the problem environment. In general students worked individually, accessing resources online and in texts, and 'touched base' with the teacher and with other team members only intermittently. Session 2 is chronologically the next Studio session. Here the change to group interaction is noticeable. The bulk of interactions involve members of the group with or without the teacher exploring and questioning the understanding they had constructed in the previous session. Session 3 occurred some time later, and is based on students coming to grips with a new area of discipline knowledge. Here the bulk of interactions are focused on students questioning, discussing with the teacher, and the teacher explaining. Table 2 provides a summary of the interaction schedules.

4. Conclusion

The Studio Learning model is a dynamic one – students and teacher negotiate how the learning will take place. Studio Learning is designed to give confidence in decision

making to the student throughout the classroom experience - the student who comes out of such a classroom should be much better prepared for professional practice. As such, this student may perform differently from previous conventionally trained employees. They may be more willing to make their own decisions and apply their new skills. The students themselves suggest this is occurring:

From: [Student 1 (in Figure 2)]
Sent: Wednesday, 10 May 2006 12:08 AM

I have been waiting on definitive answers regarding internship possibilities. I mentioned that I had a job for next year ..., well a Software Project within the Company arose that fitted within the guidelines of the University for an Internship. The particular project is a large one and most likely I will only get to the simulation phase. I will be redesigning a complete operating system [...] I am confident of doing the task with both my background in mechanics ..., and also using the methodology of Software Design you have taught me. ...

I still stand by that the Software Design Studio you taught last year really has given much confidence in the process and the importance of Software Design. You should feel good about yourself that you have a positive and practical approach to teaching. ...

The student exhibits many of the attributes this research was attempting to target. He expresses confidence in his own ability to learn and apply new knowledge as well as adapt what was learned. This confidence is based on both the knowledge and metacognitive skills that have been encouraged and developed throughout his formal education.

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