How Entrepreneurial are Project-based Courses in Engineering Education?

O. Hagvall Svensson[1]
PhD candidate
Chalmers University of Technology
Department of Technology Management and Economics
Göteborg, Sweden
E-mail: oskarsv@chalmers.se

T. Adawi
Professor, Engineering Education Research
Department of Communication and Learning in Science

M. Lundqvist
Professor, Entrepreneurship
Department of Technology Management and Economics

K. Williams Middleton
Associate Professor, Entrepreneurship
Department of Technology Management and Economics

ABSTRACT

This paper addresses the ongoing integration of entrepreneurship into engineering education and investigates the relationship between inductive teaching methods and teaching through entrepreneurship. The potential for learning experiences leading to the development of entrepreneurial capabilities in project based courses is investigated, through a qualitative multi-case study of eight courses, applying effectuation and new value creation to assess ways in which project-based learning is 'entrepreneurial'. It is found that even in cases where students are engaged in new value creation towards an external actor, the structure of projects seems to mainly call for students to enact a causal rather effectual logic in their actions and strategies. Pedagogical implications for educators wanting students to develop entrepreneurial capabilities are discussed.

Conference Key Areas: Engineering Education Research, Engineering Skills, University-Business Cooperation

Keywords: Project-based learning, Entrepreneurship, Inductive teaching, Effectuation

[1] Corresponding Author:
Oskar Hagvall Svensson
oskarsv@chalmers.se

INTRODUCTION

Entrepreneurship is being increasingly infused in all educational levels and across a wider set of disciplines [1, 2], including engineering education [3]. In engineering education, entrepreneurship has shown potential in increasing student engagement, creativity and perceived relevance of courses [4, 5], proven effective in imparting professional skills [6], and has been advocated as a key part of preparing engineering students for contemporary working life [7]. While this gives legitimacy to endeavors aiming to include entrepreneurship in engineering education, research on the subject is still in a nascent phase and there is still major conceptual confusion regarding how 'entrepreneurship' in engineering education should be understood.

In any case, the discourse regarding integration of entrepreneurial activity into engineering education shares many aims with inductive teaching and learning approaches, such as inquiry-, problem- and project-based learning [8]. Contrasted against more traditional deductive methods used in engineering education, where instructors introduce theory that students are then asked to apply to constructed problems, inductive teaching methods are more student-centered and use authentic problems as the starting point for learning. This has generally been found more effective than deductive methods [8]. In entrepreneurship education, a similar comparison is often made between on one the hand teaching *about* or *for* entrepreneurship and on the other teaching *through* entrepreneurship [9], which has recently been deemed preferable. Teaching *through* entrepreneurship is facilitated by engaging students in self-directed action and creation within dynamic environments, with the aim of developing entrepreneurial capabilities [10, 11]. Teaching *through* entrepreneurship aligns with the theory of effectuation, conceptualizing the expertise of entrepreneurs who are found to rely upon *effectual* logic (based in iterative creative action) rather than *causal* logic (based in linear planning and prediction) [12]. Thus, teaching through entrepreneurship could be regarded as giving students opportunity to enact an effectual logic in decisions and actions during a course.

In this paper, we explore similarities and differences between an inductive teaching philosophy and teaching through entrepreneurship, by investigating eight project-based engineering courses, posing the question "How entrepreneurial are project-based courses in engineering education?". As active, experiential and student-centered approaches to infusing entrepreneurship in engineering education have been found effective [13], project-based engineering courses could potentially serve as a training ground for entrepreneurial capabilities. It has, however, been suggested (but not substantiated) that engineering education rely predominantly upon causal rather than effectual logic [14], which could potentially hinder such development. With this study, we draw conclusions in regards to how project-based courses are already 'entrepreneurial' (i.e. gives students opportunity to enact an effectual logic), and ways in which they may become more 'entrepreneurial'. Pedagogical implications are briefly discussed, intended to guide engineering instructors wanting to support the development of entrepreneurial capabilities among their students.

1 METHODOLOGY

This paper is based in a qualitative multi-case study [15] of eight project-based engineering courses. This allows for cross-case analysis, where earlier work on entrepreneurship in engineering education seems to be dominated by single case studies. Using an analytical framework, described in Section 1.1, the extent to which the examined courses are 'entrepreneurial' was assessed. The courses and data collection is briefly presented in Section 1.2.

1.1 Analytical framework

To assess entrepreneurial activity in the project courses, we first had to decide upon a perspective on entrepreneurship to adopt, as the research field of entrepreneurship has yet to converge upon a clear definition of 'entrepreneurship' as a phenomenon. Bruyat and Julien [16] propose a conceptualization of entrepreneurship as a field of research focusing on the continuous interplay between an individual (the entrepreneur) and a project of *new value creation*. This definition presents entrepreneurship as a system in which the individual creating new value is, at the same time, being constructed (shaped, influenced) by the new value. This process of dual influence, over time, constitutes an entrepreneurial process, which is situated in a dynamic and uncertain environment, both influencing and being influenced by the ongoing creation process. The value created is manifested in a created object (often an innovation, product or solution), and in terms of 'exchange' value – i.e. value that is determined inter-subjectively rather than objectively set. Entrepreneurship as new value creation has been presented as a useful definition when intending to infuse entrepreneurship in education [17], and is applied here as a conceptualization for the nature of an entrepreneurial project-based course. Building on this new value creation definition of entrepreneurship, the theory of *effectuation* [12] is used to guide the analysis of how entrepreneurship could be enacted in decisions and behavior in the context of a project-based course.

Effectuation is an entrepreneurship theory which presents the decision-making logic applied by entrepreneurs [18]. Sarasvathy [18] studied experienced, serial entrepreneurs to determine how they acted in order to create value under dynamic and uncertain conditions. Accordingly, if students are given opportunity to enact an effectual logic in their courses, they are in a sense 'acting like an entrepreneur' and might then develop entrepreneurial capabilities.

Sarasvathy [18] found that entrepreneurs focus more on what they can and want to do with available resources, and less on fixed end goals. As follows, "Causation processes take a particular effect as given and focus on selecting between means to create that effect. Effectuation processes take a set of means as given and focus on selecting between possible effects that can be created with that set of means" [18]. In Sarasvathy´s definition [18], causation is the classical way to make business or management decisions, focusing on "predictable aspects of an uncertain future" (p. 252). Effectuation, instead, focuses on "controllable aspects of uncertain future" (p. 252). Hence, rather than resting upon the logic of prediction ("to the extent we can predict future, we can control it"), effectuation instead builds upon the logic of control ("to the extent we can control future, we do not need to predict it") (p. 251). An effectuator then approaches a decision starting from 'Who I am', 'What I know', and 'Whom I know' and imagines potential ends that can be created with these resources, choosing amongst these imagined effects. Moreover, an effectuator experiments with many strategies to approach an unpredictable future instead of trying to optimize one single strategy and aims to find strategic alliances and early commitment from potential stakeholders.

Value creation [16] and effectuation [18] were broken down into key themes and organized into a framework, as presented in Figure 1. The framework is built upon the notions of *decision, action* and *re-evaluation*, where both decisions and actions can deemed be 'entrepreneurial' as guided by the theory of effectuation. The general idea is that in order to enact an effectual logic, students need to be given freedom to make choices regarding what to do, act upon those decisions, and get to re-evaluate and re-direct their focus and strategy (c.f. pivoting [19]).

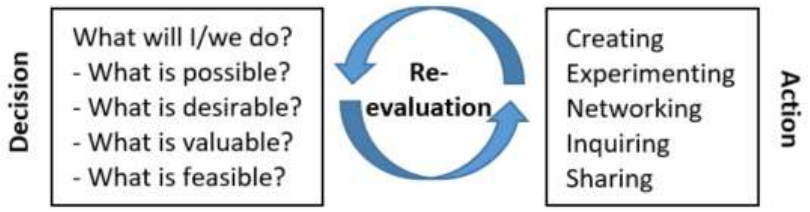

Figure 1: A graphical representation of the analytical framework, capturing key aspects of entrepreneurial decision and action

'Entrepreneurial decisions' is used here to discuss the nature of the choices students get to make while engaging in a project-based course, and questions they need to relate to in order to make such a decision: *i) What is possible?* relating to open and self-directed ideation or visioning, e.g. in the choice of focus or problem to take on; *ii) What is desirable?* taking into account internal contingencies, e.g. own commitment and motivation, in order to engage in self-directed action in uncertain or complex situations, *iii) What is valuable?* explicitly taking into external contingencies in the form of the perspectives of others (e.g. external receiver) on the quality and value of solutions, and *iv) What is feasible?* relating to both internal contingencies, in terms of own resources, such as knowledge, skills and networks, and external contingencies, e.g. taking into account constraints put up by teachers or other involved actors.

'Entrepreneurial actions' is used here to discuss the nature of project activities and actions taken by students. Aspects of entrepreneurial action include: *i) creating* - having an emphasis of the creation of something, e.g. a design, solution or product; *ii) experimenting* - investing time and effort in several ways to approach undertaking a project or solving a problem, 'keeping several doors open', and slowly converging on a single way by continuously evaluating what focus and strategy is useful; *iii) networking* - communicating with external individuals in order to build commitment to project or retrieve resources to use; *iv) inquiring* - searching for new information and input that can help evaluate what strategy is most useful, and in realizing this strategy; and *v) sharing* - continuously showing, presenting or performing the outcomes of current and planned activities for internal and external individuals while communicating ownership of created outcomes, in order to get input on further activity, e.g. in term of what is valuable for someone else.

1.2 Data collection and courses

Eight courses were sampled by examination of course documents for all courses at Chalmers University of Technology, aiming to find courses which might follow an effectual logic and purposively surveying courses across educational areas, including those with and without 'entrepreneurship' in the course name. The resulting sample includes courses ranging in class size from 10 to 100 students and course credit from 6.0 to 15 credits (hec). The eight projects range in extent and complexity from straightforward task projects, e.g. investigating the materials and production of a product, to more complex projects where students e.g. develop a technical solution in co-creation with an external actor, or design and build an entire car.

Semi-structured interviews were conducted with the eight educators responsible for the project-based courses. The interviews focused on learning environment, teaching and learning activities, assessment, and aspects relevant for an entrepreneurial experience (e.g. uncertainty, teamwork). The interviews were transcribed and analyzed using the framework delineated in the previous section, assessing the extent to which the students were given opportunity to engage in 'entrepreneurial' decision and action, i.e. activities guided by an effectual logic.

2 RESULTS

The result of the analysis is presented in Table 1.

Table 1: The extent to which students get to relate to a number of decisions and engage in specific actions in project based courses. Here, a small circle indicates that the specific aspects is possible, and a larger circle indicates an emphasis on this decision or activity.

	Aspects	Courses 1	2	3	4	5	6	7	8
Decision	Possible?		●	●	•		•	•	●
	Desirable?		•	•	•		•	•	•
	Valuable?		•	•	●	•	●		•
	Feasible?	•	●	●	●		•	•	•
Iteration			●	•	●				•
Action	Creating		●	•	●	•			•
	Experimenting		●	•	●	•			
	Networking		•	•	•	•	•		
	Inquiring	●	•	●	●	●	●	●	•
	Sharing	•	●	●	●	•	•	•	•

2.1 Entrepreneurial decision

The degree of freedom to choose *what* to do, and *how* to work is central to enacting effectuation, since it rests upon a logic of control. In many of the courses, students are given freedom to decide upon what problem or product to choose (Possible?). Three courses are especially open for students to introduce own ideas (2, 3, 8). However, the *nature* of the project seems to be defined mainly by teachers. I.e., the students do not seem to be engaged in defining what kind of endeavor they will undertake (e.g. through setting objectives) to a larger extent (course 3 is an exceptions). This could hinder enactment of effectual logic, and moreover affect students' motivation, commitment and ownership of projects and outcomes. The students are frequently asked to make decisions regarding *feasibility*, both relating to *focus* of their project and to some extent *actions* taken towards finishing the project (mainly courses 2, 3, 4). However, this seems to be mainly focusing on external contingencies (e.g. time-constraints, picking an invention which 'will work' for achieving the project task), rather than internal (such as identifying own resources and knowledge). Similarly, it seems uncommon that students get to explicitly relate to what they desire and are committed to doing, i.e. not starting from questions such as: 'What do I want to do? Who am I?'. Starting from one's own commitment and resources is central to effectuation, connected to ability to create something in

conditions of uncertainty and coping with acting and creating in a dynamic environment. Explicitly taking into consideration the perspectives of someone else on quality and value of solution (Valueable?) was slightly more common, emphasized in two of the courses (4, 6).

In some of the courses (especially 2 and 4), the students get to search for input that can redirect their decisions regarding their solution or product, i.e. engaging them in explicit iteration on this level. However, none of the courses includes iteration on the level of project definition. The project is most often set from the beginning by teachers (in course 3 defined by students), but there is no re-evaluation on this level, i.e. not re-posing the question “is this the right project to do?” and redirecting action accordingly. Iterating on a project level, enabling students to do real pivots, could be needed for an effectual action logic to be enacted, as it does not rely primarily on fixed end goals.

2.2 Entrepreneurial action

The courses seem to be mainly engaging students in some kind of self-directed inquiry. Some of the courses also engage students in creation (of products, design or solutions), either as a core activity (courses 2, 4) or as a side activity (courses 3, 5, 8). These two aspects give students the possibility to enact specific aspects of an effectual action logic. Moreover, all courses give the opportunity for students to share their work, although most presentations are internal and do not explicitly call for students to ‘defend’, ‘pitch’ or ‘own’ their project outcomes. Students do need to communicate with external individuals in many cases (courses 2-6), for example reaching out to external researchers to get input, or interacting with an external stakeholder with which the students have been put in contact by their teacher. However, there is only one case (course 2) where networking was discussed, for students to build commitment or retrieve resources from an external individual. However, even in this case it was not a necessary activity. Another potential barrier for enactment of an effectual logic is that students seem to be investing their time into only one path or strategy, experimenting in some courses (mainly 2 and 4), however only on a problem or product level, and not on a project level, choosing among different ways to approach their endeavor.

3 DISCUSSION

New value creation and effectuation was applied here in order to assess ways in which project-based courses are entrepreneurial. The results indicate that three courses stand out in engaging students in projects through which effectuation could be enacted (courses 2-4). One of these courses (course 4) explicitly involve creation of an artefact (a software application) in relation to an external stakeholder, while the other two engaged students in highly self-directed inquiry, creation, experimentation and sharing of results. Involvement of an external actor as a receiver of students’ solutions creates natural opportunities for students to inquire into and reflect upon what is valuable for that person or company, and opportunities to share and communicate ownership of project results. This has earlier been advocated as a key part in enhancing engagement in student-centered learning [20]. Arranging project activities around real-world problems and having students co-create and present to external stakeholders could increase the level of authenticity of projects. Accordingly, project-based engineering courses with external actors could potentially provide students with opportunity to engage in entrepreneurial decision and action.

It seems however, even in courses involving external stakeholders and creation of new value, that *i)* lack of explicit recognition of own commitment and resources, *ii)*

lack of iteration and experimentation on a project definition level, and *iii)* lack of networking activity and external sharing of project outcomes, constitute barriers for the enactment of an effectual action logic in project based courses. This analysis suggests that engaging students in new value creation for or together with external individuals could be seen as necessary but not sufficient criteria to enable the enactment of an effectual action logic. Overcoming the three barriers stated above puts demands on self-direction, flexibility and management of uncertainty on part of the students, to be able to handle open and dynamic projects and to dare to engage in networking activities. This would indicate that trying to achieve a proper enactment of effectual action logic might be more suitable in later years of engineering programs, or in early years with thorough use of scaffolding techniques. Furthermore, open and complex projects call for a teacher to manage designing course structure and assessment able to account for large varieties in project processes and outcomes. We propose here that such course design and assessment should rely predominantly on recurring reflection assignments (featuring reflection and evaluation of new knowledge gained, decisions made and actions taken), instead of large product, project or reflection reports only at the end of the course. Similarly, we believe that such a course should focus on implementation of methods, processes and strategies to improve these, rather than on developing a nice product, and on what is purposeful and valuable rather than technical details. Through this, project-based courses could give students further opportunity to enact effectual action logic, and could also contribute to the development of adaptive and flexible mindsets, and help students get accustomed to managing and coping with uncertainty.

We have investigated here the relationship between an inductive teaching method, the project-based approach, and learning through entrepreneurship, which has gained prominence in later years following a substantial amount of initiatives for the inclusion of entrepreneurship into education. We believe that the shift from casual to effectual modes of teaching is in line with the shift from deductive to inductive teaching in engineering - especially sharing an emphasis of student-centered and self-directed learning and inquiry. In the context of project-based engineering courses investigated here, we also found a shared emphasis on creation, indicating that through some strategic changes in course structure, these courses might be potential training ground for entrepreneurial capabilities.

REFERENCES

[1] Kuratko, D. F. (2005), The emergence of entrepreneurship education: Development, trends, and challenges. *Entrepreneurship theory and practice,* Vol. 29, No. 5, pp. 577-598.

[2] Walter, S. G., & Block, J. H. (2016), Outcomes of entrepreneurship education: An institutional perspective. Journal of Business Venturing, Vol. 31, No. 2, pp. 216-233.

[3] Duval-Couetil, N., Shartrand, A., & Reed, T. (2016), The Role of Entrepreneurship Program Models and Experiential Activities on Engineering Student Outcomes. Advances in Engineering Education, Vol. 5, No. 1

[4] Ohland, M. W., Frillman, S. A., Zhang, G., Brawner, C. E., & Miller, T. K. (2004), The effect of an entrepreneurship program on GPA and retention. Journal of Engineering Education, Vol. 93, No. 4, pp. 293-301.

[5] Bilán, S. G., Kisenwether, E. C., Rzasa, S. E., and Wise, J. C. (2005), Developing and Assessing Students' Entrepreneurial Skills and Mind-Set*.

Journal of Engineering Education, Vol. 94, No. 2, pp. 233-243.

[6] Dabbagh, N., & Menascé, D. A. (2006), Student Perceptions of Engineering Entrepreneurship: An Exploratory Study. Journal of Engineering Education, Vol. 95, No. 2, pp. 153-164.

[7] Yasuhara, K., Lande, M., Chen, H. L., Sheppard, S. D., & Atman, C. J. (2012), Educating engineering entrepreneurs: A multi-institution analysis. International Journal of Engineering Education, Vol. 28, No. 2, pp. 436-447.

[8] Prince, M. J., & Felder, R. M. (2006), Inductive teaching and learning methods: Definitions, comparisons, and research bases. Journal of Engineering Education, Vol. 95, No. 2, pp. 123-138.

[9] Mäkimurto-Koivumaa, S., & Puhakka, V. (2013), Effectuation and causation in entrepreneurship education. International Journal of Entrepreneurial Venturing, Vol. 5, No. 1, pp. 68-83.

[10] Neck, H. M., & Greene, P. G. (2011), Entrepreneurship education: known worlds and new frontiers. Journal of Small Business Management, Vol. 49, No. 1, pp. 55-70.

[11] Blenker, P., Korsgaard, S., Neergaard, H., & Thrane, C. (2011), The Questions We Care About: Paradigms and Progression in Entrepreneurship Education. Industry and Higher Education, Vol. 25, No. 6, pp. 417-427.

[12] Sarasvathy, S. D. (2009), Effectuation: Elements of entrepreneurial expertise: Edward Elgar Publishing.

[13] Boocock, G., Frank, R., & Warren, L. (2009), Technology-based entrepreneurship education: meeting educational and business objectives. The International Journal of Entrepreneurship and Innovation, Vol. 10, No. 1.

[14] Mäkimurto-Koivumaa, S., & Belt, P. (2016), About, for, in or through entrepreneurship in engineering education. European Journal of Engineering Education, Vol. 45, No. 5, pp. 512-529.

[15] Merriam, S. B. (2009), Qualitative research: A guide to design and implementation: Revised and expanded from qualitative research and case study applications in education. San Franscisco: Jossey-Bass.

[16] Bruyat, C., & Julien, P. A. (2001), Defining the field of research in entrepreneurship. Journal of Business Venturing, Vol 16, No. 2, pp. 165-180.

[17] Lackéus, M. (2016), Value Creation as Educational Practice-Towards a new Educational Philosophy grounded in Entrepreneurship? , Chalmers University of Technology.

[18] Sarasvathy, S. D. (2001), Causation and effectuation: Toward a theoretical shift from economic inevitability to entrepreneurial contingency. Academy of management review, Vol. 26, No. 2, pp. 243-263.

[19] Eisenmann, T. R., Ries, E., & Dillard, S. (2012), Hypothesis-driven entrepreneurship: The lean startup.

[20] Lee, E., & Hannafin, M. J. (2016), A design framework for enhancing engagement in student-centered learning: own it, learn it, and share it. Educational technology research and development, Vol. 64, No. 4.