

Developing Critical Thinking and Intellectual Design Skills via Collaborative Projects in Engineering and Business Postgraduate Studies

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STRUCTURED ABSTRACT

CONTEXT

This paper studies a multi-objective project design for postgraduate engineering and business unit of studies to develop critical thinking, idea development, and intellectual design skills in students. In the real world, people from different disciplines need to work collaboratively in the new product development process. However, in the current curriculum and teaching environment, the collaboration part is missing. Although new product/innovation subjects are offered in Faculty of Engineering and Business School, they are run separately only focusing on one aspect of the process. Business students will focus on the business components and ignore the technical design part. Engineering students will focus on the product design and pay less attention to the business components. By using an interactive framework which links students from both sides together, they will learn how to identify the real-world problems, how to propose effective solutions, and how to incorporate the customer feedback into their designs.

PURPOSE

This paper evaluates the new initiative in the postgraduate engineering unit of studies, where a multi-disciplinary project component was introduced. The purpose is to engage students from engineering and business schools in several collaborative tasks to develop critical thinking, idea development, and intellectual design skills in students. The project aims to create an environment for real collaborations between different sectors to work on real-world problems.

APPROACH

A unit of study component was designed that consist of 10 modules. Five modules focus on business aspects of a product and five other modules focus on technological aspects of a real product. Students from both sides are paired to work together on these modules and provide feedback to their team mates. Business students will have a hands-on experience in actual product design, incorporating feasible features into the product while considering customer needs and competitive offerings and learn to start to develop business strategy early in the new product development process. Rather than just developing pre-defined projects, this project helps engineering students to work with business students to understand the real-world problems, customer needs, and develop their own idea/products. The students are interviewed at the end of the semester to identify the pros and cons of this approach.

RESULTS

Unit of study surveys and feedback for teachers showed a high level of satisfaction by the students enrolled in this unit of study and performed this collaborative project. They found the designed modules very useful and expressed their willingness to develop their ideas even further to build the prototype.

CONCLUSIONS

This paper studies a new collaborative project component in engineering unit of studies the collaborative project for engineering and business students with the aim to close the gap currently observed in the engineering and business postgraduate study curriculums. The students engage in the whole process of developing a real product from both technical and business viewpoints. Students' feedback showed a high level of satisfaction for students engaged in the collaborative project.

KEYWORDS

Collaborative project, critical thinking, intellectual design, postgraduate coursework.

Introduction

The 2017 Australian Student Experience Survey (SES) (Australian Government Department of Education and Training, 2017) demonstrated that the quality of the entire education experience was rated positively by 79% and 76% of undergraduate (UG) and postgraduate coursework (PGC) students, respectively. Learner engagement criterion got the least positive rating in the 2017 SES in comparison with the other four criteria; skills development, teaching quality, student support, and learning resources study area. Although skill development was positively rated by about 80% of students, work related knowledge and skills attracted relatively low overall scores at 63% in 2016 and 62% in 2017. Developed ability to work effectively with others was also rated positively by only 65% in 2017.

SES results in various years demonstrated that students generally rated the interaction with other students outside study very low, the overall score of between 45% and 51%. However, working with other students as part of their study, attracted higher overall score of 69% in 2017 (Australian Government Department of Education and Training, 2017). Only 5% increase in the overall interaction was observed in these areas from commencing to later year. These demonstrate that the higher education curriculum needs a paradigm shift to improve the interaction between the students from different disciplines.

Nowadays, companies are using multi-disciplinary team working, which has been shown to produce a better range of ideas, reducing the development time and costs, and speed up the process of developing better products (Bonnet, Quist, Hoogwater, Spaans, & Wehrmann, 2006). For students, team working will increase motivation, especially when the project has direct links to industry (Parlett & King, 1971). Team working will also improve attitudes, personal self-confidence, tolerance, and people's ability to learn new skills (Buchanan, 1989). There are however several challenges in implementing effective team working projects as some students will find it difficult to adjust to team based work (Frank, Lavy, & Elata, 2003).

Working with peers from other disciplines enables the students gain different perspectives, helping them to examine their own values and pre-existing knowledge (Frank et al., 2003). Although, homogeneous teams which usually formed by peer selection tend to be harmonious in the initial phases of the project (Rosca, 2005), they may lack a range of perspectives that will promote innovative ideas (Wang & Kleppe, 2001) and more fruitful active discussions (Fayolle, 2008). Heterogenous groups also tend to progress more slowly through storming and norming stages (Hackman, 1983). Students need to spend much more energy in establishing relationships and identifying a common aim in heterogenous teams (Donnelly & Fitzmaurice, 2005). This may increase conflicts at the early stages as the team is spending less energy on the actual task itself (Chia, 1996). Another challenging problem is that students in each group will work together for a limited time, which is in contrast with a team in an industrial context that tackle a series of tasks over extended periods. In industrial context, the relationships will be developed in a more cohesive and productive manner.

There has been several instances of unit of studies that cover business topics related to engineering and promote entrepreneurship skills (Hynes, 1996; Martin & Iucu, 2014; Rosca, 2005; Bonnet et al., 2006; Glen, Suciu, Baughn, & Anson, 2015; Wang & Kleppe, 2001; Fayolle, 2008). However, there is only a little known on how to clearly engage students from different disciplines in the whole process of designing a new product. There is a lack of a systematic process which links the students from engineering and business schools to work together in solving real world problems. In the current curriculum and teaching environment, the collaboration part is missing. Although new product/innovation subjects are offered in Faculty of Engineering and Business School, they are run separately only focusing on one aspect of the process. Business students will focus on the business components and ignore the technical design part. Engineering students will focus on the product design and pay less attention to the business components. This paper proposes an interactive framework which links students from both sides together. They will learn how to identify the real-world problems, how to propose effective solutions, and how to incorporate the customer feedback into their designs. Business students will also have a hands-on experience in actual product design, incorporating feasible features into the product while considering customer needs and competitive offerings and learn to start to develop business strategy early in the new product development process. Rather than just developing predefined projects, this platform helps engineering students to work with business students to understand the real-world problems, the customer needs, and develop their own idea/products.

The Proposed Framework

This project aims at developing an interactive learning platform for students from the Faculty of Engineering and Business School to work together in solving real world problems and explore both technological and business aspects of a real product. Students will engage in the whole process of developing a real product from both technical and business viewpoints. In the proposed framework, engineering students will be paired with business students and jointly work on identifying real world problems, seeking feasible solutions, identifying targeted customers, studying customer needs, and developing a product and potentially launching it. This project aims to close the gap between engineering and business students and provide a framework for effective collaboration through multiple specially designed modules to develop a real product. We designed 10 separate modules to cover both business and technological aspects of a new product.

We use a lean canvas, as depicted in Figure 1, to demonstrate the inter-connection between the modules. Students will spend one week to complete each module.

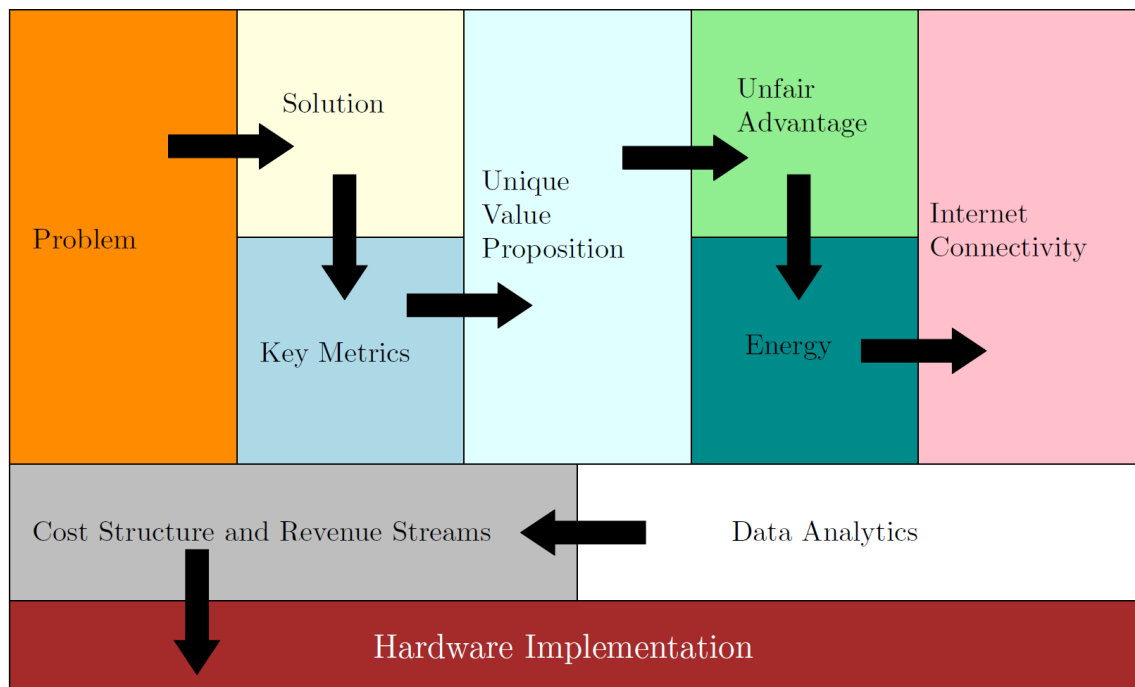


Figure 1: Modified Lean Canvas to develop an Internet of Things product

Explanation of the Modules

The first 5 modules will cover the business aspects of a real product. Each new product is developed to solve a real world problem, otherwise it cannot compete with the other products. The students are encouraged to think carefully about their everyday life and find a real problem that they are facing every day. They need to list at least three main problems that they are addressing. Once the problems are identified, the students need to propose several solutions. The students are encouraged to be very ambitious, but they need to keep in mind that the solution should have the ability to be implemented with real devices. They need to list at least three features of their solutions. They need to pivot on one metric and develop on it. The metrics should include the range of services or products they like to provide. Irrespective of industry or size, every business will have some key metrics that are used to monitor performance. A solution should always have the capability to recognize whether or not it has an unfair advantage over others. Unfair advantage can come in different forms like getting expert endorsements, a dream team, insider information, existing customers etc.

The rest of the modules will cover the technical aspects of a real product. We mainly focus on the product with the capability of providing the service over the internet. Such products are now becoming very popular with the emergence of Internet of Things (IoT) technologies. Energy is a very important aspect of an IoT device. How the device is powered will affect its application in different scenarios. The students need to find a suitable energy source for their product. They need to answer the following

questions: What is the life expectancy of the product? if it is battery operated, which battery is suitable? Is battery replacement feasible? if not, is there any other solution?

Connectivity is a major component of every IoT solution. It mainly determines how the device will communicate with the world. The wireless technology should be chosen carefully according to the requirement of the product. Finally, the product which usually collect the data should be able to analyze the data and provide useful feedback to the customer for decision making. The students need to answer how this data is analyzed and processed? Do we need cloud computing? How does this data affect the business plan?

The last two modules is to develop the actual product and evaluate the cost and revenue stream. The students from both s need to work closely with each other to develop the product in the most efficient way.

Assessment Tasks and Collaborative Platform

As stated in the active/collaborative learning (ACL) literature (Rosca, 2005), the characteristic elements of ACL are: positive interdependence, individual accountability, group processing, social skills and face-to-face interaction. In the proposed framework, these elements are practiced in several assessment tasks. The detailed assessment tasks are listed in Table 1.

Table 1: Assessment tasks for the proposed approach

Task	Detail work	weight	Submission Type
Progress Report 1	Modules 1, 2, & 3	15%	One page summary
Short Video	Modules 1, 2, & 3	15%	A three minutes video explaining the main concepts of the project.
Progress Report 2	Modules 4, 5, & 6	15%	One page summary
Progress Report 3	Modules 7, 8, & 9	15%	One page summary
Final Report	All Modules	20%	A technical report which contain, the name of the product, summary statement explaining the main feature of this product, the completed lean canvas, each module as a separate section, a figure explaining the whole ecosystem of the product, and a bibliography section.
Final Presentation	All Modules	20%	The final presentation is more technical and the students need to discuss about the technical details and the business study of their product.

Two students from engineering and two others from the business school form a group. The groups will be formed by the lecturer as the students from different disciplines do not usually know each other. They also need to form a group and discussion board on Canvas to complete the lean canvas model. The collaboration platform allows the students to fill-out the modules and provide comments to other group members. The lecturer will have access to the platform and provide timely feedback to the students.

The first face-to-face meeting for each group will be facilitated by the lecturer/tutor to introduce the students from different disciplines to each other. The lecturer/tutor will also facilitate the brainstorming to identify real-world problems. Each group needs to attend and record a meeting in preparation for each assessment. An online discussion board will be created for each group on Canvas to facilitate the active discussion.

The students need to prepare different kinds of presentations to reflect on their understanding of the business and technological aspects of their idea. For Mini-video, they need to introduce their product with a very simple language. The focus is mainly on the business aspects. In the final presentation, they need to talk about the technical aspects and explain how the requirements for their product have been met. They also need to explain how they incorporate the feedback from the peers into their design.

Students from the business schools play a key role in identifying the customer requirements and translating them to their peers from engineering. Engineering students need to translate the technical limitations to their peers from the business school. The aim is to reach a feasible solution and provide justification for every step in the design process. They need to prioritize the main product functionalities

according to the business needs. Team performance is judged according to the quality of presentations and technical reports. Timely feedback is provided for each assessment task and the students are asked to provide a summary page and explain how they have addressed the comments. The students are given the opportunity to revise their reports and resubmit. The progress reports and mini-video are formative assessments. The final presentation and final report are mainly to evaluate the student progress and teamworking capabilities.

Evaluation of the Proposed Scheme

In 2018, 40 postgraduate and 26 undergraduate students enrolled in this unit and completed the lean canvas. A subset of students were interviewed to discuss about the advantages and disadvantages of this unit. Mid-semester feedback, feedback for teacher and unit of study survey were used to evaluate the performance of this unit.

Most students found this unit very useful. They found the new initiative such as mini-video very useful. One student mentioned that

The Mini-Video was a bit confusing for me at the beginning as I could not understand why we need to make a video. Later when we made it we found that we have difficulties explaining our ideas to public so to be understood by even my peers from the business school.

More than 39% and 51% of the students were respectively strongly-agree and agree that they have developed relevant critical and analytical thinking skills in this unit. Moreover, more than 43% and 42% of students were strongly agree and agree to the statement “I can see how the knowledge and skills I acquired in this unit of study are relevant to my degree and/or to my future professional work”, respectively.

Here, I also quote some of the comments from the students:

This is a very useful course, and students can benefited a lot from the course.

most of the knowledge in lecture are highly-related to our common life except some of them are a little bit hard to understand.

The most interesting part for students were the collaboration with peers from the other discipline. They also found the feedback very useful and mentioned that the practice of addressing the comments significantly helped them to improve their project.

It was amazing to see the feedback specific to our work on submissions.

great feedback on reports and always open to discussion

very broad project allowed for creativity and presented a chance to perform research into interesting areas.

Students from the faculty of engineering found the process of collaborating with Business students very useful and they mentioned that they have expanded their knowledge through collaboration. Business students specified that they are now more familiar with technical limitations and can think of proposing feasible products rather than imaginative/virtual ideas.

From teachers' perspective, we found establishing the collaborative framework very challenging. The lecturer needed to study with the students to better understand the context of the project each group is working on. The lecturer from both sides need to be synced while each school needed to pay more attention on their specific subjects.

The students who were interviewed, mentioned that they are now more confident in working in a company as they experienced how working in a multi-disciplinary environment looks like. They developed skills in promoting their ideas, introducing them to the non-experts, and working with their peers from other disciplines.

They however felt that the initial stage was challenging as forming the groups and agreeing upon a specific topic were time consuming. Their understanding of the world is different and that made identifying the problems very challenging.

The students also wanted more interaction with the lecturers. They needed a leader to guide them in completing different modules of the project. This is a challenging problem as the number of groups is large and having a weekly meeting with all groups is infeasible.

Conclusion and Reflection on the Proposed Approach

In this paper, we developed a new learning framework that encourages students to take deep approach to develop their own ideas to solve real-world problems. The students are encouraged to develop their own ideas which will help them to put what they have learned into practice, rather than just doing a predefined project. A systematic feedback process was built to optimize the evaluation process and maximize the learning achievements. Engineering and business and marketing are two essential components for successfully launching and implementing a new innovative product. This project will build an interactive framework which links students from both sides together and closes the gap between them, as they will be closely working together on the same project and exploring different aspects of a real product. Students will be working in a multidisciplinary environment, similar to companies.

There are several challenges which need to be carefully considered when designing such units. First of all, the students have different perceptions of the project and they have even different understanding of the world. Students from the business schools are more ambitious and would like to work on real-world problems in a bigger scale, such as global warming and poverty. On the other hand, the engineering students usually think about useful and practical solutions for small problems. Students found it difficult to agree upon the problems they are going to work on.

Second, students from different disciplines use different technical languages which are not quite familiar to the others (Frank et al., 2003). The lecturer needs to facilitate the discussions in the first meeting and make sure that they understand each other. They need to clearly state the requirements from each side so to be able to define the project.

Third, engineering students can usually get along with business students and working on the business aspects of the product. On the other hand, the business students do not want to get involved in the hardware development. The last two modules is then performed individually and the students can provide feedback to their peers from the other school.

Fourth, the marking criteria for the different schools should be different as the learning objectives are different across different disciplines. This is a challenge how to design a marking criteria for different component of this project.

Fifth, the students can develop their own idea and the lean canvas should be updated accordingly. Therefore, it is the responsibility of the instructor to update the marking criteria accordingly. Some students may focus on software development and the others may develop an actual physical product. It is then quite challenging to evaluate the group performance in multi-disciplinary projects with broad range of topics.

Last but not the least, different disciplines have different priorities which reflect in their curriculum. Defining such collaborative projects between two disciplines need to be discussed in higher levels to agree upon a common theme for educating the students. Different schools need to synchronize the course offerings. The major challenge is to make sure that the groups can be formed effectively and there are enough number of students from each school in each group. The course planning should take place with sufficient time in advance for the proper scheduling.

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