A "CRAZY MACHINE" PROJECT WITH TEAMWORK AND INTERTEAM NEGOTIATIONS

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ABSTRACT

The paper describes an approach to undergraduate laboratory projects that require both teamwork and inter-team negotiation skills. The authors have both implemented teamwork projects based on the CDIO learning paradigm over several years but considered that there were some important aspects of the engineering process that needed greater emphasis. Teams rarely work alone; they interact with other teams often producing only one subsystem within a greater whole.

What was needed was a project which could be subdivided so that all teams had tasks of similar complexity, which needed negotiation with other teams for overall system interfacing and execution. The result was a "Crazy Machine" for which each team created a module. Each module received a steel ball from another team, initiated activities to achieve some "spectacular" operations and then within a specified time period passed the steel ball to the next section. Implementation of each section required construction, control via either a Field-Programmable Gate Array (FPGA) or microcontroller, and debugging.

The paper describes the project, the students' reactions, their work and overall feedback concerning the project's ideas and implementation. The use of online tools to collect design considerations and decisions, report on design, planning, and implementation, reflective reporting, peer assessment and finally the use of independent interviews to assess the overall success/failure is also discussed.

KEYWORDS

Teamwork, Negotiation, PBL

INTRODUCTION

The practical introduction to design within the laboratory context of an engineering course is an important step towards competence as an engineer. The problems, faced by academics in this context, are to provide a useful experience for the student both in working with other students and achieving a "real design". Often a specific design problem is used to accommodate resource constraints and even supervisor competency with the consequence that student teams are all following the same path to the same product with the added potential for copying design ideas.

This paper describes the implementation of unique team designs within the context of a global specification and adds the need for interaction between team designs. The consequence of interaction is that teams are no longer independent and must negotiate the specifications of the interfaces between them.

BACKGROUND

The use of design projects within some units of the Computer Systems Engineering degree at Curtin University has been common for some years. Two third year, second semester units had considerable commonality between them: Advanced Digital Design 320 (ADD 320), emphasising FPGA based design, and Embedded Software Engineering 302 (ESE 302), emphasising microcontroller based design. Some consideration of merging the design laboratory aspects of the units had been discussed, however difficulties were anticipated as ESE 302 served as part of a Mechatronics Engineering course and was also an optional unit for students taking "Communications and Electronic Engineering" and a Bachelor of Technology in "Computer Systems and Networking" and a number of double degree courses.

It has been stated [1] that success is a product of ability and motivation and that strong motivation is linked to achievement and good situational expectations [2]. It was considered that a common project within the expected competence of the student cohort would enhance their professional competence while promoting the unit specific learning requirements. The project could be implemented using either technological base but that those students taking both units needed to be placed in specific teams and to address some additional specifications.

There are some aspects of professional engineering design experience that are not addressed by the usual undergraduate teamwork designs [3]. Specifically, the failure to consider interface implementations/environmental factors, and the common need to negotiate specifics with other design teams and/or deal with standards or legal requirements.

Introducing the need to consider interfaces and to negotiate requirements increased the reality aspect of the project, and adding a fun and competitive aspect to the whole process resulted in enthusiastic teams enjoying their learning.

LEARNING THROUGH DESIGN

The "Crazy Machine' project (CMP) specification

The objective was to set a challenging problem requiring an open-ended solution. It was explicitly desired to take students out of their comfort zone and encourage them to use their creativity and develop a sense of confidence in what they know. The project specification is described below as presented to the students (without university unit specific information).

A technology museum is looking for a new display for its embedded systems section. The curator of the museum visited Switzerland during his holidays and saw the machine shown in the following video: Link to YouTube for the Crazy Machine

Your team's job is to create one module of a machine that moves a steel ball in original ways. Your machine must satisfy the following requirements:

1. *The dimensions of the machine should be **180 x 90 cm**; divided into 8 modules of **45 x 45 cm**. Teams will be allocated one module at the beginning of the project.*
2. *Each module should pass the ball to the next module. Teams will have to negotiate entry and delivery points with neighbouring teams.*

3. *Every module must keep the ball in motion for a minimum of 30 seconds and a maximum of 1 minute. Alternatively, the ball may trigger the activation of a moving mechanism that must operate within the same time limitations. Once the mechanism finishes its operation, the ball must be delivered to the next module and reset with no human intervention.*

4. *The ball's trajectory may span for more than one module; but in that case teams need to negotiate use of system real estate so that modules do not interfere with each other.*

5. *Every module must use **at least two different sensors and two different actuators**. Available sensors are: touch switches, tilt sensors, infrared proximity sensors, pressure sensors and current sensors. Available actuators are: servo motors, DC motors with H-bridge controller, LEDs, and small speakers. Other sensors and actuators may be used, but they will have to be sourced by the design team.*

6. *Materials for the module will be sourced by the design team. Cost must be minimal, hence the use of recycled materials is highly recommended. (How many uses can a plastic bottle have?)*

7. *The machine will be powered with a single PC power supply providing 12V, 5V and 3.3V.*

8. *Every module should be controlled by independent processors (microcontroller and/or FPGA).*

Some students initially felt uncomfortable with the open-ended nature of the project, but soon appreciated the freedom to be able to explore within these constraints.

The "Crazy Machine' Project Environment

The intended objective was to get maximum participation by all team members so personal availability was one of the team member selection criteria. A laboratory was set aside for use by the two units and the students given 24/7 access to the space. The two unit coordinators delivered their lectures in their own space, but assumed the role of facilitators for both groups during laboratory time. Assessment occurred in an ongoing basis with feedback being provided by facilitators and peers through blogs and rubrics. Academic supervision of the laboratory was for two sessions of three hours per week, however, student questions often led to additional time spent with the teams. The laboratory space included soldering facilities, therefore, safety requirements had to be met and led to a minimum of two students present at any time. They did not have to be on the same team.

A very important part of setting up the project was establishing communication channels for and between the groups with academic monitoring included. Blackboard was used, taking full advantage of the file exchange, blog and journal functionality. Students' assessment breakdown was formally specified as in Figure 1 together with rubrics for the mark distributions within each assessable module. The design document, teamwork minutes and blog, the final report, oral presentation, machine demonstration and logbooks were all contributing factors in the overall assessment. In addition to team assessment each team member provided independent peer assessment information.

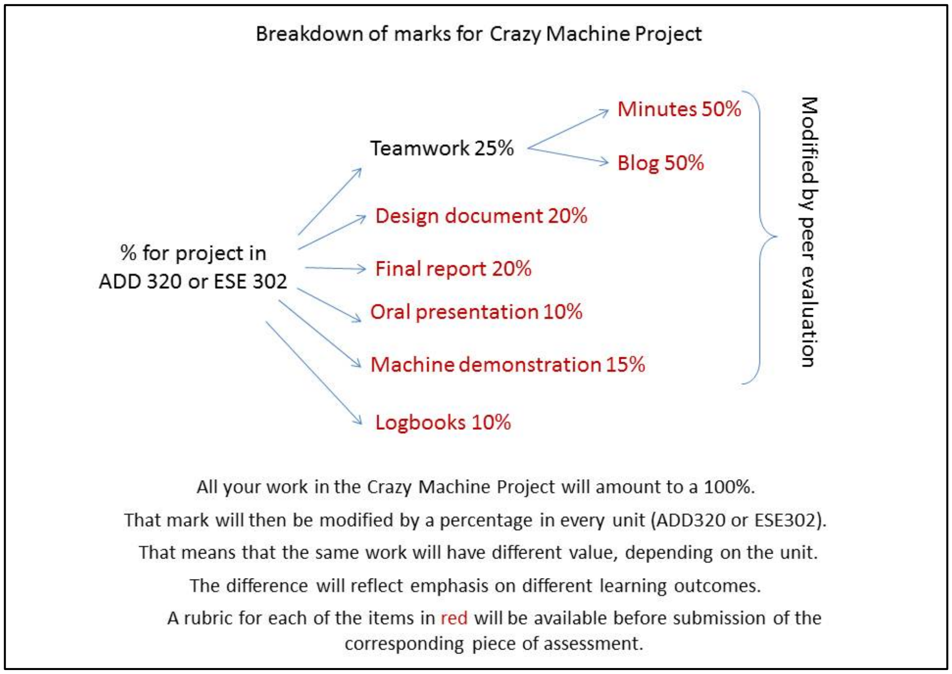

Figure 1. Breakdown of marks for the Crazy Machine Project

An example module

The students' modules were very varied and an example is shown below in Figure 2 where the steel ball enters on the top left and is detected and moved anticlockwise around the "water wheel". At the same time synthesized music is played and LEDs flashed. The movement of the wheel and the LED sequencing are synchronized with the music. The ball then rolls down the spiral transparent tube with additional LED flashing effects. At the bottom it enters the vertical tube and is raised by a simple lift. When it reaches the top of the lift it runs down towards the left where the diagonal conveyer belt (also synchronized to the music), which moves a strong magnet, picks up the ball and carries it to the top right where it falls and takes the exit path to the right. All this is completed in 40 seconds.

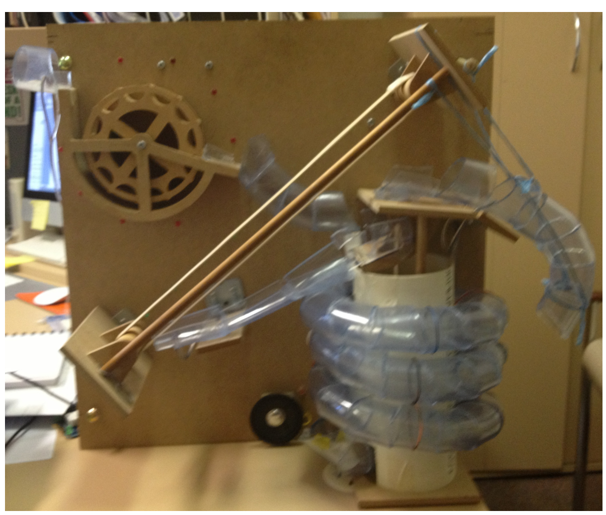

Figure 2. A module from the "Crazy Machine"

Construction of the modules was the teams' responsibility and in many cases with remarkable ingenuity. The electronic assembly could be done in the laboratory but mechanical work was not included. Out of hours access was too tempting for some teams and they brought cutting and drilling tools in to speed up the development process. It is considered that these activities do need to be catered for in future as well as the consequent need for a laboratory cleaning requirement.

From the beginning it was considered important to determine the students' own reactions to the project so ethical clearance was obtained to survey and interview students independently of the assessment process. The results of this investigation are discussed in the next section.

FEEDBACK

Student reaction

The student survey conducted at the end of the units is shown in Table 1 and the resulting distribution chart shown in Figure 3. It can be seen that the overall student reaction to the project was strongly positive, though enthusiasm did not increase in a number of cases!

Answer Options	Question #
Before this project I had significant experience in team working	1
My team always completed tasks in time	2
All members of my team contributed equally	3
All members of my team were initially enthusiastic about the project	4
The level of enthusiasm in my team increased as the project progressed	5
It was worth investing my time for the amount of learning I achieved	6
Inter-team communication was a crucial element for the successes of our project	7
My knowledge of embedded systems grew substantially during this unit	8
The Crazy Machine Project provided me with opportunities to develop professional skills	9
There was an element of fun in the project that made my learning easier	10
I wish I had the opportunity to develop projects like the Crazy Machine in the laboratories	11

Question #	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	5	9	10	1	0
2	6	9	3	6	1
3	3	12	4	4	2
4	9	14	2	0	0
5	4	8	7	6	0
6	7	15	2	1	0
7	13	7	4	0	1
8	12	8	5	0	0
9	11	13	1	0	0
10	12	9	4	0	0
11	13	6	5	1	0

Table 1. Student survey results table

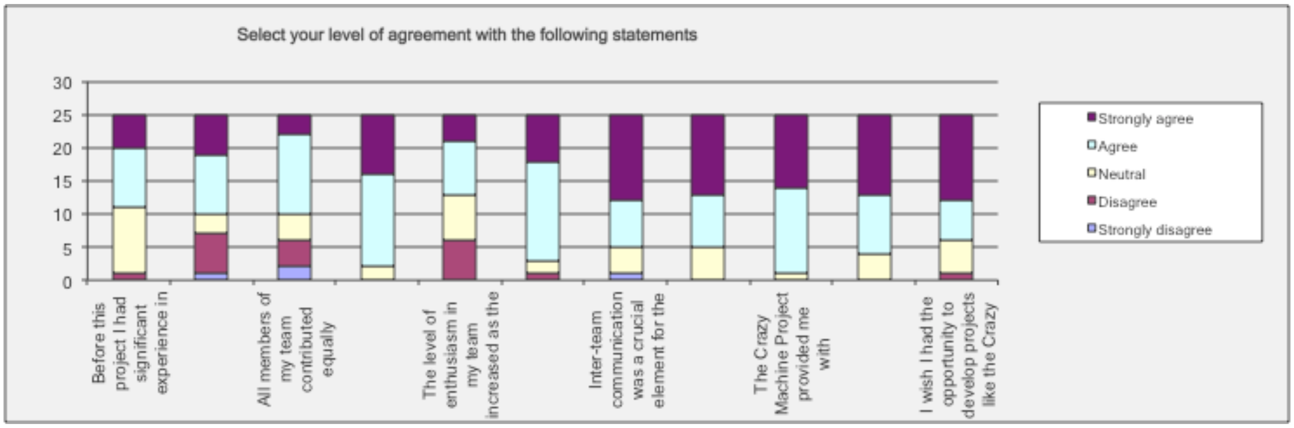

Figure 3. Student survey results distribution chart

All engineering students at Curtin take introductory units in the first year of their degree that include an introduction to a teamwork based project. In addition, some of the courses continue with small team projects during the second and third year. Despite being in third year, second semester only 56% of the students responded that they had had significant teamwork experience before starting the CMP.

An independent researcher interviewed a member of each team in order to determine the overall student reaction to the project. Reaction and response to the project was varied but overall there was a very positive perception. A few relevant questions and quotes of verbal responses follow here.

How do you feel about the Crazy Machine now?

"Not only is it good for teamwork with the small group but also working with the other teams as well. Because in my course a lot of the project units we do are just within a small team. We don't actually interact with other teams whereas here it is a great opportunity to interact with the other teams and to learn how to communicate with other teams with deadlines outside of your own team. I really appreciated that...
It is important that that will happen... Yes that will happen in real life."

If next year somebody would say "Hey buddy, you have done the Crazy Machine Project. How is it? What is the one thing that comes to your mind."

"I think it's very oriented by what the team is like. So if there is a lot of people in the team it's slightly different, … particularly for bigger teams, make sure you do a lot of the organising upfront, so may be roles, that kind of thing. Make sure you know what you want to do for the project, make sure you get that organised 'cause you don't want that in the way. And once you start actually doing things like building, don't underestimate it, it's going to take a lot more time than what you expected, and it's going to be a lot of issues. Yes, organisation and time management are two of the things."

"Did you enjoy it overall?"

"I guess it was quite interesting. I guess it's a really enjoyable feeling to see your project running on top. It was a pretty exciting feeling as well, being able to actually make something …

previously we knew about sensors, we knew about the motors and stuff, but I don't think we knew how to control them so being able to apply them [made] us actually relate pretty close to electronics."

"How do you feel about it now?"

"It was really, really a good experience. …. Worrying about approaching a task that I might have not learnt how to go on initially. So it's given me a bit of confidence in doing things like that. I really enjoyed it because I have developed so many different things like technical skills or working with a team or spending time problem-solving things so yeah. It was a really good project all around."

"If one day you get the chance to run or coordinate this project what would you keep and what would you change?"

I would definitely keep the demonstration and the documentation that we had to submit...I'm not sure about the logbooks though….To me a logbook is my own personal reference 'cause I in turn do software development so my logbook is rather personal so I don't particularly expect to make them make a lot of sense to anyone. At the same time it communicates reflective documents, which say what I've done and my processes. OK....but my logbook...it doesn't mean much to anyone other than me because of the way I develop. My assessment of the logbook was I did not expect a high mark...or get a high mark.....but I think there should be some other way of assessing how or what are our visual processes..."

The university has a unit evaluation process (eValuate) [4] and here again the feedback has been very positive including "I loved the CMP, it really helped develop some teamwork skills and let us work on our individual skill sets. I hope that the CMP can be continued in future years."

Staff Reactions

There are several aspects of the academic support for the CMP that need to be considered. Particularly the effort involved in the establishment, ongoing support and resource requirements. The project specification, online support for the teams, assessment processes and supporting rubrics required considerable effort by the two academics involved in the establishment of the CMP, however, that effort has established a solid basis for continuing usage.

The ongoing support during the progress of the CMP was essentially ensuring that there was enough staff availability to help the teams' progress. This was handled by providing fixed periods of direct support in the laboratory for the students. Monitoring of associated learning/understanding of the students' progress together with responding to concerns and questions as soon as possible within the normal working week was also a priority. In retrospect, team performance and success needs closer monitoring than was provided with the consequence that one team had considerable difficulties which if detected early enough could have been minimized.

Resources (such as motors) provided by the university were sourced by the academics to the teams to determine demand and usage. The availability of wire was at one stage the biggest resource constraint.

It was considered that the students approached the CMP with considerable maturity and enthusiasm particularly as it was introduced without prior notice.

Additional Incentives

Although not part of the formal unit assessment two “awards” were presented to teams after the end of semester demonstration. The first was a “People’s Choice Award” for the best module as voted by the students and the second was a “First Penguin Award” based on Randy Pausch’s criterion [5] chosen by the two academics.

CONCLUSIONS

The Crazy Machine Project required students to work in an environment resembling the one they will find in their professional lives. This experience gave students the opportunity to develop professional skills and learn about the design of embedded systems. Analysis of questionnaire responses and personal interviews revealed that the CMP encouraged students to reflect more on their learning and how it happened (or not). One of the students manifested that he had learnt more about engineering during the CMP than in the previous five semesters of his course.
At the Electrical and Computer Engineering Department this was the first time two units shared a project-based laboratory component. Preliminary results suggest that the CMP should be repeated in future editions of ADD 320 and ESE 302. Improvements derived from students’ feedback and facilitators’ personal experiences will be included. From the unit management point of view, it is expected that the workload for academics will be significantly reduced now that the Blackboard site and assessment tools have been developed.
Projects like the Crazy Machine have the potential of producing well-rounded student engineers who have the ability to solve problems with confidence and creativity in a multidisciplinary, multicultural team environment.

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BIOGRAPHICAL INFORMATION

Clive A. Maynard, is a Senior Lecturer in the Department of Electrical and Computer Engineering at Curtin University, Western Australia. He has been an academic since 1970 and has tried a number of educational paradigms during this time. He has been informally following the CDIO framework for several years and has finally decided to publish some of the innovative topics he has tried related to the students' laboratory experience and its impact on teaching and assessment.

Dr. Cesar Ortega-Sanchez is a Senior Lecturer in the Department of Electrical and Computer Engineering at Curtin University, Western Australia. He facilitates learning in digital design and embedded systems using FPGAs. He is also the Department's Chair of Teaching and Learning. He has been involved in academia for 20 years and is always looking for ways to help students discover knowledge by themselves. His current research focuses on computational intelligence, students' perception of feedback and curriculum development methodology.

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