An initial step towards developing techno-entrepreneurs in the engineering curriculum

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SESSION

C2: Interdisciplinary and cross-disciplinary engineering programs and learning environments

CONTEXT

Innovation and creativity are essential and related to entrepreneurial learning, skills, knowledge and mindset. Previous research specified requirements for engineering educational programs to boost students' creative skills in engineering. In order to enhance creative thinking among engineering students, our teaching team has developed an interdisciplinary subject integrating entrepreneurship components into a traditional operational management perspective. Our teaching team endeavoured to build capabilities that allow future engineer graduates to engage in a creative process to solve a problem or to design and make a new artefact and become techno-entrepreneurs. Our works analysed whether a major assessment within a subject in third year engineering curricula – a team project to develop a business plan based on a new idea – help students to implement their learning into tangible outcomes and develop their creative skills.

PURPOSE

The main research question in this paper is whether students utilize or implement the lecture content in their group projects to learn effectively and enhance their learning.

APPROACH

Researchers in this paper analysed students' projects, which were submitted as group assignments during three years between 2014 and 2016 in regards to how students applied the lecture content and tutorial activities in their projects. Focusing on creativity and innovation as the main elements of selecting a new idea for the project, we evaluated whether the teaching and learning process helped students to learn and apply concepts of creativity and innovation in a practical project. In addition, we were looking to classify types of ideas and areas of businesses that engineering students have been interested in.

RESULTS

The findings showed that majority of engineering students were focusing on new technologies to introduce new products and develop new services. On the other hand, although the concepts of creativity and innovation are necessary for their projects, students mainly followed up the current trends in technologies that pioneered by large corporations in high tech industries. In these circumstances, it seems students followed the type of innovation known as "incremental innovation" or steady improvements based on sustained technologies.

CONCLUSIONS

Students paid attention to the concept of creativity and incremental innovations in their projects as part of the lecture content and learning objectives, but often they did not try radical innovations or fundamental rethink based on disruptive technologies. This evidence encouraged our teaching team to modify the requirements of projects, give more values and marks regarding radical innovation in assessment rubrics and at the same time, take more emphases in lectures and tutorials to encourage students to try radical innovations.

KEYWORDS Creativity, entrepreneurial mindset, innovation, engineering students

Introduction

In the article written by Jack McGourty (2009) for Journal of Engineering Education, he reviewed a recent study of engaging peer-engineering schools in entrepreneurship educational programs for their engineering students. McGourty (2009) raised a question why there is a growing educational focus on entrepreneurship in higher education. Then, he responded that the world's attention concentrated on the global economic crises. He continued that while Fortune 500 companies are making public announcements in regards to job losses on a daily basis, entrepreneurs are generating millions of new jobs. For instance, in 2007, small and medium firms managed just below one million new employments. There is another evidence, which Robert Waters (2010) restated and referred to the analysis of the US Census data from 1976 to 2005. The results illustrated that each year, new firms created approximately two-thirds of new occupations in the US and the technology sector established significant portions of these jobs. In regards to engineering education, McGourty (2009) believed that while business schools host the majority of entrepreneurship programs, engineering schools are recognising that entrepreneurship is a vital area of study for engineers and applied scientists. Waters (2010) viewed this matter too and mentioned that although there are an estimated 600 engineering schools in the US, only around 23 engineering programs propose formal technological entrepreneurship education. One of interesting observations by Waters (2010) in his article is that while he reviewed the entrepreneurship programs in different universities he also focused on whether there is entrepreneurship education in engineering management programs. His findings showed that entrepreneurship education has not penetrated into more engineering management programs. There are some reasons such as: the dominance of the business schools in the field of entrepreneurship or with declining university budget, some executive deans may hesitate to fund new activities or courses that they do not consider "real" engineering.

Our work outlines the learning process within a particular subject in our institute's third year engineering curricula. The teaching staff in this subject teaches concepts of operational management; however, in order to address Engineers Australia's suggestions, we teach some business aspects such as: Finance and Accounting, some Legal concepts that engineers should know (e.g. elements of Contract Laws, aspects regarding Intellectual Property – IP) and also teach basic entrepreneurship skills to engineering students. Students have to form a group with their peers in tutorial class and work on an entrepreneurial business plan as part of their research project.

Literature Review

In the era of rising market competiveness and business forces, there is an essential need for engineers with entrepreneurial knowledge and skills. Among these skills, we can focus on abilities that have links to creativity and innovation. Although many scholars defined creativity and innovation, we use definition by Byers, Dorf and Nelson (2015, pg. 164) as "Creativity is ability to use the imagination to develop new ideas, new things or new solutions." They also defined Innovation as invention that has produced economic value in the marketplace. In regards to engineering education, Rodrigues and her co-authors (2015) mentioned that the traditional engineering curriculum often does not offer students an entrepreneurial education. Tom Byers and his colleagues (2013) believed that ongoing innovation is required to address pressing problems and helped firms to survive in high global competitive environments and engineering is the foundation of much of that innovation. Rodrigues and her peer researchers (2015) pointed out those students from any discipline or program with entrepreneurial training can contribute valuable skills to the workplace. In the same context, another group of professionals led by Byers (2013) focused on engineers and said that in additional to their technical and analytical expertise, engineers need to be creative and have ability to recognise and capture opportunities. All of these skills as well as being able to cooperate effectively as leaders, in teams, and with their peers can and should be taught to engineers

as part of their formal education. In other words, some researchers such as Rodrigues and her team (2015) figured out that engineering schools and institutes should teach engineers how to manage interdisciplinary teams, think critically, understand business basics, communicate effectively, and solve open-ended problems. Referring to the above comments from different researchers and professionals, engineering educators should understand that they have responsibilities to enhance the above skills in their engineering students and enable them to be more innovative and entrepreneurial. To support the above points, Remeikiene and her research partners (2013) explained the results of a study conducting among students in two different programs, Economics and Mechanical engineering, at Kaunas University of Technology in Lithuania. They concluded that programs in higher education institutions should develop entrepreneurial capacities and especially those programs designed for the students with technical specialization should have subjects enabling students to practice entrepreneurial knowledge and skills. Nelson and Byers (cited in Byers et al. 2013) believed that for engineers, who completed formal entrepreneurship programs; the above skills and knowledge give them solid experience in market analysis, product design and development, prototyping, and understanding technology trends.

One of the skills that almost all entrepreneurship programs focus on is enhancing creative thinking and being innovative. According to Daly, Mosyjowski and Seifert (2014) a university course can improve students' creative skills by supporting course content, training materials and components, assignments and tests. In another words by developing the environment towards creativity-focused learning goal, universities can enhance students' creative skills. They reviewed many research outcomes and restated that students can develop and foster their creative skills by focusing on training on cognitive skills, which are necessary active components in enhancements on students' creativity skills. Researchers such as Daly, Mosyjowski and Seifert (2014) described creativity as a type of novel thinking, where in the field of engineering, this emphasizes on the need to meet functional requirements in a novel way. Concerning the definition of cognitive processes in creativity, Fink, Ward and Smith (cited in Daly et al. 2014) pointed out that thinking patterns including problem finding, information gathering, idea generation, and idea evaluation are main parts of cognitive processes, which guide students to creative tasks.

Reviewing literature illustrated that a common instructional approach in engineering education in relation to enhancing creativity skills is open-ended projects, where instructors will not define the target product in order to allow students to search for creative opportunities. Most of times students work on teams in their projects to generate solutions and instructors also allow students to choose their own project topics. From instructors' points of view, they often offer students different tools to guide students to either consider important aspects of a problem or help them to generate ideas and new designed products or services.

The specific research question in this paper is that:

Do students utilize or implement the lecture content in their group projects to learn effectively and enhance their learning?

In the next stage of this paper, we summarise the main contents of a particular subject in our institute. This also provides information in regards to how our teaching team through a wide range of lectures and tutorial activities teach basic entrepreneurship skills and combine the concept of operational management with developing a new business plan for a start-up firm.

Particular subject unit and its contents

This subject is part of our institute's third year engineering curricula and several engineering programs such as Mechanical, Civil, Product Design, and Robotics and Mechatronics engineering programs offer this subject in their curricula. Figure 1 shows the main concepts that our teaching team addresses during 12 weeks lectures.

The contents of this subject are including of operational management focusing on technical aspects used by managers of firms and some basic knowledge of business fields that engineers should learn.

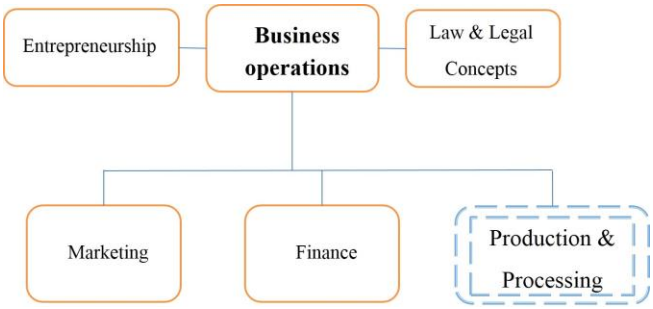


Figure 1: The main concepts which be taught during 12 weeks lectures

This subject is part of engineering curriculum, and therefore, our teaching team focuses on different aspects of "Production and Processing" during 7 weeks of semester. In Figure 2, more details are available regarding "Production and Processing", and we link different aspects from "Operation Strategy" to "Operation Management".

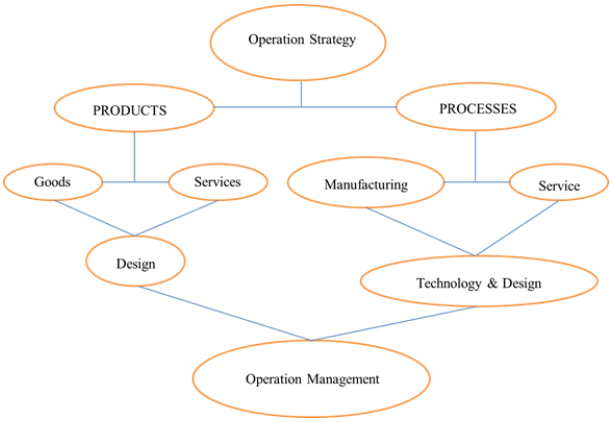


Figure 2: The pathway from "Operation Strategy" and its components to "Operation Management" within the section "Production and Processing

Figure 3 shows that the teaching team looks at other related aspects to operation management. For those new operational activities, the teaching team also looks at the concept of project management.

In addition to 12 weeks considering 3 hours lecture per week, students have to attend 2 hours tutorial classes during 9 weeks. There is no tutorial in weeks 1, 5, and 8 of semester.

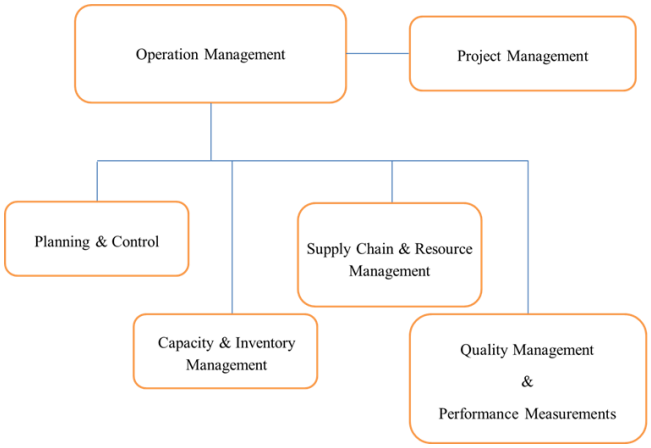


Figure 3: The components related to the concept of operation management, which be taught during semester period

Part of student's assessments, there is a research project that students should work as a team and based on a new idea. Students need to complete their business plan for establishing a new venture by the end of week 10 of the semester and present their plan either in week 11 or week 12. The value of research project is 34% of total final mark for students and there are four stages that teaching team evaluates students' research projects. In week 5, instructors evaluate stage one followed by week 8 as stage two. The last two stages are final report in week 10 and presentation in weeks either 11 or 12.

In their research projects, which we consider as a business plan for establishing new venture, students need to introduce a new idea either as a product or as a service or even combined product and service. They need to provide market and customer analysis, define target market, address technical process requirements including design process and requirements, quality control process and requirements and inventory management and supply chain management.

Students must address some legal and financial aspects in their business plan and there are guest lecturers who teach these concepts during semester. Meanwhile, instructors also provide some guidelines to students and provide feedback to students during semester in different stages.

Methodology

This paper reflects on teaching activities in one particular subject in our institute's engineering curricula. In this paper, researchers paid attention to three aspects of lecture content, which are creativity, innovation and entrepreneurship. The focus was on whether students try to think creatively and develop a new idea to solve a problem, develop a new service or product and establish a new venture. For this purpose, in each semester, the lecturer spend one hour of lecture in week one on the concept of creativity, innovation and entrepreneurship and distribute a document as a guideline for encouraging students to think about new problems, trends, ideas and compare products/services and technologies, new and old. Then, following up of that particular lecture, teaching team in week two during two hours tutorial encourages students within a team to come up with a new idea to establish a business. Teaching team uses some slides and notes to help students in their process of developing new ideas such as Figure 4.

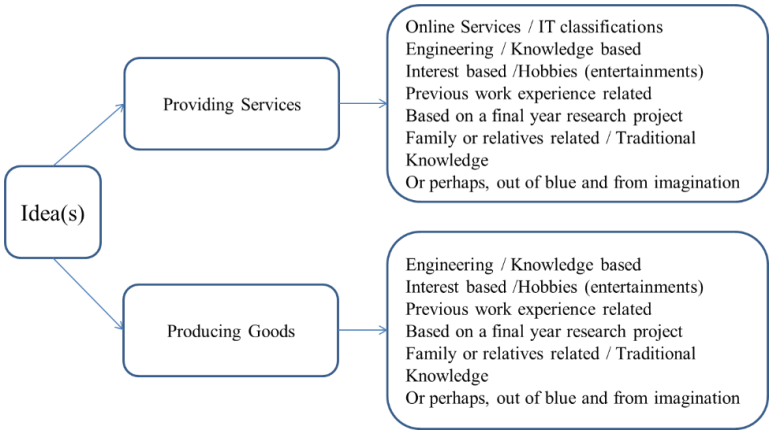


Figure 4 – Concept tree approach to help students find an idea

Focusing on creativity and innovation as the main elements of selecting a new idea for the projects/business plans, we evaluated whether the teaching and learning process helped students to learn and apply concepts of creativity and innovation in a practical manner. We analysed students' projects submitted as group assignments during three years from 2014 to 2016. We obtained data from final reports of students' projects (as group projects) and we collected data via Blackboard (LMS) system as students needed to upload their projects into Blackboard. We reviewed the contents of reports and based on classification showed in Figure 4, we identified whether students were looking to create new services or make a new product. Then, by studying students' reports in details, we identified how students decided to work on new ideas and develop a business plan based on the ideas. We have undertaken further work to check the reliability of findings.

It is worthy to consider that students can choose either a product or a service. According to a guideline provided to students during tutorials, students can also choose ideas based on their previous work experience as a full time or part time employee, their hobbies and interests, family and cultural background and even based on just their imagination and out of blue. The Figure 4 shows student can choose the topic using concept tree approach.

In addition to the above, we were looking to classify types of ideas and areas of businesses that engineering students have been interested in.

Findings and discussion

During one hour lecture in week one every semester the lecturer of this particular subject explains two different types of innovation. One is "incremental innovations", which are mainly about steady improvements and based on sustained technologies, e.g. improving smart phones. Byers, Dorf and Nelson (2015) mentioned that people could categorize incremental innovations as quicker, improved, and/or low-priced version of existing products. Another one is "radical innovations", which are mainly about fundamental rethink and based on disruptive technologies, e.g. developing iPod by Apple Corporation or as Byers, Dorf and Nelson (2015) mentioned that 3D printing is an example of radical innovation because radical innovation could transform the relationship between customers and suppliers, restructure the markets by creating new product categories. We believe that in real world practices, only few very smart and creative minded people pursue radical innovation and we should call most of other innovations as incremental innovations. Therefore, in order to classify different ideas, we proposed in our context that while students were using the contents of their final year research projects as the basis of their new ideas, they might be able to rethink of the usage of technologies radically. This approach will allow authors of this paper to classify those projects as attempt to have "radical innovation" - because those students' projects would not be ready for the real world. Without any doubt, we have strong opinions that behind those

high tech devices that changed the lives of people around the world, and can call them as "radical innovation", there were technological experts that created new products and services. On the other hand, if students only used their engineering knowledge and developed new ideas, we classified students' ideas as "incremental innovation".

From 2014 to 2016, students within a group of three to five have submitted 288 business plans as part of students' projects in this particular subject. We looked at what type of ideas students used as a new approach to providing a service or producing products. The teaching team asked students to come with new ideas and being creative/innovative and write a business plan based on new ideas.

After reviewing the ideas behind groups' projects, in regards to providing services, we found that majority of students in groups used engineering and knowledge-based contents for basis of new ideas for their research projects (business plans) in each semester during a period of 2014 to 2016. We considered these types of innovation as "incremental innovations" (39 out of 87 – 44.8%). In regards to providing services, we considered only very few projects as "radical innovations" (5 out of 87 – 5.7%) due to use final year research project as a basis of their ideas. The Figure 5 shows distributions of projects based on source of ideas, which focus on providing services.

In regards to producing goods and making tangible products, engineering students showed their passion to focus on manufacturing and technical knowledge for their ideas for business plans. In fact, the total number of business plans focusing on producing goods is more than double of those focusing on providing services (201 research projects/business plans compared to 87).

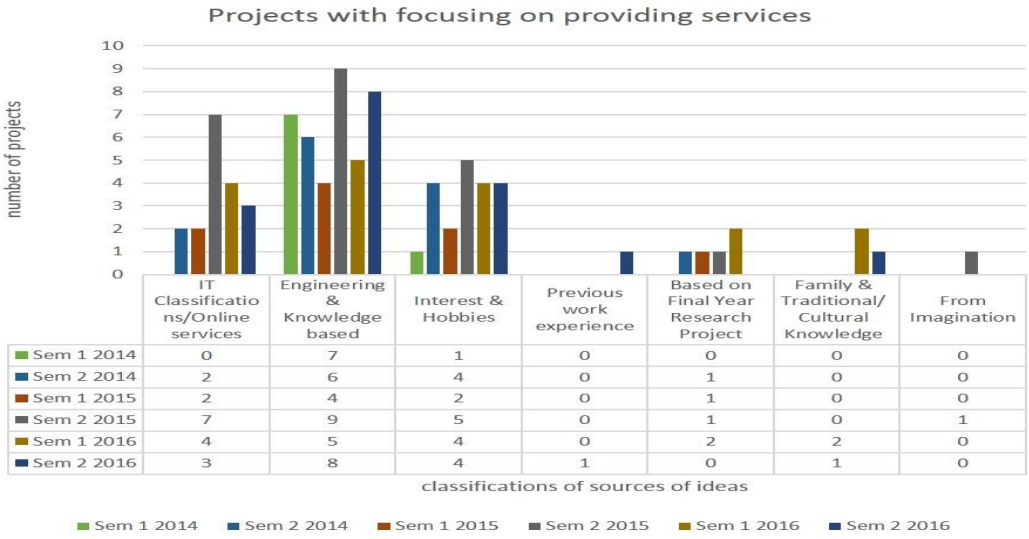
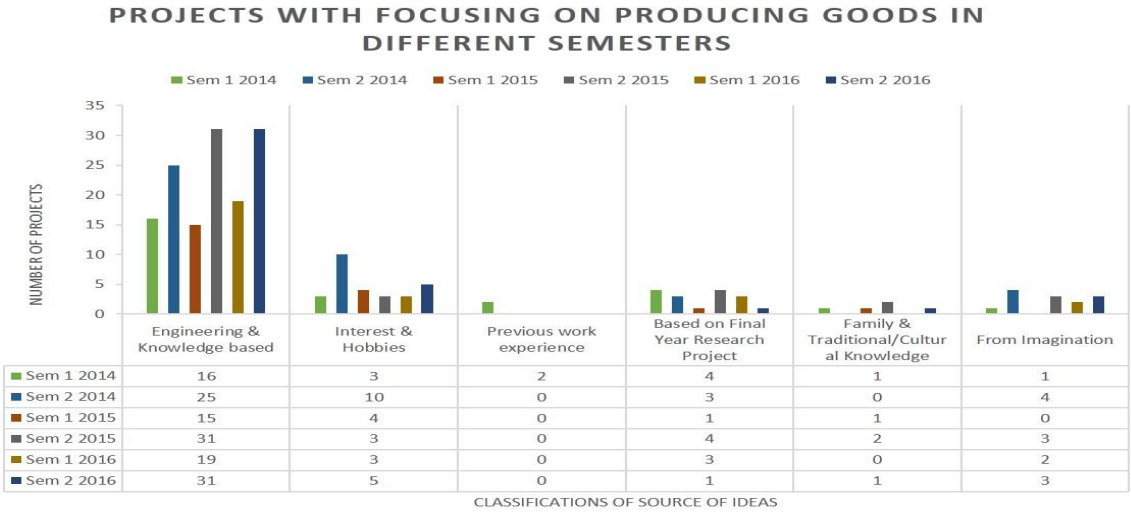


Figure 5 – Classification of sources of ideas in projects focusing on services

It also showed that engineering students used more their final year research projects as sources of ideas for making products than providing services (16 ideas compared to five ideas respectively). While 137 groups of students (68.2%) looked at their engineering knowledge for sources of new ideas for producing goods and tangible products and we considered their approaches as "incremental innovations", only 8% of students groups (16 research projects/business plans) tried to approach as "radical innovations" based on their final year research projects. The Figure 6 illustrates the types of sources for new ideas to develop tangible products and producing goods.

We understand that other types of sources might provide opportunities for a new business plan and new venture start up based on incremental innovations or even radical innovations;

however, in this paper, we focus on the areas that students used their engineering knowledge, either general engineering knowledge or based on final year research projects. We expect and assume that students would like to pursue their future career in their field of knowledge.



	Engineering & Knowledge based	Interest & Hobbies	Previous work experience	Based on Final Year Research Project	Family & Traditional/Cultural Knowledge	From Imagination
Sem 1 2014	16	3	2	4	1	1
Sem 2 2014	25	10	0	3	0	4
Sem 1 2015	15	4	0	1	1	0
Sem 2 2015	31	3	0	4	2	3
Sem 1 2016	19	3	0	3	0	2
Sem 2 2016	31	5	0	1	1	3

Figure 6 – Classification of sources of ideas in projects focusing on products

It is also very difficult to say that all ideas were 100% new. We understood that students tried hard to convince teaching team that their ideas were to some extent new. For example, students might say that they were targeting new type of customers, or new geographical locations and providing services or products to customers that previously not served by other companies. This paper has limitations to address all questions scholars may have while analysing all projects and we have plans to overcome difficulties in this matter. This paper is a starting point to better understanding where students are looking for new ideas. We know that we have to work hard to provide a holistic picture in this area.

Meanwhile, we are able to present other findings such as special trends by students to look at some ideas used or developed by very big organisations. Students tried to form a group with other students enrolled in the same program, e.g. in some groups all students studied Civil and Construction engineering program or Mechanical and Product Design Engineering. We could recognise some trends in new housing structure, pre-cast concrete, modular housing with particular approach based on their Civil or Construction programs. We recognised several approaches to use drones by wide range of students. Prototype manufacturing, 3D printing, using new and complex materials for making products, using iPhone and developing apps, developing medical devices and making special clothes are very popular ideas among all types of engineering students.

Conclusion and recommendations

Although teaching team tried to encourage students to find new ideas and approach to their ideas as radical innovations, but students could not have enough time to come with a brilliant ideas. In addition to above points, it seems to us that students did not have enough motivation to think seriously about new ideas, and therefore, students came with similar ideas from another group either in the same tutorial or from another tutorial. It is very important for teaching team to provide feedback to students and has authority to reject an

idea due to similarity with very popular trends in the current market. Having said that, we found a wide range of ideas generated by students and it is interesting that engineering students were focusing more on producing goods and tangible products than providing services only.

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