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Beyond planned learning objectives: Entrepreneurial education as the source of accidental competencies for engineering students

Aleksandr Litvinov; Anne Gardner; Sojen Pradhan, Jeri Childers
University of Technology Sydney, Sydney, Australia
Corresponding Author Email: aleksandr.litvinov@student.uts.edu.au

ABSTRACT

CONTEXT

A growing number of educational institutions and professional associations are emphasizing the importance of an entrepreneurial mindset and competencies in engineers and other technical professionals. The inclusion of entrepreneurship education components in engineering activities contributes to the development of technological innovations, which are aimed at solving essential social and human problems. However, despite the value of entrepreneurship education for engineers, there are limited approaches to evaluation that consider the complexity of the learning process and emerging practices.

PURPOSE OR GOAL

The purpose of this study is to understand the competencies that engineering students develop through participation in entrepreneurial educational activities. The learning process of engineering students was investigated through the lens of Accidental Competency Formation concept. Additionally, in this study, the authors evaluated how the chosen theoretical lenses provide understanding about the role of specific learning activities in forming students' competences.

APPROACH OR METHODOLOGY/METHODS

The authors followed the interpretive methodology and used in-depth semi-structured interviews as the data collection method. This research is qualitative and serves as a reminder of importance of students' perceptions and beliefs in understanding the effect of educational interventions on students' formation. Data was collected from 11 engineering students, who participated in the UTS Techcelerator 2020 program, which is a deep tech early-stage accelerator designed to promote prototyping skills for technology students.

ACTUAL OR ANTICIPATED OUTCOMES

The main outcome of the study is the elicitation of the three different accidental competencies such as self-regulation, adaptability and empathy, which are formed in the engineering students participating in entrepreneurial activities. Additionally, certain activities and elements of the Techcelerator program educational process were identified as having a particular impact on the formation of competencies, based on students' accounts.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This study provides a holistic approach that allows evaluating the role of entrepreneurial activities in the formation of engineering students' competencies, considering the complexity of the learning process. This conclusion is based on the fact that this study revealed formation of students' competencies that are not projected in program's learning objectives.

KEYWORDS

technopreneurship, engineering education, accidental competencies

Entrepreneurship education in engineering

Entrepreneurship is an important component of economic development and social wellbeing in both developing and developed countries. At the same time, over the past few decades, technology startups have been playing an important role contributing to the main economic indicators of countries. According to the Crossroads 2020 report, 7 out of 10 biggest companies (by market cap) are tech firms where more than half of the specialists working for these startups are engaged in technological roles (STEM skills) (McCauley & Gruszka, 2020). The growing importance of tech start-ups has driven universities and other educational institutions to incorporate entrepreneurial subjects or extracurricular programs (e.g. accelerators) into their information technology and engineering courses. Thus, entrepreneurial subjects for engineers are now a substantial focus in many engineering programs delivered in Australian universities for example, the University of Sydney (Incubate accelerator program), UNSW (10x Accelerator). Other educational institutions have gone even further by offering entrepreneurial development trajectories within the framework of their undergraduate engineering programs. A minor in Entrepreneurship offered by the University of Adelaide is an example of this. In terms of extracurricular activities, there are some opportunities available for technical students to develop their entrepreneurial skills and mindset in Australia. For instance, engineering and IT students wanting to establish their own tech business now have access to a large number of entrepreneurial programs within the Australian entrepreneurial ecosystem such as standard educational courses, accelerators, incubators and other structured and unstructured programs (Maritz et al., 2019). A good example would be the Techcelerator program that was launched in 2019 as a deep tech early-stage accelerator to enhance students' prototyping and entrepreneurial skills. Therefore, it can be concluded that the importance of technology entrepreneurship has been endorsed by many Australian educational institutions, which has been further emphasised by the active incorporation of entrepreneurial activities into engineering and IT programs.

The importance of entrepreneurial skills for technical specialists was also highlighted in industry reports prepared by professional associations. For instance, the Australian Council of Engineering Dean's (ACED) issued the Engineering Futures 2035 scoping study where entrepreneurial competencies are denoted as essential for future engineering experts. In this study, the World Federation of Engineering Organizations (WFEO) 2018 International Forum on Engineering Capacity communiqué (Crosthwaite, 2019; p.37) is also referenced, where it was emphasised that:

"We should enhance comprehension of the role of engineering in society and the training of engineering ethics, humanity, nature and entrepreneurship."

The American Society for Engineering Education (ASEE) also accentuates that engineers need well-developed entrepreneurial skills. To further illustrate this, the Innovation with Impact (IWI) report (ASEE, 2012) concludes that by teaching entrepreneurial skills to engineers, it will be possible to shape a generation of technical specialists who will collaborate more efficiently, be culturally responsive while focusing on the development and design of innovation with impact.

Despite the widespread trend of implementing entrepreneurial programs in universities and other educational institutions, there is a small amount of research aimed at studying engineering and IT students' attitudes towards entrepreneurship, the impact of entrepreneurial interventions on their learning as well as the formation of competencies and professional attributes of engineering students (Bosman & Fernhaber, 2018). The challenge of studying the role and impact of entrepreneurship education for engineering students correlates to the fact that there are many definitions of entrepreneurship as well as because of the large number of assumptions about the specific competencies, mindset characteristics and knowledge that an entrepreneur should possess (Duval-Couetil et al., 2012). This diversity of views on entrepreneurship has formed the preconditions for the creation of an array of approaches to entrepreneurship education.

It is also worth noting that when including entrepreneurial interventions into other educational programs such as engineering, it is important to understand how entrepreneurial education contributes to the formation of certain competencies. Additionally, an educational program must be certified by certain professional associations and must contribute to the formation of a certain set of graduate attributes. That is why it is important to know how several types of learning activities contribute to the formation of specific learning outcomes. This understanding might also further help to evaluate the effectiveness of integrated entrepreneurial programs.

Graduate attributes in engineering education

Most educational disciplines and sectors in the late 1990s saw a paradigm shift take place, with the focus shifting from inputs or processes to educational outcomes. Engineering education was not an exception. In Australia, the starting point for these changes was the publication of Engineers Australia's 1996 review "Changing the Culture: Engineering Education into the Future" (Engineers Australia, 1996). This review led to the development of the Australian Graduate Attributes (Engineers Australia, 2005). The new approach has broadened the scope of education since some non-technical aspects such as cultural awareness or ethical conduct have been added to the list of attributes. It is noted that some researchers assume the implementation of the outcome-focused approaches led to positive changes in the overall education process. One example is Lemaitre et al. (2006), who declared the focus on "professional competence has always been the ultimate goal of engineering curricula" (pp. 45). At the same time, it should also be noted that there are some critics of this outcomes-based approach. According to Miles (2003), targeted competencies are usually framed too broadly, which in turn makes their holistic development difficult. Additionally, some researchers and educators assume that the creation and implementation of these graduate attributes into educational programs has not solved the problem with the continuous existence of a gap between engineering education and the workplace.

It is also essential to mention that the introduction of the outcomes-based approach into educational programs focusing on specific competences and attributes has formed certain practices among engineering educators. When designing educational programs, some learning designers and coordinators might have the assumption that it is enough to choose a particular learning intervention (activity) to achieve a specific learning goal (development of an attribute) (Walther et al., 2006). Sometimes educators juxtapose planned attributes and educational interventions making a linear structure of the programs. When using this approach, educators do not take into account the complexity of the learning process and do not look at the education holistically. The existence of these challenges leads to the fact that at the moment, it is quite problematic to determine how extracurricular activities and other important extracurricular practices such as work integrated learning (WIL) as well as other meta-influences such as university culture affect the formation of competences.

As mentioned earlier, entrepreneurial education for engineers can be composed of different elements and have different formats, such as being optional (university incubators) or integrated into the curriculum (subjects). At the same time, there can be a combined format such as university accelerators when some students take part in the program voluntarily while other students can get some credit points for completing this program. As previously discussed above, accelerators are entrepreneurial interventions that have begun to be actively introduced into engineering curricula to encourage a formation of an entrepreneurial mindset among technology students.

According to Bliemel et al. (2016), accelerators can be defined as programs that involve parameters such as seed funding, a certain cohort of participants during the entire program, structured learning and development program, mentoring and co-location. It is evident from this definition that alongside the planned educational activities like workshops, accelerators also include many other less structured opportunities such as mentoring, cross-team discussion or interactions with customers for engineers to develop certain competencies associated with their professional formation. It is important to identify how the holistic structure of the given program affects the formation of educational outcomes to better recognize its effectiveness as well as the impact of accelerators on the formation of certain competencies among engineers. It is challenging to understand how such complex programs as accelerators involving various types of activities can be evaluated in terms of effectiveness and learning outcomes just by using traditional assessment tools. For such purposes, it is necessary to use approaches that consider the complexity of learning process.

In this article, we propose to use the view of Accidental Competency that holistically conceptualises the process of developing competencies as a complex system (Walther et al, 2006). According to Walther and Radcliffe (2007), 'Accidental Competencies are abilities important to performance in professional practices that are not linked to targeted instruction of the stated learning outcomes of the course' (p.45). The authors state that engineers shape competency through a variety of complex interactions, both within the framework of traditional interventions and under the influence of other elements that surround a student. The main idea behind this perception is that within the learning process framework, students acquire different types of competencies, such as accidental competencies, intentional learning outcomes and accidental incompetency. These are all formed under the influence of different clusters of a complex learning system, namely: learning activities, other curricular elements (exams, assessments etc.), student disposition (educational background, traits etc.), extra-curricular elements and meta influences (teacher as a person, prevailing culture etc.) The focus of this study will be around accidental competencies. This theoretical approach will enable us to take into account the complexity of accelerator programs as an entrepreneurial learning intervention while also identifying which accidental competencies are acquired by engineering students.

In this article, we state that in order to understand the effectiveness of entrepreneurial education for engineers, it is important to understand the formation of both planned goals and accidental competences. This complete understanding can help learning designers while simultaneously helping educators to develop curricula for the future T-shaped engineers.

The authors in this preliminary study considered the participants' beliefs in relation to developed competencies to determine exactly what abilities they think were developed. Choosing this approach, the authors proceeded from the point of view that beliefs can influence and predict the behaviour of an individual and shape his or her response and actions (Smith, 2016). A number of studies emphasise the importance of beliefs for self-efficacy, which, in turn, affects the behaviour of the individual (Bandura et., 1999), also the nature of knowing and intelligence (Dringenberg et al., 2019), capabilities (Eliot & Turns, 2011). Taking into consideration the theoretical approach and research focus, the following research question has been formulated for this study: *RQ: What are the engineering students' beliefs about their acquired accidental competences after participation in the accelerator program.*

Methodology

Since students' beliefs are not always explicitly articulated and can be both unconscious as well as conscious, semi-structured in-depth interviews were chosen as a method to explore the complex construct of participants' beliefs through the stories about their experiences during the accelerator program (McNeill, et al., 2016). In-depth semi-structured interviews with students allowed researchers to focus on the diverse variations of beliefs shared by participants and investigate all their aspects (Creswell & Miller, 2000). As accidental competencies could not be-predefined, this kind of interview gave the researchers flexibility during the conversation.

As mentioned above, this is a preliminary study that considers only participants' beliefs about the acquired competencies. This study was conducted with participants of the UTS Techcelerator 2020 program, which is a deep tech early-stage accelerator designed to promote prototyping skills for technology students. This was a free 6-month program that ran from July to December 2020. UTS students who had a startup prototype were selected for participation through a multi-step application process that involved a range of information and selection activities during three months. During the participation in the UTS Techcelerator, students went through a number of structured learning activities such as workshops, learning circles as well as unstructured one-on-one consultations with experts and guest speakers. Moreover, participants were also given access to facilities, mentors and funding.

This program was chosen as a research site because the authors being employed by UTS had access to UTS Techcelerator. One of the authors is also the Director of Techcelerator program and could provide access to the program participants. In the 2020 cohort, 22 individuals from the Faculty of Engineering and Information Technology (FEIT) participated in the Techcelerator program representing the Bachelor’s, Master’s and Doctorate students. Due to the limited number of program participants, all of them were invited for interviews via email. Consequently, eleven participants from seven technology enterprises participating in the program expressed their interest in being interviewed for the study. These participants allowed researchers to collect a range of insights and provided sufficient data saturation - which is the common approach in determining a sample size. A mix of educational programs and genders of the participants was ensured. Due to COVID-19 restrictions, all interviews were 60 minutes in duration and conducted online via zoom.

From the learning perspective, UTS Techcelerator aims to achieve the outcomes that are focused on developing a range of practical skills and an entrepreneurial mindset among the participants. Planned outcomes included outcome one, outcome 2, outcome three, outcome four, outcome five and outcome six. In order to understand how these outcomes were formatted in this research, it is important to take into account the fact that the UTS Techcelerator is part of FEIT. Thus, the graduate attributes formulated in the university and faculty strategy determined the outcomes reflected in the Techcelerator program outline. (UTS FEIT graduate attributes are aimed to shape students who are attribute one, attribute two, attribute three, attribute four, attribute five, attribute six).

Understanding the outcomes was an important aspect to consider at the data analysis stage. These outcomes and related competencies declared in the UTS Techcelerator 2020 program formed the analytical strategy based on the Accidental Competency Formation concept.

The authors analysed the interviews focusing on the competencies formed as a result of participation in the program but were not declared in its planned outcomes. During the interview, the participants were asked about their perceptions and impressions of various accelerator experiences. Some of the questions were also focused on identifying the student’s beliefs about takeaways as well as their achievement and challenges during the program participation. Then using thematic analysis, authors evaluated the acquired data. This approach allowed the researchers to examine and summarise perspectives of different participants and found unanticipated insights (Nowell et al., 2017).

Results

As mentioned earlier, the main goal of this empirical study was to understand whether traces of formed accidental competencies can be tracked in the responses given by the participants. Also within the framework of this study was an attempt to understand how this theoretical approach would be suitable for identifying unplanned learning outcomes. After analyzing the acquired data, the following results were obtained.

Self-regulation

Self-regulation and other self-oriented competences are not part of the lists of accelerator and faculty attributes lists. Zimmerman and Labuhn (2012) defines self-regulation as an ability to take the lead in helping oneself using proactive behavior and developing learning strategies to get out of difficulties. In this situation, an important characteristic is the ability to act proactively. Learning and other extracurricular activities (group work etc.) of the accelerator program were structured in a way that challenged participants to be involved into a variety of new situations and interactions with team, stakeholders, and customers. Further to this, the teams worked on their own individual projects (startups), compulsory reporting about the budget expenditures as well as a strict time frame of the program where it was necessary to present a minimum viable product. Due to this, the commitments shaped conditions for proactive behavior.

Participant 1. The client said that he would like to change some design elements in a short time. Since we did not have enough funds to hire a specialist, we had to quickly learn the basics of design and the necessary tools to create these elements. It was a new experience for us in solving problems without funds. Now I believe that I feel more confident working in design programs like Figma and dealing with unexpected situations.

After analysing qualitative data, it was identified that different learning activities and other influences manipulated the students' ability to feel more confident when they encountered sudden problems. This example shows how different categories of educational activities stimulate students to form self-regulation competence. For example, during structural and planned learning activities such as workshops, students got instructions on how to communicate with potential customers. Then, students within the framework of social interactions (extra-curricular activities) faced the problem of lack of money and customer suggestions (meta-influences). The students also proactively formed the strategy to solve this problem (they decided to learn some design principles) which helped them get out of this situation with newly formed competencies.

Adaptability

According to Herman (2013), adaptability is defined as the ability to adjust to different changes in the selection environment. Miller and Bound (2011) mentions accelerators themselves represent a competitive environment. Within the considered research site (accelerator), students had the opportunity to compare their achievements with the results of other teams. Within the framework of this program, there is also a series of milestones when students must present their intermediate results. These parameters characterize accelerators as a fairly competitive environment. Additionally, according to Bliemel et al. (2016), accelerators form authentic experiences of complex entrepreneurial activities when students consider a range of factors affecting success of their project and solve various problems.

Participant 2. I feel a big self-progress. At the beginning of the program, I felt overwhelmed, due to the large number of meetings, events and information. I could not keep up with the pace of combining the accelerator and other objects. However, the other students and mentors explained me some of the basic principles of time management and gave me some personal advice. Now I'm not afraid to ask for help.

This answer shows how a student in new conditions, with the help of various elements of the accelerator such as group work and personal consultations with a mentor, received new knowledge and methods for adapting to new conditions. This example portrays how different types of events and meta influences directly impact the formation of the student's ability to adapt to new, stressful conditions with more workload.

Empathy

Empathy is a commonly used phenomenon in different fields, ranging from social work and nursing to engineering and entrepreneurship. At the same time, empathy has many different definitions. For example, Cuff et al. (2016) found at least 43 definitions of empathy. It is essential to mention that there are some assumptions that empathy is an important element of communication, ethics or cultural awareness. In this study however, when reporting on empathy as an accidental competence, we use the definition of Walther et al. (2017). He developed a concept of empathy for the engineering context while taking into consideration the complexity of this attribute that is conceptualized as a skill, practice orientation and a way of being. As part of our research, it was determined that under the influence of entrepreneurial education, some students had all three facets of empathy.

When I realized that our clients had lost a lot during the COVID event since the public events were not allowed, I realized that we needed to reduce the price of our product and make it more affordable. It's great that our advisor recommended us to use the empathy map…...I underestimated the knowledge of other people. I didn't realize what a big market. I didn't realize how giant it was in Europe and China……...Because we thought of this great solution, but if the public doesn't need it or want it, there's no point

Here we can trace how accelerator activities such as interactions with clients and meetings with advisors contribute to the formation of all three facets of empathy in students. In this example, a student believes that some of the tools and knowledge (empathy map) helped him use the skill of perspective-taking and understand a client's outlook. Walther et al. (2017) consider perspective-taking as a learnable skill that is part of empathy. It can further be traced to a student who has started thinking about macro opportunities for his business, demonstrating the micro to macro practice orientation orienting towards larger systems-level implications (Walther et al., 2017). And finally, the participant also demonstrates the elements of service to society way of being declared that the products should be developed for the needs of society. It's worth noting that Walter's empathy model includes other elements as well, such as emotion regulation, epistemological openness, dignity and worth of all stakeholders etc., on different levels. However, in this study, it was possible to trace the formation of three facets afterwards and reveal the influence of accelerator activities on the formation of each facet.

Discussion

In this empirical study, the authors investigated the acquisition of accidental competencies by program participants using the concept of Accidental Competency. The influence of all categories including but not limited to extracurricular activities, meta-influences, student disposition and other curricular elements were taken into account. As a result, it was noted that participation in this entrepreneurial program (accelerator) contributed to the acquisition and formation of a number of accidental competencies such as empathy, self-regulation and adaptability of a majority of the students' participants.

This study also notes that by using a theory that considers the learning process a complex system and explores the impact of various learning activities, researchers may determine the development of competencies that were not originally set for the program. This understanding is important due to the established trend towards forming T-Shaped engineers who must possess a range of both technical and social skills (Crosthwaite, 2019). It is thus important to have a tool that allows practitioners to define a range of competencies that could also be included in the training programs of engineers. This approach can further make it possible to analyse existing programs that identifies accidental competencies and, therefore, expands their outcomes and strengthens them by introducing additional activities or by adapting existing ones.

Also, within the framework of this study, the essential role of all types of activities that affect the learning outcomes was highlighted. This is because after analyzing the data, it was confirmed that, for example, extracurricular activities or meta-influences could play the same important role in the formation of certain competencies as structured ones. Currently, there are attempts to integrate other practices such as Work-integrated Learning (WIL) into engineering education in addition to entrepreneurial interventions. The effectiveness of WiL also depends on many parameters, including other curricular elements or extracurricular elements or meta-influences. Therefore, the results of this study, which support the fact that different types of activities are equally important in the formation of different types of competencies, including accidental competencies and even accidental incompetencies, can help learning designers and educators to understand the important role of holistic approaches in developing and delivering educational programs as well as understand the important role of holistic and complex evaluating approaches.

Limitations

The primary limitation derives from the fact that the research focuses on beliefs while simultaneously defining acquired competencies. As there is a perception that beliefs do not always impact the actions of an individual, it is valuable to observe a participant or investigate a reported behaviour (Wyatt, 2015). Therefore, in order to define the connection between beliefs and real actions, studies of the educational context often consist of two components: exploring how participants state their beliefs and their behaviour after completion of the program (Guanes et al., 2021). Since the study is preliminary, however, it did not involve exploration of individuals' behaviour since it was conducted immediately after the end of the program. This research is therefore the basis for further study of the behaviour of participants after taking part in the program. This develops an understanding of the relationship between their beliefs and reported behaviour and makes further conclusions on acquired competencies.

Another limitation is related to the sample size, as only one program with students from the same university was investigated in this study. Since the outcomes of the programs should have been aligned with the graduate attributes of the faculty and the university, some identified accidental competencies might be relevant only for a given university. As a result, an extension of the sample would be beneficial.

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