

CDIO-BASED ENTREPRENEURSHIP COURSES AS DRIVERS OF INNOVATION IN INDUSTRIAL SEGMENTS

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ABSTRACT

In this paper, we describe and discuss how in two CDIO-based entrepreneurship courses at Linköping University, Sweden, we encourage students to identify and solve challenges and problems in two adjacent industrial sectors, i.e., environmental technology and agricultural/green industries. Both courses are offered to a broad range of engineering programs. The industrial sectors chosen give the students a delimited context incorporating direction, business culture and technology, that forms a basis for the students on which to build their entrepreneurship cases. Working with real challenges gives real-life experience of how models and frameworks can be utilized and correctly executed. In addition, it increases project relevance, student motivation and learning.

One challenge to overcome is the fact that many students lack previous work-life experience and a thorough knowledge of the industrial sectors in focus. Experiences from earlier courses told us that this made it difficult for students identify and develop realistic, yet challenging and new business ideas on their own to. To remedy this, we tested facilitating interaction with industry, and through this help the students to detect real problems. Furthermore, it was anticipated that interaction with external actors, such as established businesses, organizations and potential customers, helps students to adjust and fine-tune needs and demands to create business ideas that could have real potential. As an added benefit, this approach could enable academia to act as co-creator in industrial problem solving, i.e., to put academic knowledge to practical use in society. Based on our own experiences and student feedback we discuss how this approach forced the students out of their comfort zones, challenged their creativity and enhanced their learning.

KEYWORDS

CDIO standards 2 (learning outcomes), 7 (integrated learning experiences) and 8 (active learning)

INTRODUCTION

In our teaching practice, we have realized that individuals learn and engage in problem solving in different ways (see e.g. Kolb, 1984, who discusses different problem-solving styles). Through a mixture of different teaching approaches, more students can be addressed and reached in ways that fit their individual ways of learning (see e.g. Garrison and Kanuka, 2004; Ginns and Ellis, 2007; Lopez-Perez et al., 2011). This can be done in several ways such as creating a mixture of traditional lectures, seminars and workshops, films and e-learning that facilitate independent study. Through our practice, as well as from theory, we have realized that both relevance and the “fun factor” are important motivators that improve learning (MacInnis, Ramsden and Maconachie, 2012; Norrman et al., 2014; Norrman et al., 2016). These findings led us, in a previous project, to develop a model for learning, the ERL model (Expanded Room for Learning) (Norrman et al., 2014), which has now been implemented in several of our courses. The ERL model puts the learning objects in focus and emphasizes that the teaching design is influenced by the stakeholders (e.g. teachers and students), pedagogics and technology (e.g. the mix of teaching approaches and the ICT tools used), and context (e.g. setup and cases).

In this paper, we put our focus on the context factor of the ERL model as this is important for the learning process. In addition, the CDIO framework (see e.g. Crawley et al., 2014) emphasizes the importance of relating learning to a context, as it increases understanding, motivation and relevance. This is also important for achieving quality learning by means of what Biggs (2003) terms conditional and functional knowledge or, as expressed by Crawley et al. (2014) the engineering students’ ability to engineer. In the courses that form empirical cases for this paper, we have used the chosen contexts to incorporate direction, business culture and technology, which form a basis for the students on which to build their entrepreneurship cases.

Another important aspect is entrepreneurial learning, as this could be utilized in teaching to enhance both learning as such and knowledge about entrepreneurship. Our ambition is not to push (all) students into business venturing, but merely to foster a more business-oriented mindset, which they could benefit from regardless of where they end up after their education. According to Cope (2003), the learning process of entrepreneurs is action oriented and experience based, i.e., entrepreneurs use “learning by doing” strategies, which are about trial and error, problem solving and discovery. This is also shown by McGrath & McMillan (2000), who stress that an “entrepreneurial mindset” incorporates passionate opportunity seeking, tenacity and execution focus in idea realization, and the ability to engage energy from people around them. Politis (2005) stresses that entrepreneurial learning is synonymous with experimentation. One problem though, according to Gibb (2002), is that most university courses related to entrepreneurship focus on learning about entrepreneurs and entrepreneurship rather than learning for entrepreneurship, or the above-described “entrepreneurial learning.” Gibb argues that this needs to be changed and that the focus ought to be on giving the students tools that could be used in later entrepreneurial processes and to create more activity-based learning where they can gain experience.

To us, as teachers in entrepreneurship courses for engineering students, it is a challenge to make our students engage in real and relevant tasks. In our lectures as well as in our seminars and workshops, we strive to encourage creativity, courage, experimentation and an attitude towards problems that is in line with what we found written on a wall at Stanford Ventures in 2012: “Every problem is an opportunity - the bigger the problem, the bigger the opportunity.” Like Gibb (2002), we strive to encourage entrepreneurship and entrepreneurial learning and we want our students to acquire practical tools useful for entrepreneurship, rather than theoretical knowledge about entrepreneurship. Our main goal is to encourage experiential learning, which is in line with the CDIO goal that the engineers should be able to engineer (Crawley et al., 2014). Without experience during their studies, they will only get theoretical

knowledge. Another mission is to support the role of universities as co-creators rather than knowledge banks (see e.g. Frankelius and Norrman, 2013) and encourage entrepreneurial experimentation, both among our students and ourselves, i.e., we want to learn together with our students.

In some courses this is solved by letting the students work with real-life cases (see e.g. Creed et al., 2002), which has been tested previously in a course (TEIO20) that forms one of the cases in this paper (see Norrman et al., 2014). However, during recent courses, this approach was abandoned due to several reasons: First, it is both time consuming and difficult to find business cases that work in courses and are owned by firms that are willing to leave them in the hands of students. Second, even if cases are found and even if the idea owners assure in advance that their participation can be assumed, this is not always the case in practice. The result of this is that the conditions, by the students, are regarded as unfair as some groups get dedicated idea owners and other get those that care less. Third, when comparing the engagement and student satisfaction in the courses (TEIO20 that had cases, and TKMJ49 that was run on the students' own ideas), we realized that the students preferred to work with their own ideas. However, to make this work, previous experience has taught us that it is important to guide the students into a specific context, as this helps them to focus and prevents them from going for low-hanging fruit (e.g., they create an app, financed via advertisements, and conduct market investigations among their close friends).

A challenge, when choosing a context to relate the teaching and learning process to, is the fact that many students lack previous work-life experience and a thorough knowledge of the industrial sectors in focus. Experience from previous courses has told us that this made it difficult for students to identify and develop realistic, yet challenging and new business ideas on their own. To resolve this, we have tested facilitating interaction with industry, and through this help the students to detect real and relevant problems.

Furthermore, it was anticipated that interaction with external actors, such as established businesses, organizations and potential customers, helps students to adjust and fine-tune needs and demands to create business ideas that could have real potential. As an extra benefit, this approach could enable academia to act as co-creator in industrial problem solving, i.e., to put academic knowledge to practical use in society. Based on our own experiences and student feedback we discuss how this approach forced the students out of their comfort zones, challenged their creativity and enhanced their learning.



Students in TKMJ49 engaged in problem solving at Cleantech Park. They were inspired by Ian Hamilton from Econova AB, who previously had given them his view of current problems in the “cleantech” industry. (Photo: Olof Hjelm)

University research and education and their role and contribution to regional and business development have been debated for more than two decades. Concepts such as triple helix (Etzkowitz, 2000) are being extensively used to describe joint efforts for regional economic development, and the so-called “third mission” of universities to contribute to economic development is becoming more and more established. The third mission adds to the more traditional roles of research and education. Recent streams of literature suggest looking beyond this third mission and promote a fourth mission, the mission of co-creation (Trencher et al., 2014). This would mean a development from the entrepreneurial university to the transformative university in which universities collaborate with diverse societal actors in development of specific locations, regions or societal sub-sectors. This is in line with Frankelius and Norrman (2013), who claim that there is a need to enlarge the role of academia in innovative processes. Academic research can lead to innovation and in order to stimulate this development, policy focuses on commercialization of research projects. In addition, student-driven entrepreneurship is encouraged, while the universities support trade and industry with well-educated workers. In these cases, academia is regarded as the source from which innovation springs, develops and is diffused. However, far from all new ideas are born inside universities - sole inventors as well as industry contribute a major share of ideas generated. Along with Frankelius and Norrman, we argue that the role of academia in the innovation process can be enlarged through increased cooperation with surrounding industry, i.e., ideas from outside the universities can be developed and refined e.g. by students and then continue their development towards commercialization outside academia. This type of interplay adds relevance and meaning to education and allows students to gain real-life experience during their studies, which is in line with the CDIO approach.

METHODS AND APPROACH

In this section, we present the general design of the two courses from which we draw our experiences and give a deeper description of the approach with inspirational seminars. We also report how we surveyed students’ experiences of taking part in the courses in general and inspirational seminars in particular.

To start, this experiment used two existing courses; “Entrepreneurship and New Business Development” (TEIO20) and “Environmentally Driven Business Development” (TKMJ49). Both courses are offered to various engineering programs at Linköping University and students generally take these courses in their fourth or fifth year of study. This year the first course (TEIO20) had a focus on the agricultural sector and the second (TKMJ49) focused on environmental technologies. Both courses introduce and use a number of theories and tools for entrepreneurship and business development, such as NABC (Carlson & Willmot, 2006), business model development (e.g. Osterwalder and Pigneur, 2010), Porter’s five forces analysis (Porter, 2008), SWOT (Strengths, Weaknesses, Opportunities and Threats), etc. These approaches and tools were presented in lectures followed by interactive seminars in which the students applied the theories and tools to their own business ideas. During the course the business ideas were developed and refined and documented in a report. Students were also encouraged to go out and interact with external actors such as presumptive competitors and customers, in order to verify their ideas and value propositions. At the end of the course, the business ideas were presented in an exhibition at which the students invested toy money on what they perceived as the best ideas, and a winner was selected. We also used an external jury with business people from the region who gave a prize for the most promising idea.



This is a final seminar where no one falls asleep! About 75 students from TEIO20 and TKMJ49 have joined together in Mjärdevi Science Park at the open arena CreActive. (Photo: Olof Hjelm)

To help students in formulating ideas to be developed we arranged inspirational seminars at the start of the courses. For the course focusing on the green (agricultural) sector (TEIO20) we brought the students to Vreta Kluster, which is a meeting place and development arena for technology and business development that contributes to the green sector's development and growth. For the other course (TKMJ49) we visited Cleantech Östergötland, a network of environmental technology companies. To both seminars, we invited experienced entrepreneurs who made short presentations describing challenges they saw in their line of business. Based on the challenges given, groups of four or five students jointly started to formulate business ideas aimed at solving selected problems. In forming the groups, students were instructed to mix with individuals from other engineering programs to broaden the team's experiences and interests, e.g. mixing industrial economics with environmental engineering. During problem formulation and idea generation, the invited industry representatives served as coaches and helped the students in the initial formulation of a first business idea. The ideas were then further developed and refined throughout the courses as described above.

For assessment of the chosen approach with inspirational seminars, we used a number of complementary sources of information. First, we used an online survey focusing on the inspirational seminars sent to the students after the courses were complete. The students were asked to give input on strengths and weaknesses with the seminars. We also used personal reflections written by each student on their learning outcomes of the full course. Finally, we used online course evaluations that students fill out for each course they take at the university.

From the students' answers and reflections, we summarized their experiences and looked for quotes describing different views on the seminars. The analysis was quantitative because of low response rates (10-30%). In any event, we found 30 comments on the seminars. All comments were classified as being positive or suggestions for improvements/negative. Furthermore the theme for the comment was noted (e.g. if it was about involvement of external actors, learning about industry challenges, etc.).

STUDENT ATTITUDES TOWARDS THE INSPIRATIONAL SEMINARS

Of the 30 identified comments on the seminars, six could be labeled as suggestions for improvements/negative and 24 were positive. The negative comments/suggestions for improvements dealt with issues regarding better instructions to speakers and students before the seminars and more support in the workshop when the students started to develop their ideas.

Of the positive comments 11 students mentioned that the setting of the seminars as such created an inspiring context and a good start for the courses. Below we have displayed some of the quotations:

- *“Inspiring, informative, a great way to start the course”*
- *“The seminar at Vreta Kluster was very interesting and rewarding - keep this step in the course.”*

Another seven comments were about the opportunity to meet external actors such as industrial representatives and business development coaches. It was also appreciated that they could learn about the industry as such and the problems the industry was facing now.

- *“The “pitch day” at Vreta Kluster was funny. It was interesting and rewarding to get insight in the industry segment that was target for our business idea development.”*
- *“Interesting to hear from those that are working in the industry”*

A few commented that they liked the way of working (such as using Lego and coaching from industry representatives) which was new to them.

- *“It gave perspective on obstacles that companies deal with in their daily work and it was a good occasion to talk more to other course participants and the firm representatives about the business idea proposal.”*

Finally, we got some comments that suggested matter for improvements:

- *“More help in the idea generation process - if you are not able to come up with an interesting idea you risk falling behind in the course”*
- *“Connect the speakers even more clearly to the course content”*

ANALYSIS AND CONCLUDING DISCUSSION

Firstly, we can conclude that letting the students meet with representatives from the industrial sector was appreciated by most students. However, to make the concept work smoothly, careful planning and preparations are key. At our first try, the seminar at Vreta Kluster, six speakers were invited and they were told to give evidence of problems in the agricultural sector. The seminar was announced publicly and invitations were sent out to a broad range of actors. The oral comments during the seminar and shortly afterwards were that the speeches were interesting and that the students found it inspiring to get knowledge about farming. Unfortunately, they had problems in transferring the problems into needs and approaches that could form new business ideas within their own disciplines where they could utilize the domain knowledge acquired during their education. Some of the groups took on the mission and succeeded, but about one-third of the groups ended up in problems outside their own knowledge domain, e.g. in low-tech or retail-based business ideas such as meat boxes, internet forums for farmers, automatic milk stands or small-scale vegetable markets. About one-third of the groups found ideas where they could make use of their engineering skills in biology and chemistry and came up with ideas using sensor technology for watching crop-drying processes, using bio-pesticides for keeping insects away from plants or using hydro-optic systems for growing plants indoors, etc. The remainder were on a scale between high-tech and low-tech.

The seminar at Cleantech Park took place a couple of months after the Vreta Kluster seminar. Here we had the advantage that most of the students had taken several courses in environmental technology, and through this had a basic understanding of the cleantech industry. Another advantage was that the invited guests were representing technology-based firms, i.e., they had a shared background with the students.

In January 2017, another round of TEIO20 was started, and this time too we decided to start the group work with an inspirational seminar. Since we had the two previous trials from 2016 to start from, the approach was changed a little bit. First we prepared the students better, already at course start. They also got a presentation displaying about 100 problems collected from questionnaires used in a research project concerning innovation in the agricultural sector. Finally, the students were encouraged to start out from their own knowledge domains and try to come up with problems and solutions from that point of view. The representatives from the agricultural industry (one researcher and two crop growers) were informed that they would meet with students in innovative computer programming, mechanical engineering, biotechnical engineering, chemical engineering and engineering physics. The seminar was held at LiU and the farmers gave a short overview of the technology development in farming and showed pictures of the tractors they started with and the ones they use now in their own farming business. They showed pictures generated from harvesters and N-sensors and talked about software systems for precision agriculture. The researcher gave an overview of how UAVs could benefit the farming industry. After the presentations, we continued with group work, where the guests mingled with the students. The ideas that popped up were technology-based to a higher extent than previously.

One factor that can affect how seminars like this work and are perceived by the students is the number of participating students. At Vreta Kluster there were about 60, divided into 12 groups; while at Cleantech Park there were 15 who worked in three groups and at LiU Campus there were 25 students working in five groups. The atmosphere was more intimate and less stressed at Cleantech Park and at LiU Campus due to the smaller number of participants, which may have allowed for more questions. At Vreta Kluster everything was new, the students arrived by bus to an unknown environment, and not all external participants were presenters, and were thereby not recognized as possible sources of knowledge by the students. As teachers we did our best to toss the groups together with different industry representatives, but still it was a very large event to handle.

It should be noted that the arrangements that were done in TEIO20 and TKMJ49 in 2016 required resources that exceeded the original course budgets. This was possible since we had external funding to develop our pedagogics. However, in TEIO20 2017, the seminar was arranged without using any extra resources besides the contact network of the teacher. Irrespective of economic resources teachers wanting to do similar things should have a broad network with industry representatives or start collaborating with industry associations, science parks, etc. to be able to pick suitable individuals who want to interact with students.

Future development of the concept could include better preparation for both students and industry representatives and that industry representatives come back and give feedback on the business ideas after they have been developed a bit.

Further, we believe that this approach could be a good way of bridging the gap between academia and industry. Using students in collaboration projects not only gives relevance to education and enhances learning, but it is also an attractive and low-cost way of starting collaboration with industry which later can result in new product or business development and joint research projects (see Hjelm and Lindahl, 2016). Finally, an underlying ambition is that our courses could create continual entrepreneurial activities generating both new startups and well-equipped engineers, taking advantage of their entrepreneurial mindset in their

employment. Given the short period after these recent experiments in our courses, this is not yet possible to evaluate, but could be an interesting topic for further examination.

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REFERENCES

Carlson, C. R., Wilmot, W. W. (2006). *Innovation - the five disciplines for creating what customers want*. New York: Crown Business.

Cope, J. (2003). Entrepreneurial Learning and Critical Reflection - Discontinuous Events as Triggers for 'Higher-level' Learning. *Management Learning*. Vol. 34 (4), 429-450

Crawley, E.F., Malmqvist, J., Östlund, S., Brodeur, D. R. and Edström, K. (2014). *Rethinking Engineering Education - The CDIO Approach*. New York: Springer.

Crawley, E. F., Malmqvist, J., Lucas, W. A., & Brodeur, D. R. (2011). The CDIO Syllabus v2.0. An updated statement of goals for engineering education. In: Proceedings of 7th International CDIO Conference, Copenhagen, Denmark.

Creed, C.J., Suuberg, E.M., Crawford G. P. (2002). Engineering entrepreneurship: an example of a paradigm shift in engineering education. *Journal of Engineering Education*, April, 185-195

Etzkowitz, H., Webster, A., Gebhardt, C. & Cantisano Terra, B.R. (2000). The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm. *Research Policy*, Vol. 29, 313-331.

Fayolle, A. & Gailly, B. (2008). From craft to science - teaching models and learning processes in entrepreneurship education. *Journal of European Industrial Training*, Vol. 32, no. 7, 569-593.

Frankelius, P. & Norrman, C. (2013). Uppfinningars betydelse för Sverige. Stockholm: Vinnova rapport VRn 2013:03.

Gibb, A. (2002). In pursuit of a new "enterprise" and "entrepreneurship" paradigm for learning: creative destruction, new values, new ways of doing things and new combinations of knowledge. *International Journal of Management Reviews*, Vol 4 Issue 3, 233–269.

Hjelm, O and Lindahl, M. (2016). Roles of Academia in Supporting Eco-design in Small Companies for Better Environmental and Economic Performance. *Procedia CIRP*, Vol. 50, 745-750.

McGrath, R. G. and McMillan, I. (2000). *The Entrepreneurial Mindset: Strategies for continuously creating opportunity in an age of uncertainty*. Boston: Harvard Business School Press.

Osterwalder & Pigneur (2010). *Business Model Generation*. Wiley

Politis, D. (2005). The process of entrepreneurial learning: a conceptual framework. *Entrepreneurship Theory and Practice*, July, 399-424.

Porter, M. E. (2008). The five competitive forces that shape strategy. *Harvard Business Review*, 86(1), 78-93.

Trencher, G., Yarime, M., McCormick, K.B., Doll, C.N.H & Kraines, S.B. (2014). Beyond the third mission: Exploring the emerging university function of co-creation for sustainability. *Science and Public Policy*, Vol. 41, 151-179.

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