Large Group Cooperative Learning for Engineering Students

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Abstract – This paper describes our experience of implementing a problem-based cooperative learning project offered as one of the final year subjects. It is a project-based subject for all Bachelor of Engineering in Computer Systems degree students in Faculty of Engineering at the University of Technology, Sydney (UTS). The subject, Computer Systems Design (CSD), aims to develop transferable skills that students can utilize beyond their academic training settings such as their problem-solving ability, skills in teamwork, project management experience, and abilities to become lifelong learners. The subject also has the added benefit of familiarizing students with specific technical skills that students can choose to develop further if they so desire.

I BACKGROUND AND MOTIVATION

Often it is not enough to just have technical know-how to succeed in the engineering profession, supporting skills such as interpersonal communication, working in teams, project management, self management, and research techniques are equally important. Jackson (2003) envisions a cross training of managers and technical experts for the 21st century science and engineering workforce in order to attract and retain science and engineering workers. Engineers Australia recognizes that "communication skills and some management skills would be considered essential for the effective performance of engineering activities" when formulating the National Generic Competency Standards for professional engineers (IEAust, 1999). Therefore it is important that students are given a chance to develop technical and these supporting skills before they enter the workforce.

At the UTS Bachelor of Computer Systems Engineering (CSE) degree, the subjects are organized according to core subjects and field of practice subjects. The core subjects are common to all engineering undergraduate students and taken by all, these subjects deal with the fundamentals and common domains across all engineering discipline such as mathematics, physics, and management topics. The field of practice subjects are tailored towards each engineering discipline and are taken by students enrolled in that program. CSD is a final year field of practice subject for the CSE program, and students usually undertake CSD in their final semester of study. Most students at this stage of their studies have finished most if not all of the core and field of practice subjects. They would have been exposed to considerable amount of engineering fundamentals, electronics hardware, and software development type subject materials. Students then have a chance in CSD to consolidate their previous experience and learning.

A Group Size in Problem-based Learning in CSD

A problem-based cooperative learning project is used in CSD for students to role-play as a development team of around 20 people in size. This team needs to work and act as a team and dynamically divided their team to sub-teams depending on the tasks for each assignment in the semester. Engineers need to be able to work and contribute in a team environment because as technology becomes more sophisticated and specialized, these tasks increasingly requires the joint efforts of many people (Committee on Education of Facilities Design and Construction Professionals, 1995). Students were already familiar with group work during their previous subjects at UTS, but they are usually conducted in groups ranging from 2 to 5 in size. Students are exposed to a team of around 20 people in size in CSD, which is a new experience to most of the students in an academic setting.

B Cooperative Learning in CSD

Shannon and Brine described a six-week cooperative problem-based learning project for graduating architects which they argue the teaching method “increases students’ confidence in their ability to learn and is closely linked with promoting the concept of lifelong learning” (Shannon & Brine,1995). The CSD project aims to emulate an industrial project where the students need to work as a team to deliver a product to their client. Students are acclimatized to academic staff directed learning environments in their prior educational settings; CSD is usually the first subject where they are expected to work in a cooperative manner and a self-directed learning setting with the academic staff acting as facilitators instead of the experts with all the answers, unless it becomes necessary to redirect the students project to ensure they can finish the project on time.

II METHODS

A Description of CSD project

CSD revolves around a major project simulating the workplace setting, where students role-play as a professional engineering development team being hired to develop the system. The major project is a mock-up chocolate factory called an Assembly Machine Cluster (AMC) that produces boxes of pseudo chocolates. UTS provides the hardware components which include two vertically articulated industrial robot arms, a long conveyor and its motor controller, a color video camera attached to an image capture card, and a gauging station with pneumatic and infrared sensors. Figure 1 shows a top-view of the factory layout as currently setup in the laboratory.

Raw material inputs to the system consist of plastic inserts which play-act as the chocolates and metal boxes with four slots having a picture of one of the inserts affixed to each slot. The inserts need to be placed in the slots with its corresponding picture. In the manufacturing process the inserts are identified by the gauging station and then manipulated by one of the robot arms, while the boxes are transported by the other robot arm via the conveyor to an assembly area. The vision camera takes a snapshot of the box as it traveled along the conveyor, and these pictures are analyzed to determine which inserts needs to go to which slots. Inserts are then loaded into the boxes by one of the robot arms.

B Students' Task in CSD

Students need to undertake the task of specifying, designing, and implementing their system as a team. Students would have already done requirements analysis and produced a high-level design document in a previous subject called Computer Systems Analysis (CSA). At the beginning of the semester, students are given some time to refine or modify their systems requirements document and their high-level design document as they see fit.

i Assessments Description

The assessments consist of three assignments; a written individual reflection of a student's learning experience, and an individual viva session at the end of the semester. Assignment one is where the students define the system's requirements, high-level system design, system testing plans, and also carry out project planning as a team, students need to submit a report and a presentation. In the presentation, the academics recommend that students should pretend as if they are bidding for a tender, while the academics have the task of switching between the roles of clients and academics for the remainder of the semester.

In assignment two students need to present their implementation progress to date with a written report, and a demonstration session. The team needs to document their project planning, the detailed design of their implementation, and any testing done by them for each of the sub-system in one report. While in the demonstration the students are again encouraged to pretend they are a team of professional engineers performing work for its clients. Assignment three is where the students present their final implemented system with a report and a demonstration session. The team needs to document any variations to the system done since assignment two, challenges they faced, and an analysis of their test report. In the demonstration the students are strongly encouraged to present a professional demonstration with an aim to convince the clients that their system is so good that they should be 'paid' for their work. In this case, the "payment" will be in the form of marks given by the academic staff instead of a monetary reward.

The individual reflection is a chance for students to reflect on their experience of the course through participation in the team project. Generally students reflect on their understanding and experience of issues they encountered within a set word limit of 600 words, which some do better than others. It is also a chance for students to practice self-evaluation of their contribution to the team and of their learning outcome.

In the individual viva session, each student is interviewed for 20 minutes by two or three academic staff associated to the course. In the closed interview, students are given the opportunity to communicate orally their contribution to the team and their learning outcomes with reference to the project. Students who genuinely contributed to the project are usually able to provide concrete evidence of their contribution. At the end of each session, the academic staff also asks students for feedback and suggestions for the course.

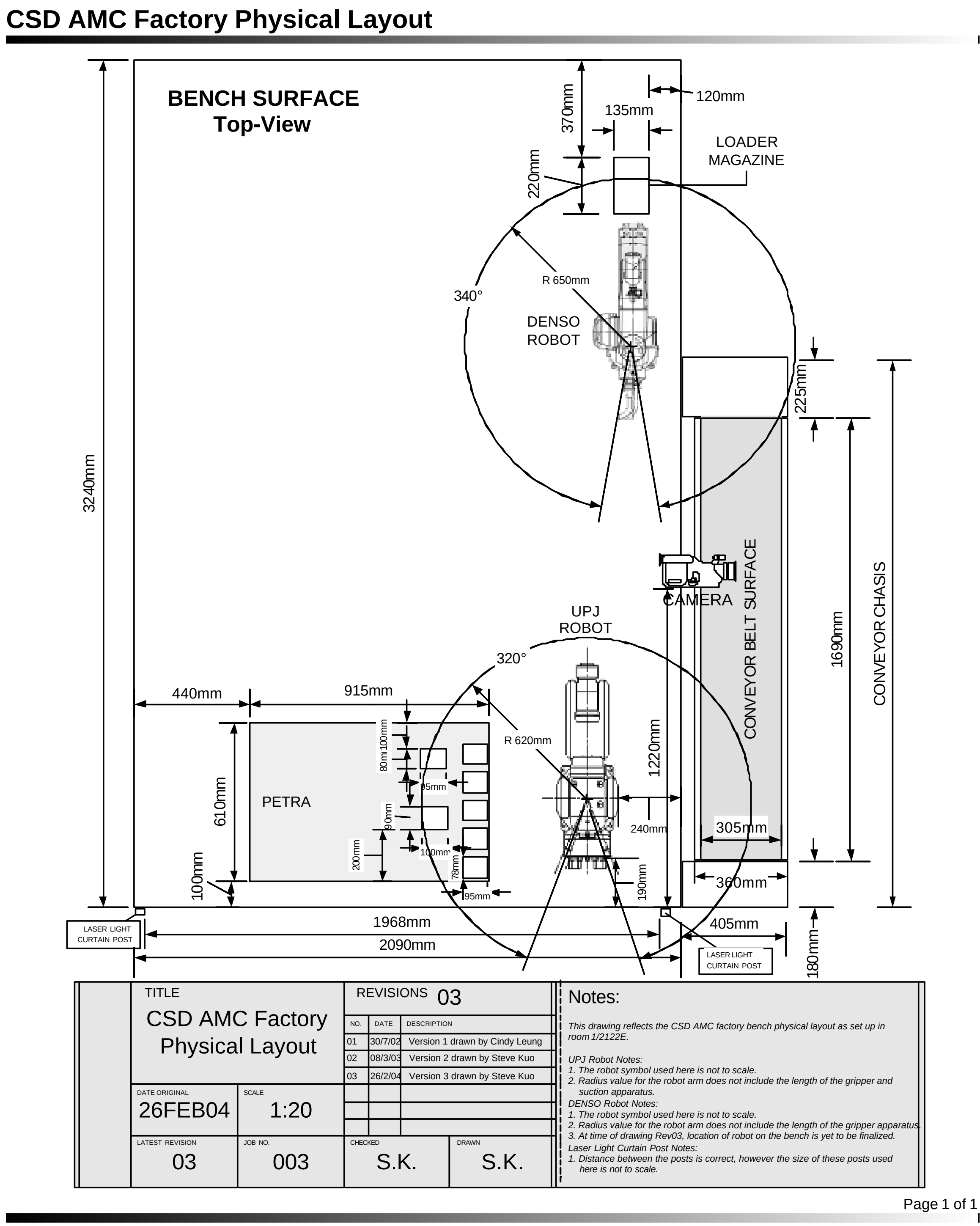

Figure 1: Top-view of factory layout

III RESULTS

Students were asked to complete an anonymous survey at the end of their project to rate level of learning benefit derived from the project. The list of questions is listed in Appendix A, students were asked to respond to each question as either: Not Applicable, Strongly Disagree, Disagree, Neutral, Agree, or Strongly Agree. The survey result is presented in Figures 2 to 10 and in Appendix B, which can be seen that majority of students surveyed tend to agree that the AMC project used in CSD provided them with positive learning experience. The survey was conducted on 34 students.

IV DISCUSSION OF RESULTS

A Increase in Problem Solving Skills

The CSD project aims to develop students' problem-solving skills by presenting them with a problem in a simulated industrial setting and allowing them to develop a solution, instead of "the solution" as a team. Berry, et al [4] suggested that due to rapid advancement of technology an emerging trend in electrical and computer education is to provide "a generic or general education that emphasizes the development of problem-solving skills" which will allow graduates the adaptability and flexibility in the workplace.

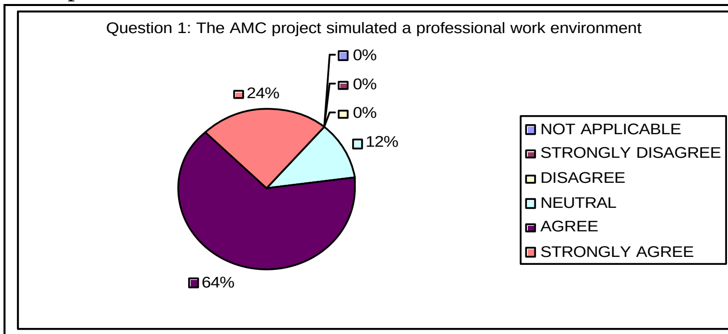

Figure 2: AMC project simulated a professional work environment.

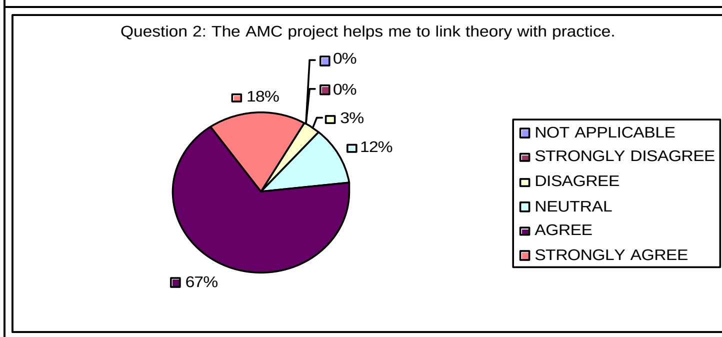

Figure 3: AMC project helps me to link theory with practice.

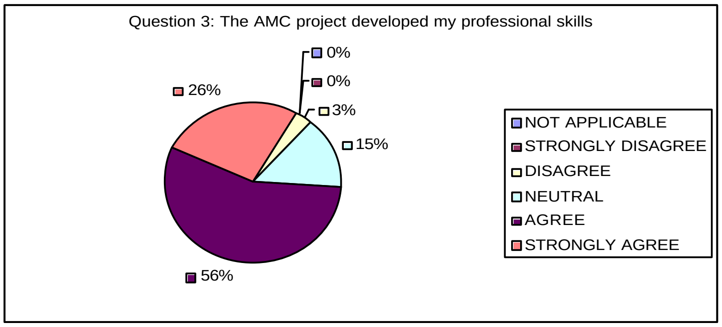

Figure 4: AMC project developed my professional skills

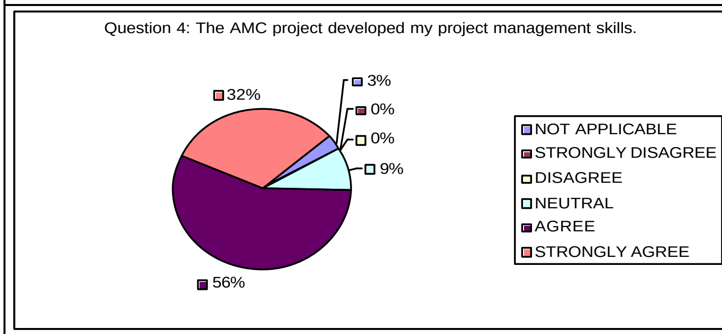

Figure 5: AMC project developed my project management skills.

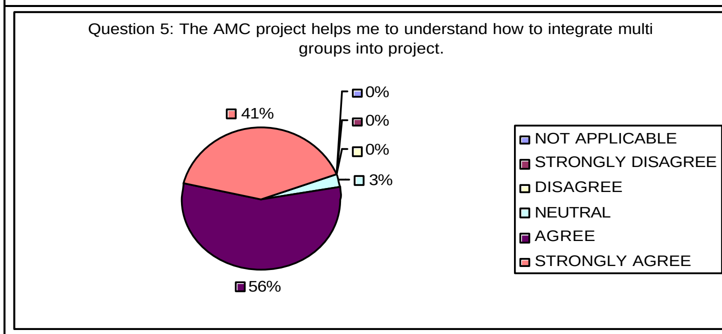

Figure 6: AMC project helps me to understand how to integrate multi groups into project.

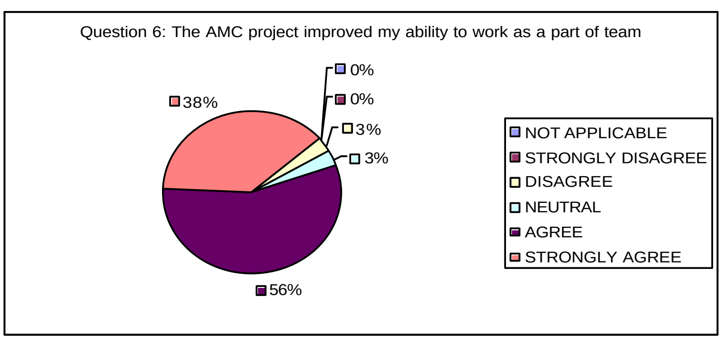

Figure 7: AMC project improved my ability to work as a part of team.

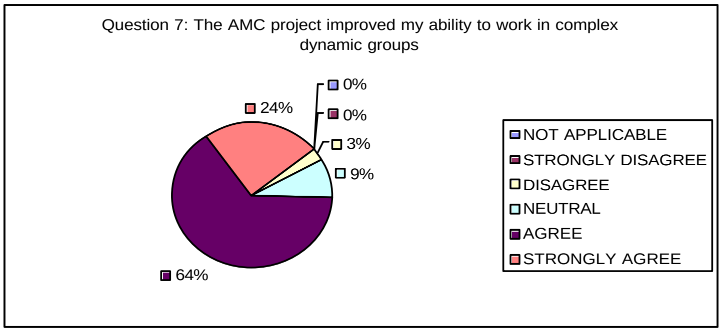

Figure 8: AMC project improved my ability to work in complex dynamic groups.

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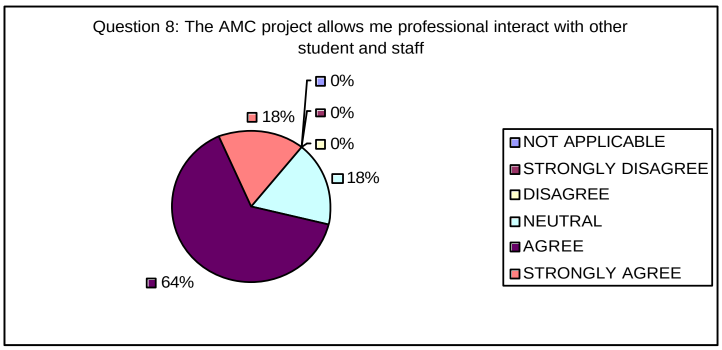

Figure 9: AMC project allows professional interact with other student and staff

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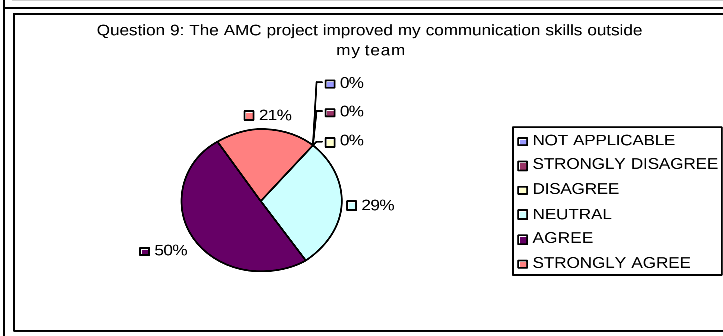

Figure 10: AMC project improved my communication skills outside my team

We always discuss with the students problems encountered in the project and how they were solved during each student's individual viva assessment. Almost every team to date encounters an identical problem of one or more team members who underperforms compare to the rest of the team. Different teams deal with that in different manners, some chose ignoring the problem and take on extra workload, some chose confronting the team member in question, some were able to motivate the team member, while some chose to encourage the team member to contribute with incentives such as free alcoholic beverage or trips to a favourite fast food outlet.

Ohlsson and Johansson [5] found that students in their practice driven software engineering courses needed very little technical guidance and support because they were able to find answers to their problems independently. We also observed that students as a team require only general directions and advices regarding technical guidance because they were able to seek out the relevant information that enabled them to complete the project successfully.

B Learning from Other Students

Students are encouraged to learn from each other, view other students as resources, rather than seeing other students as competitors, which discourages learning interdependently. Academic staffs' teaching role is to serve as additional resources to the students rather than depositories of "correct" answers. In her research of groups of medical students taking a problem-based learning subject, Duek wrote that the tutors' job "is not to teach the students but to assist them with their organization and resolution of the problem" [6]. In Duek's study, she found that the presence of a tutor affects students' participation rate and willingness to discuss ideas openly within a group [6]. This confirms our experience as we found that in instances where a tutor was present during students' team meetings, the atmosphere became formal and tense as the team leaders and their members became more eager to show the academic present that this team is doing a "proper" job. There are a few cases when a tutor suddenly walks into a team meeting in progress unexpectedly to hear the sound of jovial and relaxed discussions abruptly cut-short, only to be replaced with "speeches" delivered in a formal tone of voice. Therefore academics are now rarely present at students' team meetings unless requested by the students.

C Lifelong Learning

Independence in learning and hence the notion of being a lifelong learner is another important aspect of what the subject aims to instil in students through the use of problem-based learning. Prosser and Trigwell described a constitutionalist model of student learning where each student's prior learning experience, perception of the learning situation, approaches to learning, and learning outcome contributes to the way a student learns, since these factors are not homogeneous to all students Prosser and Trigwell suggest that this explains individual variations to students' learning style [7]. In describing key principles of effective teaching in higher education, Ramsden describes one of the principles is to promote a sense of students having control over learning and interest in the subject, because each student will learn best in their own way, and that "trying to practice inquiry is the only way to learn how to inquire" [8].

The main task of identifying deficiencies in students' current knowledge is left to the students, and they usually can do so without input from the academics. For example, some students realized a need to learn C++ programming language to develop the system; most students are able to independently identify resources such as library books, internet sites, and friends who are proficient programmers. There are also students who lack the confidence of conducting independent learning and will turn to the academics for directions; in this case they are guided in a general direction towards resources that will enable them to find the answers for themselves. Question from students such as: "How to write a comprehensive test specification document?" will prompt the academics to direct them to search for relevant industry standards, or software development textbooks, instead of being provided with specific instructions on how to write one. We believe this provides students opportunities to “learn how to learn” and to gain the confidence to learn independently.

D Increased satisfaction and motivation for learning

Lord reflected on his experience of using problem-based learning programs to develop professional skills in second-year engineering students, and reported comments from students such as: “It wasn’t simply memory work or some sort of mathematical manipulation of variables to be absorbed and practiced, but it actually made me think about the whole concept of what was being learnt.” [9]

Some CSD students reflected on the use of problem-based cooperative learning and agreed that it has increased their satisfaction and motivation for learning. One student identified a need to learn vision-processing techniques in order to successfully complete the project, and was able to accomplish this learning task in a self-directed learning manner. He reflected this is the first time he was asked to learn in this way and said “the concepts stuck in my head better than what I learnt in other subject”. Not every student felt the same way, as some reflected a sense of lack of direction, and were anxious and frustrated at times about not meeting academic staff’s expectations.

V CONCLUSION

The CSD AMC project allowed students to develop transferable skill sets such as problem-solving ability, teamwork and project management experience, and abilities to become lifelong learners. The problem-based cooperative learning project allowed students freedom to choose what and how much they wish to explore, and introduced them to be self-reliant in learning instead of relying on academics to provide all the answers or constantly searching the back of textbooks for “correct” answers to problems encountered.

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STEVE KUO is the tutor for Computer Systems Design subject. He has tutored this subject for the past 5 consecutive semesters.

VI APPENDIX A

List of survey questions:

1. The AMC project simulated a professional work environment.
2. The AMC project helps me to link theory with practice.
3. The AMC project developed my professional skills.
4. The AMC project developed my project management skills.
5. The AMC project helps me to understand how to integrate multi groups into project.
6. The AMC project improved my ability to work as a part of team.
7. The AMC project improved my ability to work in complex dynamic groups.
8. The AMC project allows me professional interact with other student and staff.
9. The AMC project improved my communication skills outside my team.

VII APPENDIX B

Survey results.

		QUESTIONS								
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
RESPONSE	**NOT APPLICABLE**	0	0	0	1	0	0	0	0	0
	STRONGLY DISAGREE	0	0	0	0	0	0	0	0	0
	DISAGREE	0	1	1	0	0	1	1	0	0
	NEUTRAL	4	4	5	3	1	1	3	6	10
	AGREE	22	23	19	19	19	19	22	22	17
	STRONGLY AGREE	8	6	9	11	14	13	8	6	7