Life in PBL: two PBL teams

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***Abstract**: Problem-based learning (PBL) continues to challenge educational institutions in terms of demonstrating its effectiveness. Prior studies have offered insight into the methods, application, and experiences of teaching using PBL. However, student behaviours and the learning cultures that develop in PBL settings are also important. In this paper, we present the ways students of a first year engineering course at an Australian university approach PBL. A number of PBL teams in the same subject were observed throughout two semesters with their consent. This paper reports on two of these teams. Some observations were video taped to aid analysis. The purpose of this study was to analyse and compare learning approaches that help or hinder successful group outcomes. It is evident from the data that individuals in the groups have a strong influence on what is learnt. Some students also focus more on exploiting the assessment system than on maximising their learning.*

***Keywords**: Problem Based Learning, learning approaches, group learning outcomes.*

Introduction

The introduction of problem based learning (PBL) in engineering education requires a radical change in the way students learn and the role that academic teaching staff play in facilitating learning (Gabb & Keating, 2006). PBL typically involves students working in groups and therefore research into learning in groups is particularly germane (Kaufman & Mann, 2001). On a more operational level, Jaques (1992) suggests that teaching and learning in small groups is a valuable part of all-round education of the students. It allows them to negotiate meaning, to express themselves in the language of the subject and to establish a more intimate contact with academic staff than more formal methods permit. It also develops instrumental skills such as listening, presenting and persuading. As the team develops maturity and ability, relationships establish, and leadership styles evolve (Tuckman, 1965).

Both psychodynamic theory, which emphasises the effect of unconscious processes in the group that exist beyond the awareness of the participant, and interaction theory, which emphasises overt interpersonal behaviour between members of the group, are relevant here (Jaques 1992). Therefore, studies of small-group learning need to attend not only to spoken discourse, but also to the participants' body-language, tone of voice, direction of attention, and the artefacts they use (Barnes, 2005).

Previous research suggests that assessment has an influence on students' learning behaviours and therefore potentially the group learning processes and behaviours. The unintended influence of assessments on students' study behaviour is often referred to as hidden curriculum (Snyder, 1971). It can be interpreted as a set of unspoken rules, which the student must follow in order to obtain higher

grades. A study conducted at a British university on the effects of assessment on student attitudes found that most students engaged in project work find their motivation in preparing themselves for exploiting the assessment system rather than using it to build a learning experience (Gabb, 1981).

Surveys conducted with first year electrical engineering students at the beginning of their course and during mid year to evaluate the use of PBL in engineering explored the experiences of students as they adjust to the PBL approach (Gabb & Keating, 2006). This study revealed that both interest-related and job-related reasons were most important in their decision to enrol in the course. It was highlighted that students' main concerns about team work were participation in unsupervised team work, distribution of workload and the marks they obtained that reflect the distribution of work among team members. Gabb and Keating (2006) also identified that even though the students were confident in their ability to work in a team, they were least confident in their ability to speak in front of a group.

While there is an established literature on what and how students learn in PBL (Hmelo-Silver, 2004; Savin-Baden, 2000), there are fewer studies that explore how students function as part of a PBL team. Hence, in the current study, the main focus is on the role of engineering students in the PBL process and its effects on their learning. The shift to PBL represents a shift from teacher-centred to learner-centred education. It also assumes a shift from independent learning to collaborative learning. This study therefore focuses, in part, on student responses to this shift in emphasis.

With their consent, the members of some PBL teams in the same subject were observed throughout two semesters. This paper reports on two of these teams. Some observations were video taped to aid analysis. The purpose of this study was to analyse and compare learning approaches that help or hinder successful group outcomes. This study also explores some of the learning cultures that develop in an Engineering PBL program and the effects of these cultures on student learning.

Data collection and analysis

This study is part of a broader qualitative study of learners in PBL setting. Of the 79 students who were initially enrolled in the course, 50 agreed to participate in this study. Their participation included informal interviews and classroom observations during both semesters. In addition, ten students were randomly selected for additional formal observation during supervised and unsupervised meetings and focus group interviews and individual interviews. Some observations were video recorded and all the interviews were audio recorded to assist analysis. After formal assessment was completed the portfolios that these students submitted were collected. All relevant subject documents were also collected for the purpose of this study. The researchers were non-participant observers in this study, that is, they were not involved in the teaching or assessment of students in the study.

The data presented in this paper was analysed by systematically searching and arranging the field notes and the transcripts of the audio-visual material. During this phase, a combined description of the field notes and the transcripts was generated. In the next phase data was coded and clustered to form categories and themes using NVivo software application (Gibbs, 2002). In the last phase inferences were drawn from the emerging themes and the data were reconstructed and presented as cases.

Context

At the university where this study was conducted, PBL was introduced in the first year of the course in 2006. The stated aim of introducing this approach was to produce "industry ready" engineers. This implied that graduates would be characterised by inquiring minds, effective communication skills, mathematical literacy, ICT proficiency, creativity, good interpersonal and team working skills, commitment to life long learning, problem solving expertise, project management skills and information literacy skills consistent with the graduate attributes recommended by (Engineers Australia, 2005).

PBL Subject details

In both first and second semester, the course consisted of a single PBL subject (50% of load) and two other non-PBL subjects concerning physics, circuit theory, computer programming and mathematics. Students were expected to attend 120 hrs of classroom contact in each semester for the PBL subjects.

Every week there was a scheduled one-hour PBL team meeting, in which student learning was facilitated by PBL supervisors. At other times, students were expected to work unsupervised both individually and in their teams. Technical staff members were available to assist students with laboratory works and workshops. Language and communication facilitators were available on a weekly basis to assist with the development of language and communication skills.

PBL Subject 1 – Semester 1

In this subject students worked in teams to solve three problems specifically designed for this subject. The first problem, which was designed to establish a team and develop team work skills, required students to construct a mobile robot. The second problem required students to design and construct a single channel audio power amplifier using a well known LM386 integrated circuit audio amplifier with particular specifications. The third problem required students to investigate the suitability of photovoltaic array systems as primary sources of energy in a sustainable environment. They were also asked to address concerns about the ability of such systems to recoup the embedded energy, pollution both in manufacturing and end-of life of the components, cost of purchase and operation costs involved, reliability of the energy supply, among other concerns. Students were expected to learn measuring and testing techniques as part of the testing and reporting process. They were required to design, perform experiments and produce a referenced research report for both the second and the third problem. Students were also required to present their solutions using audio-visual aids and submit a team technical report and an individual reflective report for the second and third problem.

PBL Subject 2 – Semester 2

Unlike the PBL Subject in Semester 1, this subject was based on a single problem. Students were able to change teams and they were asked to negotiate changes to the membership of their teams. Some chose to remain in the same team, but a majority moved to another team. Most students were given the problem (Traffic Automation) in the first week. They were asked to identify a traffic intersection in Melbourne that had traffic light timing problems. In particular, the students were asked to identify an intersection that connected a main road that was frequently used by people commuting to work and a side street that was mostly used by local residents. The problem description gave no guidance on the methods or concepts that students might use. Students were given nine weeks to provide a solution to the problem in the form of a proof of concept. They were required to implement the traffic automation concept and report back. The problem description did not provide information on assessment tasks or expected outcomes. Supervisors verbally informed students that they were required to present the group's progress in week 5 and a final group presentation in week 12, both using audio-visual aids.

Assessment

Students were assessed in both subjects only on the basis of an individual portfolio submitted in the final week of the semester. There was no formal examination. Apart from the portfolio, students were also required to submit a mid-semester team progress report consisting of a technical report and a personal reflective report soon after their progress presentation during Week 5 or 6 during the semester. In the portfolio, students were required to demonstrate the attainment of all the unit learning outcomes, including their ability to effectively work as a team. The portfolio was expected to contain peer evaluations and self-evaluations and other evidence of participation and contribution to weekly team meetings, audio-visual project presentations as well as other written work such as: reflective essays, expositions, and technical reports. They were also asked to submit logbooks used by the team (including attendance and minutes of meetings).

The learning outcomes were similar for both of the first year subjects. The expected learning outcomes for PBL subject 1 are shown in Figure 1.

- Demonstrate the successful completion of a project(s) in a specified time period.
- Demonstrate professional engineering skills.
- Use a computer to perform word processing as a communication tool.
- Use a computer to create spreadsheets and graphical outputs for reports.
- Demonstrate an awareness of general electrical safety standards.
- Demonstrate an understanding of the social and technical roles of a professional engineer.
- Demonstrate an awareness of the uncertain nature of some engineering designs.
- Communicate to professionals and non-professionals the fundamentals of the "language of engineering".
- Locate, evaluate, manage and utilise critically information for a range of purposes.
- Utilise basic electronic devices and incorporate them into a working design.
- Operate a range of standard electrical engineering laboratory equipment.
- Demonstrate an ability to write software programs.
- Demonstrate an ability to work as part of a team.
- Demonstrate abilities in time management.
- Demonstrate an ability to undertake lifelong learning and the capacity to do so.

Figure 1: Learning outcomes from unit of study guide for PBL Subject 1.

Findings

In this paper, the behaviour and learning approaches of individual students and the learning behaviour and culture of two PBL groups are analysed and presented. The two groups were chosen to illustrate two different group learning cultures observed. The names used in the report below are pseudonyms.

Team A

The five members of Team A included two mature age students, Claire and Rod. Claire was a very enthusiastic and willing student with a variety of educational qualifications and previous work experience in training and management. Participating in a team work environment was second nature to Claire. She was self motivated and self directed, with a very outgoing personality. Her writing skills were also well-developed. Rod had a related trade qualification and several years experience in the industry. He had decided to continue studying to earn a higher salary and better positions. The other three members, Cathy, Sasha and Damien, had entered the course directly after secondary education.

Cathy had taken electronics at high school as an elective because other electives like music and arts were already full but felt that she had made a good decision then because that helped her choose her career. Sasha and Damien had joined tertiary education to get better jobs and electrical engineering was their first preference course. Damien said he would have joined commerce otherwise.

For each problem in the course, Claire motivated her team members to work on tasks that were of interest to them. After the team brainstormed all the tasks, she asked each member of the team to select a preferred task before she picked her own. She played the role of a mentor to Cathy, who had trouble organising references for her research. She also occasionally helped Sasha in selecting her tasks. Before the end of every meeting she explicitly reminded team members of the date and time of the next meeting and reconfirmed the tasks of each team member. Throughout the year, Claire's management expertise was demonstrated in her handling of group tasks and team members. She led the work of her team, composed team reports for problems 1, 2 and 3 and managed tasks throughout.

Micromanaging the team members during both Semesters 1 and 2 became her primary task. Yet she claimed to dislike the role and wanted someone else to take the lead. Using her excellent communication skills, Claire persuaded Rod to take up the leadership role towards the end of Semester 1. She then worked alongside Rod to learn the technical knowledge from him that she lacked. Claire possessed clear self awareness, willingness to learn and also appreciated the contributions of other team members.

Rod on the other hand volunteered to contribute the design and construction of every problem solution in Semester 1, partly because he believed that other team members did not have the capability to see the task completed. Rod persuaded his team members to let him handle circuit design and testing. Most of the time Rod solved each problem in the same week it was delivered to the team. However, he took more time to document the solution. During team meetings, Damien showed interest in problem solving. He offered to help Rod in the laboratory, but Rod turned down the offer because it was easier for him to work at home than to work at the university laboratory. Damien's role was thus limited to testing the circuit which Rod had already built and tested. Sasha and Cathy played supporting roles in searching for resources and contributing to the final technical report compiled by Claire, which was a mosaic of individual contributions.

Damien, Cathy and Sasha played increasingly passive roles as all of the problems in Semester 1 were essentially solved by Rod. Claire described Rod as the rock of their team. She stated that Rod deserved all the credit for successfully completing the projects and that she depended on Rod to complete them. This dependence on Rod's technical expertise was highlighted towards the end of Semester 1, when he was frequently absent. Without his contribution, the team struggled to complete problem 3 on time. Claire and Damien finished most of the tasks, pulling every piece of work together with relevant research material to support their solution, but in a superficial manner. Claire also helped some of her team members in editing their portfolios. Claire knew that better learning resulted if there was effective team discussion and understanding other team members' tasks but she was willing to forgo this when time was tight. In this situation, for all team members, finishing became more important than learning.

Claire observed that the grade she obtained in Semester 1 reflected her contribution and workload. However, she felt that it wasn't fair that Rod obtained a grade lower than hers although he had contributed much more than any other team member in problem solving. She also mentioned that she could not understand why Cathy obtained a distinction despite her unsatisfactory contribution.

In Semester 2, Sasha and Cathy decided to join friends in other teams. David, Andrew and Michael then joined Team A. The team also had a different supervisor in Semester 2. Claire quickly got into the business of organising the team and assigning tasks to the team members. She appointed herself the leader of the team and briskly dispatched different roles to team members. All members took turns in taking the roles of scribe and chair under her leadership. However, much of the work was only completed at a surface level as the team only met during scheduled supervised meetings. This was possibly because the PBL learning spaces were not available until week 9.

After taking responsibility for circuit design and construction during week 3 in Semester 2, Rod started to absent himself from supervised team meetings. Rod's absence had significant effects. Tight deadlines and spectacularly misguided hypotheses brought arguments and disagreement between Claire and David. David sought help from a family member who was working in a related field and frequently changed the ideas the team had agreed upon. He also requested components from the school to build a model without advising Claire, who was co-ordinating placing an order for the parts for their design. He did not like Claire leading the team and told her that he had to take over and do things because she was a female. Claire found David's comments insulting and sexist and she reacted in a couple of emails and offered to just sit back. However, she promised to complete the tasks that she had assigned herself. After, many telephone conversations from concerned team members and an apology from David, she started to actively participate in meetings. In fact, her contribution was very much appreciated by the majority of her team members in their peer evaluations included in their portfolios. When the results arrived, Claire was surprised that a similar portfolio had yielded her a lower grade in Semester 2.

Towards the end of Semester 2, Claire became more frustrated with her PBL experience. She expressed concern that PBL was the only learning environment that she had encountered where the projects seemed to be designed to create a feeling of incompetence and failure in the students before they even commenced. She demanded a fundamental review of PBL's implementation and stated that the level of disorganisation and thoughtlessness in its structure was unacceptable.

Team B

There were five members in Team B in Semester 1: Henry, Jarrod, Yasar, Ali and Jeff. Yasar and Ali were international students. Yasar had great difficulty in communicating with his team members because of his low proficiency in the English language. To improve his communication skills, Yasar attended English Language Intensive Course for Overseas Students (ELICOS). Jarrod was a mature age student who studied part-time. Henry preferred studying individually rather than in a team environment. However, he took part in most of the team meetings. He worked part-time to fund his living expenses while studying.

Jeff came to higher education directly from high school. He believed that an engineering degree would help him gain a decently paid job. His parents assured him of moral and financial support while he studied. He mentioned that he was pretty confused in choosing the field of engineering that suited him and that he wanted to try out electrical engineering. At times he considered combining an arts or management degree with his current course to improve his employment prospects.

Jeff led the team and was determined to obtain high grades in all subjects to improve his employment prospects. Early in the semester, Jeff was advised by his supervisor that his team's success is his success and a pathway to obtain a high grade in the PBL unit was therefore to make a successful team. Jarrod mainly contributed in organising the team work and in research. He brought in a lot of research material, which was discussed by team members during every supervised team meeting. The team also met unsupervised once every week. Jeff became a firm friend of Jarrod. Consciously or unconsciously, Jeff ensured that information was shared and processed by everyone in the team. Jarrod and Henry backed Jeff, which made him even more comfortable allocating tasks and ensuring that they were completed successfully. Jarrod was considered a valuable member in this team because of his technical, time keeping, research and documenting skills. Every member in the team made use of Jarrod's involvement as much as possible.

In Semester 1, Jeff normally chose his tasks and made sure he completed all of them well in advance. He also worked on finding alternative methods to solve a problem and came up with more than one solution to every task that he handled. Interestingly, his team's solutions were not considered by other teams and sometimes surprised supervisors, who praised the team for being innovative. While his main quest was improving his own technical knowledge and skills, he also started to realise that PBL required the development of his generic skills as well. Hence, he spent more time with his team members discussing everyone's task progress and made sure they were all up-to-date. He explained research findings and technical content to his team members often one-on-one and face-to-face, depending upon his team members' availability. Occasionally he also played the role of a mentor to help Yasar and Ali when he guessed that they had difficulty in understanding the concepts. He also made sure to give each individual team member the opportunity to discuss their task and learn about the tasks of other team members.

After Semester 1, Ali dropped out of the course for personal reasons and Cathy (a member of Team A in Semester 1) and Charlie joined the team in Semester 2. Jeff was elected to lead the team in a vote. As team leader he decided to share the traffic automation project equally in such a way that each team member had a chance to learn and contribute to the survey of the intersection, coding to simulate the software model of the intersection and to construct an electronic circuit to control the traffic intersection. Jeff determined the team rules and demanded that the team met frequently in order to have enough time for discussions. Cathy initially opposed this and had difficulty coping with such demands due to her part-time job commitments. However, she promised to attend as many meetings as possible. Jeff made himself available to all team members and took the initiative to meet with them individually and also by regularly communicating with them over phone or by email. Under Jeff's leadership, each team member eventually contributed to all of the tasks.

Every member of the team contributed and analysed multiple ideas that lead the team find more than one solution for the traffic automation problem. Jeff suggested using a design built with two "decade counters" that worked simultaneously in a timed fashion. Cathy suggested the idea of using a "555 timer" instead, which she drew upon from her previous observations of how the dancing Christmas

lighting worked. The idea that Cathy contributed was ultimately taken up by the group as their final solution to the problem.

Jeff advised that in both the semesters he had obtained a high distinction. While he was proud of his results, he mentioned that it was a bit de-motivating and unclear why the rest of the team members only managed to obtain either a credit or a distinction despite the fact that they had all contributed more or less equally to the work of the team.

Discussion and Conclusion

The two cases presented in this paper describe quite different group learning approaches. Team A distributed tasks among the group members but did not work collaboratively in the manner of students in Team B. Without previous experience of PBL and relatively little guidance from their supervisors, students in both teams constructed their own and often varied understandings of what PBL required of them. Both Jeff and Claire influenced the learning of the members in their respective teams in different ways. Claire's perceptions of the requirements of PBL and possibly her previous work experiences prepared her to micro-manage the team and thereby influence team members to work individually. Whereas Jeff's understandings of the requirements of PBL and his perceptions of team work helped him and his team members to make a significant contribution to each other's learning.

Students in Team B developed a shared understanding of the problem and its possible solutions and participated in each stage of the problem solving process in both semesters. Jeff's inclusive behaviour allowed him to spend more time with his team members based on their availability. He spent more time discussing and sharing ideas with his team members. They also recognised Cathy's capability, which was either not trusted or neglected by Team A in Semester 1. The beliefs and behaviours of the members of this group indicated that they approached learning collaboratively. We would describe this team as adopting a "collaborative culture".

On the other hand, students in Team A worked individually and contributed findings from separate activities to the final solution of the problem. Hence its members thus only developed knowledge of the components that they explored individually. While Claire organised team work and assigned tasks to individual members in the team, Rod sidelined her organisation because he wanted to specialise in finding technical solutions to the problems himself. It appeared that he either did not trust any of his team members' capability or did not want his autonomous decision-making behaviour to be compromised by participating in group processes. Claire pooled Rod's technical solutions along with other team members' contributions into the team report forming a mosaic of individual contributions. The learning approaches of both Claire and Rod indicate that they were motivated to achieve high grades in the first semester. However, their approaches appeared to encourage increasingly passivity among the other team members. It may be possible that Sasha and Cathy felt compelled to adopt the norms consciously or unconsciously modelled by Claire and Rod. The behaviour of Claire or Rod may have influenced their decision to change teams in Semester 2. In the second semester, David's resentment of Claire and his responses to her leadership role motivated the members of the team to finish the problem by splitting it into separate tasks and completing them individually. The focus of the team was on completion of the problem, which relied on individuals taking responsibility for their components of the problem. We would describe this team as adopting a "finishing culture"

During most supervised team meetings in Team A, students and the supervisors discussed problems at a superficial level. Questions from individuals in Team A, who were unsure about what PBL required of them and who wanted yet more reassurance, were misinterpreted as questions about the assessment methods. According to these students, their activity in their PBL groups was directed towards "solving" the problem and then towards completing the only assessment task, namely the portfolio. Not surprisingly, in second semester, their conception of PBL was strongly influenced by the grades they received in first semester. As they saw it, this indicated what PBL was really about.

What influence did the assessment system have on the learning culture that developed in each group? Team A appeared to focus primarily on completing the group task, despite the fact that it was not formally assessed, while Team B appeared to focus on accumulating evidence for the achievement of the unit learning outcomes in their portfolios. It may be that Team B took the espoused aim of

achieving the learning outcomes seriously and Team A implicitly decided that the real aim (the hidden curriculum) was to "solve" the problem and that this would be rewarded, no matter what the unit outline said. They may have been right. Despite the fact that working effectively as a team was an important learning outcome in both semesters, most teams adopted learning approaches similar to that of Team A.

The findings reported in this paper have emerged from the observation of group processes, which we found were influenced by the learning approaches of its members and their understanding of team work. There may be other factors that have influenced individual and group processes such as the social and school background, which we have not considered in detail while analysing the data presented in this paper. We have started to identify the importance of these social and educational factors on small group processes. When working with small group of students, or bringing students together to form small groups, it is not possible to assume that a mixed ability group or a mono-cultural group will adopt a collaborative learning culture. Further analysis will elaborate the dimensions of individual learning approaches and the learning cultures that groups adopt. We hope that this will inform both the design of PBL courses and the facilitation of PBL groups to help students accomplish successful group learning outcomes.

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