ASSESSMENT OF ENTREPRENEURIAL SKILLS: EXPERIENCE FROM A JOINT ENGINEERING-BUSINESS CLASS EXPERIMENT

Zbigniew J. Pasek
University of Windsor
zjpasek@uwindsor.ca

Abstract –This paper discusses selected preliminary results from a collaborative efforts between undergraduate engineering and business students working together on a joint semester-long project. The project, though common for all students, was simultaneously a requirement in two, parallel run courses, one in engineering and another one in business. The cohort of participating students was fairly large, and involved about 240 second year students from engineering and 50 fourth year from business.

The information about students' attitudes and project teams dynamics was collected by means of two surveys, one at the beginning and the other at the end of the courses, and also through a peer-evaluation software platform.

This experiential learning efforts is one of the first in North America of this size to combine multidisciplinary entrepreneurial teams at the undergraduate level.

Keywords: Entrepreneurial education, Engineering entrepreneurship, Large class.

1. INTRODUCTION

Over the past 15 years interest in entrepreneurship has grown considerably [2]. In the US, according to a recent Gallup poll, over 40% of pre-university students have aspirations to run own their own business one day. While the preparation to do so not always matches the ambitions, support from variety of educational institutions ranging from high schools to universities offer a variety programs and courses to support that need. 68 US universities currently offer master's degree programs in entrepreneurship.

The interest in studying entrepreneurship with an academic rigor extends across variety of disciplines from sciences, through nursing to engineering. Many universities are making an effort to integrate entrepreneurial education into existing programs and expand portfolio of available courses, encouraging students to develop such interests and passion for it.

Traditional engineering education concentrates on developing students' foundational knowledge, and only recently started paying attention to development of meta-

skills (e.g., creative and communication skills), but still poorly connects these two areas with humanistic knowledge (see Figure 1). The 21st Century Skills movement [3] also emphasizes the need to develop skills particularly relevant to the following themes of:

- Global awareness
- Financial, economic, business and entrepreneurial literacy
- Civic literacy
- Health literacy
- Environmental literacy, etc.

Figure 1. Summary of 21st Century Learning Networks

Entrepreneurship can be defined in a variety of ways, but in general is connected to creation of value that may take a form of a new entity, be this a product, service or organization. Engineering entrepreneurship usually emphasizes and integrates the systematic process of problem solving, scientific discovery and application, engineering design, and systems and critical thinking, into the entrepreneurial process [9].

It is worth noting that industry has considerable interest in employing entrepreneurially-minded graduates, and the key reasons for that are the relentless pursuit of new solutions granting competitive advantage, and continuing efforts for various forms of improvement, which can be

supported within existing firms by *intrapreneurs* (e.g., employees with entrepreneurial mindset).

While universities recognize the need for entrepreneurial education, most of their efforts focus on graduate levels. However, assuring entrepreneurial literacy has to start earlier than that. The Ontario Chamber of Commerce (OCC) strongly recommended including entrepreneurship across all undergraduate curriculum in Canada in order to foster innovation and risk-taking [10]. The potential wealth generation resulting from such an expansion of campus commercialization initiatives would have far reaching economic and social benefits.

However, this increased attention to student innovation and entrepreneurship brings a number of experiential learning challenges that have to be satisfactorily resolved in order for post-secondary institutions and governments to fully maximize the benefits derived from the commercialization of student innovation.

This discuss a collaborative effort between two faculty members: one from engineering and another from business school, who wanted to ascertain whether interest in entrepreneurship beyond just acquiring entrepreneurial skills and abilities could be “taught”. Beginning with a large pool of 2nd and 4th year students taking business and engineering courses, we have made an attempt to bring these groups together to work side by side on a joint project.

2. THE COURSEWORK

2.1. Engineering: Engineering Management & Globalization

The second year course is mandatory for all undergraduate students in engineering, except those in electrical and civil engineering programs. While it introduces students to basic concepts of engineering management and global trends, it does so in the context of a new product development process [7, 8].

Its main feature is a semester-long project in which students work in teams. Each team consists of up to 4-5 students, and, preferably, of different backgrounds and experiences. The team assignment is to create a start-up company offering a new product type that fits mass-customization markets on a global scale (e.g., has potential to be offered on multiple national markets). The team’s key tasks are to:

1. Develop initial product idea and its design, including possible product variations,
2. Outline the manufacturing processes and a system necessary to make the product, and
3. Prepare a business plan elements, which cover delivery, organization and cost issues.

The course in its current form is designed to run on 12-week semester schedule typical in Canadian universities. The outline of the course is included in Appendix A. The

course centers around the idea of integration of product development, manufacturing systems and business practices (see Fig. 2). Therefore, it adopts a system-based approach, considering not only components (be it machines, processes, or knowledge) necessary in production of consumer goods, but also their mutual interactions. While this idea is perhaps not entirely new, it is also set in context of the current market paradigm of Mass Customization.

Fig. 2. Product-Process-Business Integration Need

2.2. Business: Introduction to Entrepreneurship

The course is an introduction to the field of entrepreneurship and is the Gate-in course for the Strategy and Entrepreneurship Concentration. It is a survey course in that it spans the whole field covering its various facets at a rudimentary level. It aims to acquaint rather than to develop deep skills and sophistication. The course is intended for students in their upper years of university from all disciplines who would like to explore the possibility of having a business of their own or who may become employed by a small entrepreneurial firm. The promise of entrepreneurship is compelling. Not only one can become master of own fate, creating a business provides jobs for others, builds personal wealth, and increases the wealth of the nation. Textbook used is a standard text by Kuratko [4].

Throughout the course students are immersed in a multidisciplinary business and engineering experience unique in Canada at the undergraduate level.

Over the 12 weeks through lecture, flipped and experiential classes the course introduces students to entrepreneurship in the following way:

First the cognitive foundations of entrepreneurship are explored. The focus is on issues of both human and social capital with respect to entrepreneurial venture leadership and teambuilding.

Then focus moves on to the elements of opportunity. The difference between entrepreneurship and small business is highlighted. The course will focus on issues surrounding *problem-solution fit*.

Next, the theories regarding both the economic and psychological aspects of entrepreneurship are examined, including why entrepreneurial settings differ from established firm settings. In doing so, participants develop an entrepreneurial orientation that will pervade their thinking in the future academic and practical experiences.

After dissecting the essence of entrepreneurship, major topics in entrepreneurship including marketing, finance, and growth strategies are discussed, followed by an examination of developments that are important in entrepreneurship today (e.g., e-commerce, franchising, acquisition, and global entrepreneurship).

2.3. The Project

Team-based class projects are the primary activity of students' experience and the main basis for final assessment. The primary focus of the student team projects is the Development of a New Product for Mass-Customization. The student team has to:

- Identify a product whose market share could be significantly increased if designed with variations that fit the needs of various customers (i.e., mass customization), and whose price would be attractive if its production is done with a reconfigurable, flexible manufacturing approach.
- Create a company that produces and sells the product. Develop a corporate identity (a name, logo, etc.) and its organizational structure.
- Write a report in the form of a business plan and evaluate the potential profitability of this company. By contrast to business plans offered in business schools emphasize market analysis and finance models, the focus here is primarily on product innovation, product design for mass-customization, and manufacturing systems that can cope with turbulent markets.

In the first part of the project students identify customer needs, develop product ideas, carry out product design and perform initial market analysis. They have to describe the product on a fairly detailed technical level (including technical specifications and particular, innovative technologies involved), its advantages over existing, potentially competing products, and how the selected product fits the concept of mass customization. In particular, they have to analyze the number and need for proposed product variations. The market analysis has to include the total market value, the market share expected to be captured, competition and identification of potential customer segments.

Examples of products selected by students span a fairly wide range, from products that have low-tech contents, such as, luggage or clothing, to products with high level of technology contents, such as stereo systems or smart automotive mirrors. Other examples of products selected by the students in the past course offerings included

wheelchairs, bicycles, special engines, car seats, watches, backpacks, sport equipment, sunglasses, skateboards, office furniture, golf clubs, electronic equipment, and health foods.

In the second phase of the project, teams focus on designing the manufacturing system to make their product. This includes a description of the production system, including the various pieces of equipment, discussion of system configurations, floor layout, and estimates of investment costs. For a particular process design, the teams also explore performance specifications of the production facility, such as production capacity strategies and quality issues. The use of outside suppliers is also discussed (in-house vs. outsourced activities), as well as the size and skills of the necessary workforce.

Finally, the teams focus on the development of an overall vision of the company, describing the company growth goal, and the strategies for achieving this goal (strategies in product design, manufacturing, marketing, etc.). They also address product distribution and delivery methods, and financial issues (best and worst case scenarios in sales vs. expenses projections).

The primary challenge faced by the students preparing the outline of business strategies for their potential company is the fact that it is a start-up venture. Therefore, even though they may be fairly familiar on how to design a typical manufacturing facility, development of a strategy that deals with limited resources available for a start-up creates additional, non-technical constraints that they have to consider. The issues of core competencies, supply chain management, and risk management come into play. The students also have to understand temporary nature of start-ups with high internal dynamics driven by the search for scalable solution to the original product idea.

All the project work is documented in the form of two intermediate and one final report. Each team also creates two brief videos: one introducing the team and its original idea, and another aimed at the global audience (and not in English), explaining the features of the product. These videos are shown in class in lieu of traditional presentations.

2.4 Teamwork

Since the class project is the primary and term-long activity involving students, organization and composition of the project teams plays critical role in the course. Teams are formed at the first class meeting and get to work right away. Students are offered some background on the team organization and roles they may play to help them self-organize and divide the workload within teams. Students should preferably have a variety of backgrounds and come from many engineering specialties (e.g., product design, business/marketing, manufacturing) and have prior work experience.

A key element of building team cohesion are the weekly tutorial exercises, which are carried out by the teams together. They are designed as explanatory example procedures, which after class each team has to apply to their own project circumstances. For example, Origami Engineering session involves teams building together paper airplanes, starting with design, through batch testing and quality evaluation discussions (see Fig. 3).

Figure 3 Team exercise: paper planes testing

A new element intended to accelerate the team integration was introduced. The instructional team has developed a Scavenger Hunt, a urban game, in which student teams had to answer multiple questions and locate various university and community resources and landmarks on campus – all within a 2-hour time window.

2.5 Assessment

The structure of the class to a large extent relies on the problem-based learning approach, where they are provided with only a sketchy initial problem definition (product with mass-customized market appeal) with a potential scenario (start-up) and they have to identify necessary facts (customer needs, technical solutions) and tools (engineering and management approaches), and successfully apply this new knowledge to create a solution. The process is hardly linear (see Fig. 8) and involves many iterative loops.

The primary learning objectives of the course was to expose 2nd year students to the integrative “big picture” of consumer product creation, development and delivery, and provide them with basic understanding of engineering activities required in each phase. Along the way a number of engineering tools necessary to effectively carry out these activities were also introduced (e.g., brainstorming and reverse brainstorming, SCAMPER, project management tools, QFD and Pugh chart, process mapping, business model canvas, etc.). Students had to get acquainted with

these tools, related concepts and their application. Their understanding on a basic level was tested individually. A team-based use was then requiring effective application of newly acquired knowledge, and the results were provided in the consecutive (partial) project reports. Since the final report was integrative, students also had a chance to improve the final outcome by making revisions based on feedback and observation of their peers.

Figure 4 The problem-based learning cycle

3. ENGINEERING-BUSINESS INTEGRATION

The course instructors were awarded a small grant from Ontario’s Ministry of Education to promote entrepreneurial activities among the youth segment of the population (16-24 year olds). It allowed to support an educational experiment in which two undergraduate classes, one from engineering and another from business, were partially conducted together.

The class sizes differed, but it nevertheless allowed each engineering project team to be joined by a business student. While initially the potential outcome was highly uncertain, the basic assumption was that both student cohorts will be able to establish cross-disciplinary communication, eventually understand each other, collaborate and effectively learn from each other.

There were a number of unanticipated challenges, such as incompatibility of class schedules. Nevertheless, despite these challenges, shortcomings and frustrations, students from both groups broadly admitted that it was worthwhile and that direct interactions exposed them to issues they would have never learned otherwise. They also recognized the need for joint team expertise in addressing complexities of product development and launching a new business.

3.1 Integrated Class Survey

It was also possible to conduct a small scope study of entrepreneurial attitudes among undergraduate students from both business and engineering faculties. The study was designed as a questionnaire survey. The measures used

in the questionnaire were adapted from previous theoretical and empirical work, and included the attitudes towards:

- Enterprise
- Creativity
- Similarity
- Challenge
- Interest in entrepreneurship.

The two surveys consisted of 48 questions, which were grouped into multiple measures. They were distributed in two phases: at the beginning of the course (pre-) and at the very end (post-). The summary of differences of key variables are listed in Table 1. Significant results were observed in three key indicators: perception of importance of creativity improved, challenge (e.g., difficulty) encountered was bigger than expected, and interest in entrepreneurship has grown significantly.

Table 1 Changes (from pre- to post-survey) in key variables (responses measured on a 5-point Likert scale)

Variable	Students (N=238)	
	Mean (SD)	
Enterprise	-0.06	(0.84)
Creativity	-0.14	(1.15) S
Similarity	0.08	(0.89)
Personal control	-0.09	(0.96)
Challenge	0.14	(0.84) S
Interest in entrepreneurship	1.35	(1.39) S

S – indicates statistically significant result

3.2 Peer evaluation of teamwork

Assessment of the collaboration within the project teams was carried out using the online CATME system [5], which consists of multiple tools enabling team formation and confidential peer evaluation. The system performs analysis of collected data and besides computing the individual performance scores, can also identify a set of team features (e.g., high performance or dysfunction).

The peer evaluation data were collected only once, at the conclusion of the course. The student response rate was 93%. The summary results are shown on the graphs in Figures 5 and 6, which show distributions of individual student peer evaluation scores and corresponding team performance scores. The bar chart in Fig. 5 reveals subpar (e.g., below 70%) team performance of about 12.6% of the students. The teams' performance were kept relatively high thanks to the efforts of remaining team members who stepped up their efforts.

These results nevertheless should be interpreted with caution, given that the data collected were relying on subjective measures of performance, which cannot be accurately calibrated and always carries some error in judgment. This is clearly shown in Fig. 7, which represents comparison between peer assessment and self-assessment of individual performance.

Figure 5. Distribution of student performances (N=238)

Figure 6. Distribution of team performances (N=48)

Figure 7. Comparison between peer and self-evaluation

4. SUMMARY AND FUTURE WORK

The engineering class has been created and offered since 2009, and in its subsequent edition its contents went over multiple revisions and updates. The course enrollment since its inception went up over 100% and future growth is expected as it becomes a mandatory course for all engineering undergraduates.

The most recent major modification consisted of merging the class term project for part of the term with a class on entrepreneurship offered by a business school. As a result, engineering teams was enhanced by addition of an undergraduate student from business.

As a result of these changes, new patterns in student behavior started to emerge. Presence of business students and senior advisors became a significant motivational factor. Interdisciplinary nature of the teams received natural boost, which eventually led to heightened creativity. Use of the *Lean Startup* methodology [1, 8], which requires the participants continuously verify their design and market hypotheses, has also raised awareness among engineering students that in their professional development they need to broaden their scope and add management, communication and entrepreneurial abilities to their skill set.

Acknowledgements

The author would like express his gratitude to Ms. Nira Roy for performing initial statistical analysis of the survey data. Support from the Ontario's Ministry of Education through Youth Entrepreneurship Program (YEP) is also gratefully acknowledged.

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APPENDIX A: OUTLINE OF ENGINEERING MANAGEMENT & GLOBALIZATION COURSE

CLASS SCHEDULE

Week	Subject
1	Course overview. Engineering in a global world. Team processes & communications T01: Team formation. Team-building exercise(s).
2	Global issues. Paradigm concepts. Intro to Business Model Canvas (BMC). Creative thinking & paradoxical products. T02: Thinking about team project & product. Design Thinking exercise.
3	Design process and tools. IDEO's "Shopping cart" video. Project management. Customer interview skills. T03: Intellectual Property (IP) basics. Patents and market info.
4	Product architecture. Industrial design & ergonomics. Unique value proposition. Competitors. T04: Creating value. Market & competition. BMC v.1
5	Quality Function Deployment (QFD) and Pugh chart. Engineering management. Introduction to manufacturing. Review I: Team & product idea videos.
6	Introduction to materials & manufacturing. CES software. Manufacturing machines & systems. T05: Process mapping: paper airplane assembly exercise.
7	Manufacturing custom products. CES software overview. Introduction to Operations Management. EOQ inventory model. T06: Production capacity, inventory, cost (pizza making process analysis).
8	Product lifecycle assessment. Engineering ethics. Quality management. 6-sigma. T07: Batch vs. one-piece-flow (Lego robot assembly exercise)
9	Lean production. Customer experience mapping and design. T08: Customer journey map. Prototypes & MVP. Documentary "Startup Kids 2" + Q&A
10	Business models, plans and strategies. Organizational structures. Startups. Introduction to finances. T09: Strategy and supply chain mapping.
11	Supply chain management intro. Make or buy. Marketing essentials. Product development & commercialization (excerpt from the feature film "Ingenious").
12	Global cultures & innovation. Course summary Review II: Global videos & prototypes display.

T – tutorial sessions