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Student Experiences of a Project-Based Learning Module

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INTRODUCTION

In this paper we investigate the experiences of first year electrical engineering students of a project-based learning (PBL) module in which students work in groups to design and build a robot to compete in a sumo wrestling competition. The 5 ECTS module is the first PBL module encountered by the students in this programme and is the only module of its kind in first year in which students work in groups and assessment and feedback are based on both process skills and technical knowledge. The module is designed to be student-centred, i.e. the student is encouraged to actively control and manage the learning process, and as such, individual performance in part depends on each student's expectations of learning engineering and his/her personal epistemology. Design is also a feature of the module: students have the opportunity to design the shape and body of the robot, the electrical circuits for sensors and actuators and the programme that governs the robot's behaviour.

We decided to explore how our students engage with this PBL module which has been running for several years and is perceived to be well liked by both students and staff. The sumo wrestling competition at the end of the module is a big event in the calendar and students appear to be highly engaged with and motivated to learn in the module. Taking a phenomenological approach, six students were interviewed to develop a description of what it is like to do this module. We present this description before analysing aspects of it informed by the literature on PBL, personal epistemology and design.

The themes that emerged from this exploration relate to the ways students engaged with the module, how they managed their groups, how they approached design, perceived the role of the teacher and their expectations of engineering education.

1 LITERATURE REVIEW

Project-based learning, in which students work in groups and learning is driven by the project, provides an opportunity to concurrently develop technical and non-technical skills. For engineering education, this method of learning provides a way to address the broad range of programme outcomes required by professional, accrediting bodies [e.g. 1, 2]. It is also consistent with the social constructivist view or philosophy of how learning should occur in that it provides students with the opportunity to construct their own understanding through interaction with others in a social setting [3]. Students learn in context and, consistent with a student-centred approach, are encouraged to take ownership of and manage the learning process. In this study of electrical engineering students, the context for the project is to design and build a robot to compete in a sumo wrestling competition. This can be classified as an 'assignment project' [4] as the project is chosen for the students and the teacher has a clear idea of what will be covered during the module and how the project will unfold. Through doing this module, the intention is that students will develop technical engineering knowledge and problem solving skills and will also learn how to work independently and in a group.

Student-centred learning, such as PBL, requires a very different approach to learning on the part of the student in comparison to a traditional curriculum. Students are expected to take control of and manage the learning process, use the group to facilitate learning, accept tasks and address them through self-directed work, communicate their emerging knowledge to the group, give and receive feedback and view the tutor as a facilitator rather than manager of learning [5]. However, students come to college with preconceived expectations of how to learn and what their role in the learning process is. Alignment between their expectations and what is required for PBL cannot be assumed to exist and students typically require a significant period of time to adjust and adapt, even in curricula that are heavily weighted towards PBL [6].

Personal epistemology relates to one's view of knowledge and how it should be acquired, i.e. how learning occurs, and is intertwined with what one expects to do in a learning environment [7]. Several models of personal epistemology are provided [8, 9]. Perry's model [10] describes how students develop over time from passive receivers of knowledge who see little or no value in learning from peers to independent, relativistic thinkers who are open to ideas from anyone as they possess sufficient reasoning skills to decide themselves what is of value. Schommer [11] hypothesised several areas or factors of parallel growth on this path of development: "(a) *the stability of knowledge, ranging from tentative to unchanging; (b) the structure of knowledge, ranging from isolated bits to integrated concepts; (c) the source of knowledge, ranging from handed down by authority to gleaned from observation and reason, (d) the speed of knowledge acquisition, ranging from quick-all-or-none learning to gradual learning, and (e) the control of knowledge acquisition, ranging from fixed at birth to life-long improvement*" [12]. While broadly accepting these ideas, Hammer & Elby [13] argue one can employ a range of epistemologies depending on the context. In the context of PBL, students are encouraged to operate at an advanced epistemology in many areas in order to gain the learning and development benefits it offers. Students require time to adjust and develop their approaches to learning and the experience of a PBL module depends on the ways students engage.

Project-based learning often involves the design, construction and testing of systems by students and, therefore, provides an opportunity for students to practice design and develop design skills. Crismond & Adams [14] offer a useful matrix linking a range of design strategies to designer patterns. One *strategy*, for example, is '*generate ideas*' with a corresponding *pattern* for a beginning designer being to generate few ideas and stick with these. The informed designer is more open to alternative ideas and actively attempts to develop several options through divergent thinking. Where a novice designer may avoid research and jump quickly to solutions, the informed designer investigates the problem and does research before committing. Some of these strategies overlap the literature on personal epistemology. Concepts of justification, described in King & Kitchener's Model of Reflective Judgment [15] are synonymous with Crismond & Adams strategy titled '*Weigh Options and Make Decisions*' [14]. Attempting to justify a design decision through reasoned, critical thinking is equivalent to reflective thinking on the Reflective Judgment scale. Indeed, reflective thinking is a concept used in both the Reflective Judgment model and the Informed Design Learning and Teaching Matrix. Through PBL and its requirement to engage in ill-defined, open-ended problems, students are offered the opportunity to concurrently develop design skills and practice a more advanced epistemology.

2 RESEARCH METHOD

The module occurs in semester 2 of the first year of a BE in Electrical and Electronic Engineering and is one of six modules in the semester, each with five ECTS credits and approximately 100 hours of learning. A predominantly traditional approach to learning and teaching is employed in the programme and this is the only PBL module in first year. This study took place during the 2012/13 academic year. 40 students were enrolled and were divided into groups of 2 to 4 members. They were timetabled for one 3 hour lab and one 1 hour lecture/tutorial per week. The group technical products are assessed along with the individual contribution to the group process with the latter comprising approximately 25% of the final grade and based on tutor observation and writing a blog. Assessment is also based on the robot's performance in two competitions – an early stage race to a wall occurs in week 7 of the 13 week semester and the final sumo wrestling event happens in week 13.

Apart from our own observations, we had never formally collected data on the students' experiences of this module. In order to do so we decided to employ a phenomenological framework to examine individual performance in and engagement with the group, interactions with the teacher, experiences of the competition, how students approached design and how they integrated other subjects into their activities. We collected data by conducting open, semi-structured interviews of a small sample of students taking this module (n = 6) selected based on convenience. All six students volunteered to participate and approval for the project was obtained from the institute's Research Ethics Committee. All were male aged 18 to 20.

A phenomenological approach was chosen as it guides the researcher to set aside his/her preconceived assumptions and encourage the participants to describe their experiences of the event [16]. This allows the researcher to develop a description of what the participants experienced, what they actually did and what actually occurred. Experiences, rather than participants' opinions, reflections and analyses, are sought and, from the accounts provided, a general description of the event is developed by the researcher [17]. Phenomenology offered us a method to allow the students to describe their experiences of the module in their own words and, from those accounts, develop a description of what is like to do this module.

'Bracketing' of one's suppositions and preconceived opinions and ideas, also known as the Epoche, is the first step in a phenomenological research study [16]. However, in an interview the researcher must ask questions and must decide what questions to ask thereby risking some presumption. To address this concern, a lecturer who was not teaching this module or assessing the students managed the interview process – both developing questions and conducting the interviews. The interviewer started by asking the student to describe the module and what was expected of him. He also asked the student to describe experiences of working with the group, of working outside of class time, both alone and with the group, of interactions with the teacher, and of managing the design process and making decisions. Opinions did emerge during the interview, particularly in relation to expectations, and the interviewer attempted to bring the participant back to descriptions of experience when this occurred.

Interviews were transcribed and a summary of each was developed by the interviewer. Each summary was then studied and, through interpretation, a number of themes emerged. Some were similar to the interview themes, others emerged. Consistent with the phenomenological approach, the summaries were used to develop a composite description of what was experienced in an attempt to capture the full range of individual statements. The composite description was reviewed by another author, a teacher on the module, before it was finalised.

3 FINDINGS[1]

A number of themes emerged from the study and we present these below as a composite description of the experience of taking this module in our school. The last theme, expectations in engineering education, is more a synopsis of opinion and

[1] Subsequent to submission of full paper to conference committee I reviewed the findings to improve the phenomenological analysis. I presented this at the conference and include it as an appendix at the end of this paper.

attitude than a description of experience and possibly does not belong in this composite description. However, it does represent a finding from the study.

1. Engagement is precipitated by the first competition.

Students hold back from committing to engage with the module in the early weeks. This is their first experience of group-based learning in the programme. The first competition, held in week 7 of the 13 week semester, forces them to become more serious about working on the robot. This can be a difficult period from a product point of view and some groups fail to develop a robot to do what is required - race to a wall, reverse and stop on a line. The looming competition creates a crisis to which the groups must respond, a strong extrinsic motivation to get something working. Robot performance can be significantly improved by the actions of one or more members who put in extra work the day and/or night before the competition in a last minute attempt to do well in the competition. The experience of this event can have a positive influence on the process: some groups reflect on the experience and decide to plan more and impose more management on their preparation the second competition, the sumo wrestling event. A workshop on group learning also encourages improved management. Closer and more effective collaboration between members of teams occurs for the second phase of the module.

2. Roles are defined in group which members adopt and interchange.

Groups are seen as teams with members adopting distinctive roles and specialising in an area of robot design and construction. Typical team size is three with roles commonly defined as circuit construction, programming and mechanical construction of robot body. For some teams, roles naturally emerge and are adopted only if each member is comfortable with them. Roles are often swapped and are used by some to challenge students by forcing them to engage with new material and learn. Team work is seen as reducing individual workload. For some teams, members operate independently and limit communication to keeping each other informed but the quality of interaction often increases with time. Others see the team as an opportunity to develop professionalism, learn to resolve conflicts, with members sharing information, discussing issues, brainstorming ideas, and learning from each other. All described positive experiences of sharing ideas with each other, either with their own team or with members of other teams. This was connected to learning. Some see themselves as leaders in the group. Many observe each other and form opinions on who they would like to work with in the future.

3. Design is informed by critical thinking to varying degrees.

Some defined criteria such as friction, speed and torque and used them to guide selection of wheel diameter, gear ratio and tyre material. Topics studied in their final high school exams that are taken before entering university were recalled and applied to this decision making process. Others took a more organic approach – different ideas and choices ‘fell into place’ over time. Some found that simply by solving problems as they arose, a robot ultimately emerged.

4. Lecturer guides students and acts a safety net.

The student-centred approach is readily accepted and the lecturer is seen as a guide. However, there is a desire for content or theory to be controlled by the lecturer. The self-directed approach is accepted but there is also a demand for theory to be supplied by the lecturer. In rare cases, typically microprocessor code, an issue cannot be resolved by the group despite hard work and they are rescued by the lecturer. By holding back, the lecturer allows students to learn more and develop as engineers. Students experience pride and satisfaction in creating a robot and resolving problems independently.

5. Expectations in engineering education

Some expected to undertake a group-based project and see it as integral to the development of an engineer but to others this method of learning was not expected. It was a positive experience and some reported implementing principles from other modules such as computer programming, for example. Application of theory to a real system and working with real components was welcomed.

4 DISCUSSION & SUMMARY

This description provides us with evidence of how the module is experienced by the student. It represents the spectrum of experiences as recalled by the students. The module is well received and is perceived to develop professional skills and engineering identity. The module is challenging for the students and they are uncertain what to do in the first few weeks despite communication from the teachers as to what is expected of them. Over time, students interact more with their groups. A range of approaches to design emerged.

The group is primarily conceived to be a team with well defined roles that members choose to adopt and often swap to assist learning. This is consistent with Hmelo-Silver's description of 'distributed expertise' and cognitive load sharing [5, 18]. Many descriptions were provided that show engineering students value working in teams and see this activity as important for their development as engineers. Even those whose groups performed poorly or had disengaged members shared this opinion. Engineering teachers often worry about issues of fairness and objectivity in assessing group work and should be encouraged to keep trying for the benefit of the students rather than abandon or avoid using PBL. However, only some referred to the group as a learning vehicle, and although it does not mean they did not occur, descriptions of group discussions that led to learning and indications of employing a deep approach to learning in a PBL environment [19] did not emerge.

It was interesting to hear that some viewed themselves as leaders and adopted this role without prompting. It has been reported that student engineers are inclined to see themselves as leaders of teams and managing others from positions of authority [21]. This also suggests the conception of the group is not so much a learning group but a team. Learning groups often have roles such as 'chair' and 'scribe' while 'leader' implies the more hierarchical structure of a team. The purpose of learning groups is to facilitate the learning process whereas the focus of a team is often on the product.

The first competition, the race to the wall, is an extremely important point in the module. For many, it marks the start of improved planning and performance in the module. This period has hallmarks of disjunction [20], as it brings home to students that they are the creators of the robot and must take control of the process. Either take more control or prepare to fail. All is not perfect after this competition but there is evidence of change for the better. Expectations that the teacher will step in to fix this robot may be eroded and minds are opened to the possibility that the student should take control. Through observing the performance of their robot and comparing it to other robots, the group receives feedback on product quality and, hence, quality of group performance.

As regards approach to design, some of those interviewed matched many of Crismond & Adams [14] descriptions of how novice designers perform. In the last days of preparation for the first competition one group received suggestions from the supervisor but chose not to adopt them due to time pressure and, in the end, their robot didn't work. This matches Crismond & Adams description of 'idea scarcity' and 'surface modeling' [14] . On the other hand, the descriptions provided by some of how they selected wheels point to a more advanced approach to design as they showed evidence of 'doing research', 'deep modeling' and 'valid tests' [14]. Although set in a traditional curriculum, the module offers students a chance to develop as designers.

Aspects of an epistemological nature emerged in descriptions of a desire for more theory from the teacher, the need to justify design decisions and the perceived role of the group. Perry [10] categorised some students as 'dualistic thinkers' who view the teacher as the only authority in the learning environment, place little value on the views of their peers, and expect the teacher to control learning. Aspects of this description resonate here and provide an explanation of why students hold back in the early phase of the module in the hope that the teacher will take control. Comprehensive descriptions of justifying the diameter of the wheel were provided by some while the descriptions of others indicated they were recipients, rather than generators, of such decisions. Epistemological development is reported to be rather difficult to facilitate with many students showing relatively little progress during four years of college [15, 22], particularly in science and engineering [23]. The challenge for the PBL tutor is to facilitate development of all students.

This study has deepened our understanding of what it means for students to experience this module, a project-based learning module that has a competitive element and is set in a traditional curriculum. The issues raised resonate with much of the literature on PBL, approaches to design and personal epistemology, allowing us to learn more about these issues and how we should help our students learn and develop.

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APPENDIX – Findings Reviewed

(After I submitted this paper I continued to read and learn about phenomenological methods and realized I could improve what I present above. Below is a modified version of the essential features and meanings of the experience studied in this paper. GD)

To take this module as a first year electrical engineering student is to experience a real engineering project in a team that aims to be independent of the lecturer. It is a period of change and growth in three areas – team dynamics, self as class member and self as engineer.

Theme 1, Team dynamics
You join a team and are presented with the robosumo challenge. Some signposts are provided but you're expected to be independent. Roles are easily identified and adopted in an uncritical and convenient way. Members can stay apart with few demands made and communication focused on keeping each other up to date. Some do collaborate on ideas but this is not necessarily to be expected. The competition upsets the apple cart. 'Robot fails to perform' is an inescapable observation, dreams are shattered, reality bites.
Meaning of this experience: The deficiency of the convenient approach is highlighted and made aware to all. After the salvage operation and the competition is over, the group is afforded the opportunity to self-assess performance which leads to a new improved way of operating and, along with time, helps to improve performance.

Theme 2, Self as class member
A hierarchy in competency among the class is experienced, like a jostling for position. In this student controlled module, some see their leadership identities realised and act out a desire to manage and teach others; others are managed or are persuaded to agree to decisions against their better judgement and allow themselves to be overruled – some are leaders, others subordinate.
Meaning of this experience: Through interacting with each other they decide who they can work with in the future, who they can do business with, who they aspire to connect with and who they themselves are as seen by or presented to their peers.

Theme 3, Self as engineer
On this module they experience some or all of the following: working with a team, meeting deadlines, using datasheets, doing calculations to determine components, programming, integrating maths and physics and experimenting with ideas. .
Meaning of experience : They are travelling a path to becoming an engineer; this module gives expression to the engineer within; engineering attributes are developed.