MULTIDISCIPLINARY PROJECT: A CDIO CASE STUDY AT TAYLOR'S UNIVERSITY

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ABSTRACT

The demand for competent graduate engineers with capabilities to undertake complex multidisciplinary challenges has led to the introduction of multidisciplinary project based learning at a relatively early stage in the engineering curriculum at Taylor's University. This paper documents a multidisciplinary group project to conceive, design, implement and operate an electric car for a single passenger undertaken by two third semester Mechanical Engineering and two third semester Electrical & Electronic Engineering students under the supervision of the authors. As second year students beginning with very little knowledge and experience related to the project, the students were able to successfully acquire the necessary skills and knowledge on their own, work together as a team and cross engineering disciplines to produce a fully functioning artifact within one semester. A safe and sustainable product was successfully delivered within the required timeframe. The effective application of the CDIO processes is highlighted. The learning process, the social dynamics and the positive pedagogical outcomes achieved through this intense learning experience are evaluated and presented in this paper.

The trend of engineering education is progressively shifting from the traditional content based and input centered education method to a measurable outcome based method. This shift runs in parallel with the shift from requiring highly focused professionals of single discipline to professionals with a multidisciplinary mindset as the job market continually evolves to require a mixture of technical abilities. This change to a multidisciplinary approach is not without barriers. This project was proposed to the students as a multidisciplinary project intended to break these entrenched barriers between disciplines in order to better prepare the students for the highly competitive job market. In addition to these changes in the professional work environment, the need for engineers to have leadership character, communication skills, independency, management skills, and problem solving techniques constantly increases. In this project, the students were given the authority to select their team leader, prepare Gantt chart, follow CDIO processes and closely manage their timeline. Analyzing weekly task record was evidence of students learning outcomes towards achieving the module outcomes. The key elements of this module are that students were given authority to manage their own project and practice leadership while doing extensive research under supervision of supervisors.

KEYWORDS

Multidisciplinary, Project Based Learning, Electric car, CDIO Standards: 1, 2, 3, 5, 6, 8, 11

INTRODUCTION

Engineering challenges today are becoming increasingly complex and require nothing less than multidisciplinary approaches to overcome. Hence in the present scenario, Engineers are expected to understand how to play a positive role and contribute effectively in a multidisciplinary environment. Consequently engineering programmes around the world have begun to include multidisciplinary projects and courses into their curriculum.

The recognition of the importance of taking a multidisciplinary approach to counter a "silo" mentality is not only recognized in the field of engineering but also in other fields (Masters et al, 2013). The advent to ICT has made the integration of multidisciplinary teams very conducive (Martinez et al, 2010) and can be expected to be even more so in the future.

Much informal learning takes place within the context of a multidisciplinary team. Rogers and Badger (2012) identified the potential of multidisciplinary teams in offering the richest informal learning opportunities and providing fast, imaginative solutions, more frequently and with less effort. In addition, being immersed in these rich learning environments encouraged individuals to acquire knowledge at the fringe or across disciplines thereby enhancing their individual value.

Research was done at Georgia Tech where a capstone design course compared the performance of multidisciplinary project teams against monodisciplinary project teams. Results indicated that the performance in innovation, utility, analysis, proof of concept, and communication skills was superior for the multidisciplinary teams compared to monodisciplinary teams and also on average members of the multidisciplinary were hired more frequently (Hotaling et al, 2012).

Without doubt, it is imperative that undergraduates in engineering programmes be exposed to a multidisciplinary environment at a very early stage in their undergraduate career so that a multidisciplinary environment becomes a normative in their experience which they will carry with them into their work environment in the future. This multidisciplinary mindset can certainly enhance their future contribution as an engineer and team leader.

On the other hand, it is necessary to guard against unintentionally inculcating a "discipline superiority" or a "discipline exclusivity" mindset into the student. The students need to develop appreciation, healthy respect and the openness to want to learn from engineering disciplines different from the one that they had chosen to specialize in.

BACKGROUND

At Taylor's University School of Engineering, a core module titled Multidisciplinary Engineering Design is offered to students in the first semester of their second year (or third semester of study). As stated in the course outline, the objective of this module is to "introduce students to real-life work environments where engineers from different disciplines and backgrounds work together to realise a given task."

In this module, the students are expected to form groups of between four to six students comprising a mixture of majors from more than one engineering discipline. These groups are formed by the students themselves and not being assigned to one by the supervisor(s) or

module coordinator. Within the timeframe of one semester, the students are required to produce a functioning artifact and simultaneously satisfy all the assessment components of the module.

The learning outcomes taken from its course outline and listed below were intended to meet the objective of the module.

1. Explain the principles of design for sustainable development.
2. Apply the principles of physics to achieve a specific engineering task or to build an engineering artifact.
3. Evaluate different approaches to achieve a required end result.
4. Appraise and defend ideas.
5. Predict outcomes of suggested approaches.
6. Explain the benefits & barriers associated with multidisciplinary teams.

In the Taylor's University School of Engineering curriculum, project based modules are being offered as core modules in every semester. The students were exposed to a multidisciplinary group project based learning environment starting from semester one and continuing into semester two, three and four. However as a general rule, the students even while being involved in these multidisciplinary teams, tended to focus on contributing from the within the boundaries of their own disciplines. The Mechanical Engineering students focused on the mechanical aspects of the project, the Electrical & Electronic Engineering students likewise on the electrical & electronic systems and the same with the Chemical Engineering students with matters closely related to their discipline.

In this third semester multidisciplinary project presented as a case study in this paper, however, the students crossed disciplinary boundaries and contributed in crucial aspects of the project outside of their respective disciplines.

This project offered by the authors involved building a single passenger electric car for the purpose of participating in future electric car races. This can be considered as a relatively large and time consuming project for one semester especially given the small number of students in the team. The students in this project team comprised of two mechanical engineering and two electrical and electronic engineering students.

None of the students had any prior experience in designing and building an electric car, neither was there any specific content in the syllabus pertaining to electric cars. The fundamental elements of CDIO, namely conceive, design, implement, and operate were applied.

The students were supervised by the authors, one who has an electrical and electronic engineering background while the other who has a mechanical engineering background.

METHODOLOGY

The students were given the responsibility to develop the work breakdown structure and Gantt chart and to divide up the tasks according to individual interests and capabilities. In addition to guidance from the supervisors, the students also received guidance from a senior year mechanical engineering student who had been part of a team that had built an internal

combustion engine race car previously. This student was recruited by the supervisors to serve as an ad hoc advisor to the team.

With regards to electrical engineering matters, the students at times sought technical advice from one of their friends from another university who is a major in electronic engineering and who has a good grasp of both theory and practical matters in electrical and electronic engineering.

A mechanism for reporting progress and accountability was put in place. In addition to weekly meetings with supervisors regarding progress and upcoming issues, the students were also required to update their daily progress by email to the supervisors. This was subsequently extended to a weekly basis when the students proved their consistency in meeting tasks deadlines. These progress reports were considered by the supervisors as necessary due to the tight completion time in comparison to the magnitude of the task for this small team. A team member was designated as secretary for the group and is responsible to oversee these reports and to keep team members and supervisors updated regularly. The secretary acted as the main channel of communication among team members and with the supervisors.

The students were given the autonomy to select their own Team Leader who is responsible to ensure that tasks are completed according to the tight schedule, and that members showed up on time for all meetings and tasks.

It is necessary to mention that the students were fully engaged in the design and analysis aspects of the electric car and not merely the construction of it. Alternative designs were considered, different options were continuously explored and design calculations were made including the load and torque calculations that form the basis upon which other design calculations and decisions were based. Such calculations were firmly supported by the principles of physics and mechanics. Safety was a paramount design consideration. Active and continuous learning was integrated into this module. Students were constantly searching for new ideas and information since they did not have any prior knowledge on this complex task. It was obvious that students throughout the semester were engaged in manipulating, applying, analyzing, and evaluating ideas.
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Due to the small number of students in the team, the Electrical & Electronic Engineering students helped with the Mechanical Design, CAD drawings, calculations and the fabrication of the mechanical components including welding of chassis, and assembly of the brake, steering and suspension systems. Likewise the mechanical students involved themselves in understanding the electrical components such as the hub motor and batteries and the associated calculations and parts selection.

As a result of different personalities coming together to work under a very stressful assignment, friction between members was inevitable. The supervisors lend a listening ear to individual grievances and sought to placate these situations by offering helpful counsel. In order to strengthen the bond and break any communicational and social barrier, socialization was encouraged. Outside activity and group lunching and were planned on almost weekly basis by one of the supervisors.

All the core elements of CDIO were applied. The electric car was conceived through the study of the requirements for competing in the Shell Eco Marathon. The students then designed the car considering various options, performing design calculations, and making

sound engineering decisions. Implementation involved planning the work, requesting for the timely purchase and delivery of materials, performing each task defined for the fabrication and construction of the car, and integrating all the mechanical and electrical and electronic elements into a complete system. Finally the car was successfully operated during the artifact assessment for the module.

A survey to gage students' learning experiences was conducted after project completion.

RESULTS AND DISCUSSION

Artifact

A fully functioning single passenger electric car was completed as shown in Figure 1 and Figure 2. The car consisted of the chassis, the steering system, the suspension system, the braking system, the batteries and the hub motors. The car was successfully test driven by one of the students on a normal paved road used for regular automotive vehicles for 200 meters during the artifact demonstration with no problems encountered. The car continues to be functional and safe to use.

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Figure 1. Back view of electric car

Figure 2. Front view of electric car

CDIO standards

Apart from CDIO standard 1 mentioned under methodology, standards 2, 3, 5, 6, 8 and 11 were also applied. For standard 2, the students enhanced their personal, interpersonal, and product and system building skills by working on this project. For standard 3, integration of curriculum is evident by the students willingly crossing disciplinary boundaries to learn and to assist with tasks outside of their chosen engineering discipline. This was very much a design and build experience for the students hence standard 5 was addressed. In the building of the artifact, extensive use was made of the space provided in the workshop, and the CNC machines as required by standard 6. As for standard 8, the students had to actively acquire the necessary skills and knowledge. Initiative was expected as nothing was provided without their effort. It was not just knowledge that they had to acquire but skills as well through actively seeking out information, reading, consulting with others who had the skill and knowledge and practicing the skills themselves. Finally for standard 11, the students were assessed according to the module learning outcomes mentioned in the Background section of this paper.

Student learning achievements

As there were only four students in the team, it was decided to perform a qualitative survey. Excerpts from students' comments from the survey were reproduced in quotation marks below. The survey form is found in Appendix 1.

With only four students in the team, the students were unanimous in regarding the project as overwhelming in terms of the amount of workload and time required of them. In spite of that they regarded the experience positively and considered it as beneficial preparation to face challenges in the "real world".

"I do think that it is necessary for students to be exposed to this subject and would most likely recommend others to take this module, but in my opinion, all these experiences I have acquired are majorly based on the project I am undertaking. If the project is too simple, there's not much we can experience. The project has to be somewhere difficult but possible to achieve."

"This project could actually prepare me for difficult situations of deadlines and intense nights of nonstop working. This project had quite a lot of aspects such as project management, technical and hands on work which I found them very helpful for my future."

The students also unanimously agreed that having to cross disciplinary boundaries is beneficial for them and considered the experience very useful for their future work.

"Yes, as a Mechanical Engineering student, I find it beneficial as I can learn something that is out of my field which can help me to explore greater possibilities in innovation and creativity…….Yes, it's crucial for student to be exposed to others disciplines so that they will be prepared to work with different types of people in the real world."

"Yes I have faced challenges where I had learn thing about electrical engineering so that I can solve a certain challenge and sometimes I had to combine both majors together to get a final answer…..I believe that it is necessary for an engineering student to be exposed in

different majors at least in a basic level because this would help you to understand your co worker's ideas although they from different majors."

"Yes, this experience is beneficial. I learn how to use all the tools and equipment that are generally used by Mechanical students available at the lab. This is valuable experience as I think that the real working world would want me to be knowledgeable and ready for all these types of equipment and tools. I also get to know about designing 3D objects through SolidWorks."

"Yes, I do. This is extremely beneficial as it helps us understand what their limitations when it comes to design. This will help us to compromise each other so that both the mechanical and electrical part can be worked well together….. I have learn how to use the machine in manufacturing workshop. It is beneficial as it helps EEs to be better understand MEs limitation."

The other main learning outcomes arising from this project were time management, working with others and perseverance. These can be considered as the necessary ingredients for success of an engineer undertaking any project anywhere in the world.

Students' comments regarding time management:

"The biggest challenge is the time management. 14 weeks is considered as short for a project like this. It is in a scale so big that most people will doubt it's completion in time not mentioning with the limited amount of experience and knowledge we initially possessed. However, we believe that we can only learn, gain experience and have fun when we get down and dirty in the process."

"Project management, the processes for a project to be completed must be known even (before) the project is started so that every steps is organized. Time should not be wasted or used unnecessarily."

"The time constraints were the biggest challenge for my opinion as we have to finish in time but there will always be situation going on. So we have to work extra hard to catch up the previous wasted time."

"Considering all the criteria in the designing stage before jumping to construction."

Students' comments regarding working with others:

"I was given a golden opportunity to work with different people in this team and this give me versatility in getting along with people in the future as there is a diversity of individuals that I am going to meet in the real world in future."

"I can say as a Project manager the biggest challenge for me was to keep everyone happy about what they are doing and encourage them to work overnights……Listening to everyone's idea and respecting everyone in a team."

"Teamwork, a good team will have greater capabilities to do wonders and it will definitely be better than the work of several individuals combined. Trust, it is important to trust all of the members involved as every single one plays a different role in a team."

"Do not (be) scare(d) of your boss/supervisor/manager. They are humans, so just be honest and tell them what's wrong. Just make sure you have the correct ideas."

Students' comments regarding perseverance:

"I have experienced the hardship of completing this project with only 4 members. In my opinion, this is very beneficial to me in a way that I now understand the pressure/stress/requirement of completing a huge project. This will greatly prepare me for the upcoming challenges in the real working world."

"By challenging myself for a tougher jobs, I believe I would be more mature in making decision. Besides that, I have learnt how to communicate effectively to convey the ideas I wanted to share."

While the final outcome was achieved and students were on the whole very positive about their learning experiences, yet it was not without challenges as reflected in these personal student comments below. The authors regard all experiences both positive and negative as beneficial learning outcomes in producing a capable engineer conversant in both the hard technical aspects and the soft skills of leadership and working with others. Negative experiences allow for maturity and growth as the students learn deal with them. Students should not be shielded from these experiences but instead should be encouraged to learn from them. These comments are individual comments and may not necessarily represent the opinion of the entire team.

"I think the biggest challenge faced in this project was the group itself. In my opinion, we lacked a proper team and a team leader. There was no proper direction as the team was heading aimlessly trying to complete the project. So far by sheer will and patience, we were finally able to complete the project but I think it can be done better."

"Be punctual. Someone will always be late for meeting, and it always delays our time. Other than that, when you are late, people have to explain all of the things again and sometimes he or she had completely miss out an important details."

"I will recommend you truly be yourself, and actually talk to yourself, do you like this project? If yes, go for it. However, if you ever have one bit of doubt that can you do it? No, please find your better own goal."

CONCLUSIONS

A multidisciplinary engineering design project consisting of designing and building an electric car was successfully completed in one semester by four third semester students from the mechanical engineering and electrical and electronic engineering programmes. The students involved in the project not only worked within the boundaries of their own engineering disciplines but also contributed significantly across disciplinary boundaries. Active learning and several other CDIO outcomes were achieved. The students managed to learn the necessary skills in their effort to become competent and successful future engineers. These included technical skills, project and time management skills, a variety of soft skills together with the appreciation of engineering disciplines other than their own and a willingness to engage in it.

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BIOGRAPHICAL INFORMATION

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Appendix 1 Survey Form

Questionnaire: Electric Car Multidisciplinary Project

Full Name:

1. How do you think your participation in this project helped prepare you to face the challenges in the real world? Please explain.

2. As a Mechanical (or Electrical & Electronic) student, did you have to cross disciplinary boundaries to take on tasks regarded as Electrical Electronic (or Mechanical) in nature? Was this experience beneficial? Please explain.

3. What was the biggest challenge you faced in undertaking this project? How did you overcome it? Please explain. (The challenge may or may not be related to a technical challenge)

4. What did you learn from this experience? List down 3 things and explain.

5. Do you think in this era it is necessary for students to be exposed to a Multidisciplinary project, and would you recommend to others to take this module.