Action research into project based learning in a computer design course

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***Abstract**: This paper presents the experiences of the author and the outcomes from an action research project in an advanced course on computer design. The past experiences of the author indicated that students encountered enormous difficulties during the implementation stage of a practical design project in the course. The aim of the action research was to investigate how the students' learning experiences and outcomes could be improved. The strategies implemented centred around learning from the experiences of the peers and self-assessment. Class project meetings were used as the main forum for implementing and refining the strategies over a number of cycles. The criteria for evaluation of the strategies implemented were student evaluation, project outcomes and feedbacks from colleagues.*

***Keywords**: Project-based learning, peer learning, reflective practice*

Introduction

Is everything about engineering purely applied science? Is engineering always a matter of following a predetermined set of rules, procedures and processes? Or is it as much an art as it is a science? Do engineers need qualities such as *critical thinking* and *reflection*? If they do then what are the best ways to develop them?

The *Employer Satisfaction with Graduate Skills* report, released in March 2000, noted that technical skills in most disciplines become obsolete within five years; so, employers need graduates with the ability to handle those changes. That particularly means *critical thinking* and *communications skills*. However, the survey noted that many Australian university graduates lack these qualities (Lloyd, 2000).

While teaching a final year engineering course on Computer Hardware Design at the University of South Australia in the year 2000, I observed that students were faced with difficulties in implementing a practical design often leading to a stage where they didn't have any clue as to where to go from there. The rigorous engineering methodologies, debugging techniques and testing strategies weren't proving to be adequate in many cases. Faced with this situation I decided in the year 2001 to embark on an *action research* (Kemmis and McTaggart, 1988) project to explore how the students' learning experiences could be enhanced. The primary encouragement for doing this came from my own study in a program in Graduate Certificate in Higher Education. This presented an opportunity for me to

immediately apply some of the knowledge I had gained from the program to attempt solving a *teaching problem* in my own classroom.

Outline of the student project

The computer design project forms a significant part of a final year course whereby students are required to design, implement and test a single board computer in groups of three. In addition to acquiring a core body of knowledge and developing practical design skills, the project aims to assist students in preparing for a professional career as an engineer when they would be expected to be involved in similar projects of much higher complexity. However, I observed that the students faced many problems during the *practical implementation* of their designs leading to frustration in some cases. As an example of a typical problem, students would say that the computer they had assembled would not work (do nothing), and despite checking everything they could not identify the source of the problem. The problem could be the result of errors in the original hardware design or errors in the software, or simply a solder joint on the circuit board that had cracked.

From my observations the reasons for these problems are manifold. Building the computer involves complex wiring of many electronic components on a single circuit board. Identifying the source of potential problems in such a complex circuit board can be a very challenging and daunting task. In addition, various design issues are intentionally left open ended to allow students to exercise their understanding of the area and *problem solving* ability. This is aimed to provide students with adequate opportunities for training in dealing with open-ended design problems. However, this can also add to the complexity of the problems unless the students are able to reflect on the design choices they make, and ask themselves why they made certain choices, how could those be changed and for what possible outcomes, how their peers dealt with similar issues, and which approach was better. I felt the need to bridge an apparent gap between the technical activities involving design, implementation and testing, and the students' abilities to reflect on their actions, think critically, do self-assessment, learn from their peers' experience, and above all communicate effectively. It is hard to imagine engineering graduates succeeding in their professional career without these important qualities in an era of phenomenal technological and social transformation.

Reflection, planning and action research

One of the key features of *action research* as outlined by Kemmis and McTaggart (1988) is: "action research is an approach to improving education by changing it and learning from the consequences of changes". They stressed that action research is *collaborative*, thought it is important to realise that the action research of a group depends upon individual members *critically examining* their own actions (Kemmis, 1999). An action research would incorporate planning, introduction of new strategies, analysing the impacts of these strategies and changing the strategies based on *reflections* on the previous ones (Burns, 1997; Kemmis and Wilkinson, 1998). Action research has been seen to be synonymous with reflective practice (McMahon, 1999). Indeed, I see reflective practice very much as part and parcel of any action research that aims to bring about changes in the way we teach.

So, before planning any new activity or making changes to the existing ones while delivering the course in 2001, I began to *critically examine* the learning activities undertaken in the previous year. I reflected on the various activities and their outcomes, and also considered the student feedback and final project outcomes (successful completion of project). One of the activities undertaken in the year 2000 was a seminar held in the third week of the semester where all students presented their initial designs in front of the entire class. Although many students were initially very shy about making such presentations (especially those from non-English speaking backgrounds), almost all students said that they had benefited from the exercise. Listed below is a summary of the positive feedback provided by students:

- Participation in the seminar increased their confidence in making presentations.
- Peers pointed out errors in their design and they could fix those errors before proceeding with the implementation. That was really helpful.
- Many students could see how their peers did certain things differently (in a better way).
- Students could describe the problems they had faced in doing the design and seek solutions from their peers' presentations or by asking questions to their peers.

As the above feedback demonstrates, students received useful *feedback* from their peers. They could enhance their understanding of the design and enrich their learning through *self-assessment* and comparison with their peer's work (Nightingale and others, 1996).

There is much research that demonstrates interaction among students, both spontaneous and formal, facilitates students' learning and helps students achieve the learning goals (Johnson and Johnson, 1990; Topping, 1996). Yet in my role as *session chair* of the seminar I occasionally asked questions that were relevant and not asked by the students. It therefore appeared to me that the benefits of *student-student interaction* could be further exploited in order to assist students during the implementation stage of their projects. However, I also recognised that it was an unrealistic aim to expect productive student-student interaction without some facilitator input. Herein lies the challenge to find the appropriate balance on the continuum of *teacher-centred* and *student-centred* pedagogic approaches.

Strategies

In 2001, before planning some new activities to facilitate interactions among students during project implementation I had decided to address one issue arising out of the seminar in the previous year. Many students commented that they did put in a lot of effort in preparing the presentation and would have liked to be rewarded. Some even said that they did not put as much effort as they could have because there was no mark allocated for the presentation. This made sense to me considering that the students had completed a design for presentation in the seminar and it gave their project a kick-start early in the semester. Some of the presentations were very good in terms of contents and quality. So, I decided to allocate 5% marks for the seminar in 2001. I expected that this would increase student motivation (November, 1996) and also continue to provide students with useful feedback. I suggest that allocating some marks for the seminar makes it a *summative* as well as a *formative* (Biggs, 1999) assessment task, although many might argue.

On the more important question of how to facilitate *student-student interaction* and *peer learning* during the implementation stage of the project, the weekly practical sessions appeared to be the most appropriate place. There were two practical classes of two hours duration with approximately 18 students in each. I felt that allowing 15 minutes time at the beginning of each practical class would be appropriate. I called this activity *class project meeting*. Students worked in groups of three in the computer design and implementation project. The essence of the interactions in the project meetings was to encourage students from different groups to interact, exchange ideas and benefit from each other's experience. Students would be expected to talk about the problems they were facing in their project, hear from their peers whether they had similar problems and how they went about solving them. In addition, students would be expected to share experiences, which they thought might assist other groups of students. From the assessment point of view the project meetings were *purely formative*. After each meeting I analysed the impacts of the strategies by examining student participation and feedback. Based on my reflections I modified the strategies in the next cycle to increase the learning outcomes. In total I ran *six cycles* of project meetings in this action research for two different classes. It was based on Lewin's cyclic model (Lewin, 1946), and closely resembles other derivatives of this model, such as a spiral of cycles of reconnaissance, planning action, enacting and observing the planned action (Kemmis, 1999).

Implementation, evaluations and outcomes

The various strategies implemented for the project seminar and project meetings, and their outcomes are presented in this section. Also included are my reflections, student evaluations and feedback from colleagues.

Project seminar

As stated earlier, 5% mark was allocated for the seminar. Students were advised to complete their first designs and present in a seminar in the third week of the semester. The format was ten minutes of presentation time for each group followed by two minutes for questions and discussion. Each member of a group was required to take part. Most groups used overhead transparencies for the presentation while some groups used power point slides. In the previous year none of the groups made power point presentations. On average the quality of presentations was better than those of the previous year. It was perhaps due to the fact that the seminar carried some marks and the students were more motivated to work for something that would count toward their final grade. Some interesting questions were asked and discussions were generated from most presentations. Students pointed out errors in a few designs.

Evaluation of the project seminar

I prepared a survey questionnaire for student evaluation of the project seminar. Twenty-one students returned the questionnaire. Most of the students said that the seminar was very useful for getting feedback, for assessing their own as well as their peers' work, learning from other presentations and improving presentation skills. Twenty students said that the requirement to present the design in the seminar had an impact on the work they had done on the actual design. The majority (81%) of them had worked harder to complete the design before the seminar and had prepared for the presentation. Two third of the respondents said that they had put more effort to understand the design and that there should be more presentations in this course. Most (90%) of the respondents were in favour of having (at least one) presentation in other courses as well. However, 62% said that the *time allocated for the*

presentation and discussion was too little. A colleague who was present in the seminar also expressed similar views and recommended that the time for presentation and discussion be increased.

Action research: class project meetings

In order to assist the students to assess their progress in the project I prepared a list of weekly *milestones*. The list was made available on the course web page at the beginning of the semester. The idea was to enable students to compare their actual weekly progress against these milestones as the semester progressed. I expected the students to use the class project meetings to assess their progress compared to the milestones, and then reflect and critically analyse their activities and outcomes if their progress wasn't up to the mark.

Cycles 1 and 2

The *first* class project meeting was held in week 5 of the semester. At the beginning I gave a brief overview on the objectives of the meeting and encouraged students to discuss issues of their interest and concern. The students raised only a few issues on their designs and administration of the project, but no project related problem was reported. I had to *intervene and mediate* in order to generate some discussion and explain how they could benefit by discussing issues related to the design and implementation of the project. It appeared to me that the students were unsure about their roles and were very passive. I used the *qualitative evaluation questionnaire* given in Table 1 to receive student feedback about the meeting.

- What are the three learnings you take away from this meeting?
- How did this session meet your expectations?
- How could it better meet your expectations?

Table 1: Qualitative evaluation questionnaire for cycles 1 and 2

Many students struggled to fill in the evaluation sheets and left parts of the questionnaire blank. I therefore found the student responses to be inadequate and superficial, and indicative of very little engagement in the learning task.

The *second* project meeting (cycle 2) was held in the following week with a different class. Considering the poor student participation in the first cycle, I *explained* the objectives of the meeting *in more detail* and *cited examples* on how they could benefit by discussing certain issues. I also stated what was expected of the students, how they could participate and contribute. Some of the things I pointed to were:

- Compare your progress with the milestones and *critically* analyse your observation.
- List the problems you faced. Did you attempt to solve them? How? Did it work?
- Report problems you successfully solved.
- Report on better (more efficient) ways in which you have implemented a certain thing compared to more cumbersome approaches you adopted earlier.

Student participation *improved slightly* compared to the first cycle. More issues were raised and discussed than in the first cycle. I used the same questionnaire (see Table 1) for

evaluation by students. The responses were indicative of slightly better participation by the students than in the first cycle. It was perhaps a result of more elaborate explanation of the objectives and ways of engagements given to the students. However, in my judgement the level of participation was still not satisfactory. Many of the students said that they didn't have many issues to discuss at that stage as they had not completed building much of the hardware for the computer board and had not practically tested any module. Their primary concern at that stage was to get on with the assembly of the computer board. Despite limited student engagement the first two cycles achieved a student introduction to the idea of a class project meeting and its objectives. Although some students were unsure about how they could participate/contribute, many expressed the view that they expected to benefit from future meetings as the project progressed.

Cycles 3 and 4

In order to increase student participation I wanted to ensure that the students did put some thoughts into the activity and planned accordingly. I therefore wanted them to come up with an agenda for the meeting based on their experiences in the project. I handed out the *qualitative evaluation questionnaire* shown in Table 2 at least one week before the meeting. I advised the students to prepare the answers to the first three questions beforehand and bring these to the meeting. The idea was to encourage them to prepare for the meeting by doing *self-assessment* of their project, by engaging with the related issues, and by critically analysing them. This appeared to have worked quite well. Many students came up with various issues for discussion including problems they had faced in project implementation, various ways of implementing things, and how they had dealt with some of the problems they had faced. As a result I found the students much more *proactive* than in the previous cycles.

Part 1: Complete this section before the meeting

- How did you prepare for this meeting?
- Identify 3 questions related to your project that you want to have answered.
- How will you participate? What will you contribute? How will you get the answers to your questions?

Part 2: Complete this section at the end of the meeting

- What are the answers to your questions?
- What are the 3 most important things you learned today?
- What other questions were generated in today's meeting?

Table 2: Qualitative evaluation questionnaire for cycles 3 and 4

One important difference between the two project classes was that one class had the project meeting (cycle 3) two weeks before the other class (cycle 4). This was not something planned, the class schedule simply worked out that way due to holidays. Therefore the students of one class (cycle 4) had the opportunity to think about their projects for *two additional weeks* compared to the other class. I observed that the level at which the students of this class (cycle 4) carried out discussion was deeper than that of the other class (cycle 3). I had to do some *mediation* in cycle 3 while little in cycle 4. As students were getting more deeply involved with the implementation of the project and getting further insight into the

task, they were more able to effectively participate, contribute and learn from deliberations in the meetings.

Students answered the second part of the questionnaire (see Table 2) at the end of the meetings. The responses indicated that the students gained much more than they had expected before the meetings. This was not only due to the planning, thinking and preparation before the meetings, but also due to their enthusiasm and willingness. It appears that the increased enthusiasm originated from their appreciation of the benefits of the project meetings.

Cycles 5 and 6

In these two cycles I decided to allow students to discuss their projects with very *little intervention and mediation* by me. Some groups had already got their computer boards working while others were still encountering problems. It was interesting to see that a few groups ran into difficulties with their boards after the boards had worked for a while. This was due to the complex nature of the computer boards containing many components wired together using more than a hundred wires. Despite all the problems the students took advantage of the project meetings to assess their works in the light of their peers' experience. They were spontaneously deliberating specific issues related to their projects in greater detail, critically reflecting on their actions and benefiting from their peers' experience.

Peer review of the project meetings

One of my colleagues was present in two project meetings. His comments about the activity were very positive. He especially recommended the use of the qualitative evaluation questionnaire given in Table 2 for such activity. Apart from this, I had philosophical discussions with colleagues active in the area of teaching and learning in higher education (Nafalski, McDermott and Gol, 2001) about the significance of project meetings and mediation. They agreed that mediation might be required during the early cycles of such meetings. However, they emphasised that as students develop better understanding and begin to see the relevance to their learning, they would be more motivated and able to take more responsibility in managing the proceedings of the meetings without much intervention from the teacher (McDermott, Gol and Nafalski, 2001). This is a view that I found to be in agreement with my experience during the final two cycles of the project meetings. I definitely observed the students taking more responsibility for their learning as they engaged in spontaneous discussion and analysis of project related issues.

With a view to gain feedback from a wider community of academics and researchers I presented the idea behind this work in a mini-conference in Adelaide organised as part of an Australian Universities Teaching Committee (AUTC) research project (Monash University, 2001). I was deeply encouraged by the very constructive feedback I had received.

Outcomes and observations

Ten out of twelve groups successfully completed and tested their computer boards. The percentage of successfully completed projects (83%) was higher than that in the previous year (75%). The most important outcome of the project meetings was the enhancement in students' learning experiences as indicated by the overall student satisfaction of the meetings. I used a *quantitative evaluation* questionnaire to receive overall feedback from the students. Twenty students returned the questionnaire. 79% of the respondents said that the meetings were useful because they could discuss issues related to the project. 80% thought that the feedback they had received from the meetings had helped them to judge their progress in the project. 90% said that the meetings were useful because they could see how other students dealt with some of the project related problems**.**

However, only 45% of the respondents felt that they had actively participated in the meetings. Interestingly 50% of the respondents were neutral on this question (unable to answer). These responses indicate that the students did not initially have a clear idea about the objectives of the meetings and were not sure about how they could participate/contribute. This is in agreement with my observations during the early cycles of the meetings. This illustrates the need for adequate and timely mediation by the teacher. As stated in Section 5.2.2 the use of the qualitative evaluation questionnaire of Table 2 assisted in increasing student participation in the later cycles. Perhaps an assessable student journal could be used to stimulate/encourage reflection thereby increasing participation and enhancing students' overall learning experience. As November (1996 and 1997) has experienced, a student journal has the potential to develop into a very useful tool for spontaneous reflection and for developing students' own experiential learning processes.

Conclusions

Class project meetings provided opportunities for enhancing students' learning experiences and outcomes through self/peer assessments and sharing of experiences. Timely intervention and mediation by the teacher were essential in order to maximise the benefits from these meetings, especially during the early cycles of the project meetings. Although many students were very passive during the early cycles, many participated more actively during the later cycles. Detail explanation of the objectives of the meetings, and on how students could prepare and participate was found to be very useful to encourage students. The qualitative evaluation questionnaire given in Table 2 was also found to be very useful to stimulate students' thoughts and to engage them in productive deliberations during the meetings. I would consider including an assessable student journal in future to enhance the positive learning outcomes from the project meetings and for a deeper learning experience.

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