

## **Design of an interdisciplinary engineering elective scoped around collaboration with Small Medium Sized enterprises (SME)**

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## **INTRODUCTION**

To acquire the right competences as an engineer in the 21<sup>st</sup> century<sup>1</sup> ((King, 2007), you need to be able to work inter-disciplinary and learn the necessary innovation methods and tools<sup>2</sup>.

This paper will strive to answer some of questions identified in the progress of developing and implementing a real life setting elective course, involving small and medium sized enterprises (SME) in engineering education. How do you engage with companies without compromising the learning outcome? How you manage the expectation from the companies and still maintaining the student responsibility for the problem solving? Do the interdisciplinary teams add value for the SME?

The elective *SME Innovation and Intrapreneurship* has been developed by DTU Diplom a department of the Technical University of Denmark. The department is mainly responsible for the education of the degree Bachelor of Engineering which is a 3.5 year long engineering education building on engineering industry practice as its core. All BEng educations build on the CDIO (Conceive-Design-Implement-Operate) as the overall teaching paradigm<sup>3</sup>. The development has been funded by the Danish Foundation for Entrepreneurship, and is seen as an experiment in the process of transforming the department into a hotspot for engineering innovation and entrepreneurship. Alongside this a much bolder step of introducing innovative competencies as a general intended Learning Outcome for the whole education<sup>4</sup>. The driver of this change will be the introduction of a compulsory 10 ECTS element

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<sup>1</sup> King

<sup>2</sup> Liebenberg & Mathews

<sup>3</sup> Crawley, Malmqvist, Östlund, & Brodeur

<sup>4</sup> Biggs & Tang

with focus on interdisciplinary and industry collaboration for all Bachelors of Engineering at The Technical University of Denmark in 2016.

As collaboration partner the elective has chosen to work with small and medium sized enterprises (SME) as more than half of the value added to the European economy comes from the SME's and around half of all employees work in micro or small businesses with less than 50 employees<sup>5</sup>. At the same time the barriers for university collaboration with SMEs are somewhat steeper than working with larger organizations<sup>6</sup>.

The paper will focus on the SME cooperation and proceed with an introductory explanation of the current course, how the course has been scoped including the theory behind and how the company cooperation has been developed. Finally it will bring a discussion about preliminary results (as the course is ongoing) and recommendations for the future.

## 1 THE COURSE DESIGN

### 1.1 The goal

The following is a description of the course SME Innovation and Intrapreneurship<sup>7</sup> to provide a frame for the later discussions.

The aim of this 13 week long course is to develop the student's ability to work interdisciplinary with innovation in a real-life setting. The course has special focus on the challenges and benefits of working intrapreneurially in a small or medium sized company (SME).

For that reason students from different study programs are teamed up working with a problem provided by a SME. The students are all in the later stages of their engineering education 5-6 semester and are expected to possess a strong disciplinary identity.

The intended learning outcomes of the course are that the students are able to plan, execute and evaluate a development phase from problem brief → first prototype of the chosen technical solution. This includes selecting and applying appropriate methods, applying technical, user and customer/business perspectives. Process skills involve both reflection and expectation management skills and include both being able to contribute with own core disciplinary competences but also respectfully challenge the views of others and be able to argue for choices and explain details both related and unrelated to one's own discipline. The students should further be able to demonstrate an understanding of the SME challenges with innovation and explain intrapreneurial processes they have gone through in the company collaboration during the course.

### 1.2 The structure

The first part of the course (4 weeks) is a mainly divergent phase that aims, through creative and entrepreneurial methods, to challenge the initial problem statements from the partner company and learn in theory and practice to work inter-disciplinary.

<sup>5</sup> European Commission, 2013

<sup>6</sup> Darabi & Clark, 2012

<sup>7</sup> Christiansen, Ulrich, & Pontoppidan

The transition between the two phases is marked by a planning session where the students plan out their development work together with what materials as well as disciplinary resources and help from the workshops they need.

During the R&D period (week 5-13) which is a mainly convergent phase, the students combine their disciplinary skills, as well as learn new skills, to create a concrete solution in the university workshops and laboratories for one of the formerly challenged problems. The students should during this phase come to an agreed prototype state of their solution.

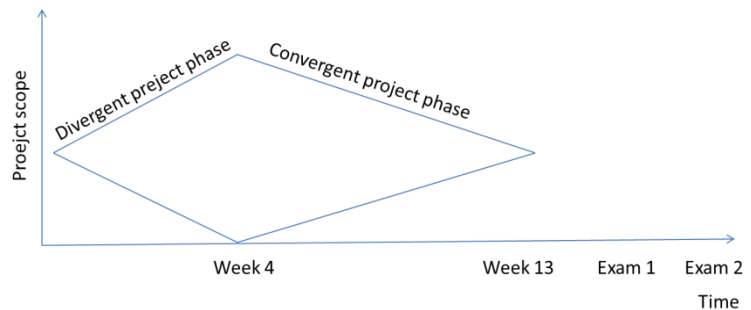


Figure 1 course structure

The projects are typically product development, re-design of existing or process design. The size of the project is tailored, so it is feasible to reach a prototype level.

The companies are involved regularly. In the very beginning they present their company and problems. In the transition between the divergent and convergent phase expectations are adjusted and midway in the R&D phase a plan for testing of the prototype or mock-ups is agreed upon.

They are also partakers in the first oral exam which is a presentation of prototype and business proposal aimed at handing over the project to the company and arguing for future business choices. The company pays a small amount (DKK 5.000) to cover extra expenses for materials.

## 2 THEORETICAL BACKGROUND

The teaching approach is inspired by newer development within entrepreneurship teaching involving a shift away from focusing on entrepreneurship research or writing business plans towards a greater focus on the training of entrepreneurial competencies among the students<sup>8,9,10</sup>. When teaching entrepreneurship you can divide between three kinds of entrepreneurship teaching<sup>11</sup>:

- **Learning to become an enterprising individual:** Primary focus on the personal competencies
- **Learning to become an entrepreneur:** Primary focus on the disciplinary skills and tools
- **Learning to become an academic:** Primary focus on knowledge skills

Where universities traditionally have focused on the academic side, and business plan courses on the disciplinary skills, the choice for this course was to focus on developing the personal competencies of the students. By focussing on the personal competences it was stressed the goal of the initiative was to create more innovative students.

Innovation and entrepreneurial competencies are very similar. Perhaps where they both meet best is in the bottom up intrapreneurship perspective where the individual

<sup>8</sup> Kirketerp

<sup>9</sup> Read, Sarasvathy, Dew, Wiltbank, & Ohlsson

<sup>10</sup> S. D. Sarasvathy

<sup>11</sup> Fayolle & Gailly

drives the business development in his/hers organization<sup>12</sup>. Intrapreneurship then have clear overlaps with employee driven innovation which is more focused on internal processes, but still an employee driven process<sup>13</sup>. In order to determine which personal competencies to emphasize, we looked to innovation researcher Lotte Darsø that defines the innovation competencies as:

The ability to create innovation by navigating together with others under complex situations.

It consists of two types:

- a) **Socio-innovative competencies:** Mastering social interaction that enhances innovation.
- b) **Intra-innovative competencies:** Consciousness & sensitivity in relation to own and others talents, preferences & potential for development and innovation<sup>14</sup>.

With a focus on the students acquiring innovative competencies it became important (as an integrated part of the course) to use time and effort to create a safe learning space where the students can work on building personal relations that will help them cross intercultural barriers and work with challenging each other to create new knowledge in the group<sup>15</sup>. This emphasis is supported by Nonaka a scholar within the knowledge management field, who has studied the process of going from tacit to explicit knowledge. Nonaka argues that the process can be stimulated in a *Originating Ba* where *Ba* means shared space for emerging relationships and *originating* refers to the socialization phase<sup>16</sup>. Furthermore the students should learn the entrepreneurship term effectuation<sup>17</sup> allowing them to act without a clear goal. A main component of this ability is self-efficacy, the belief that you can accomplish successfully what you set out to do, even if you have not tried it before<sup>18</sup>. Bandura argues that in order to develop self-efficacy you need four elements: Mastery experiences, modelling or vicarious experiences, a social persuasion from your surroundings as well as judgment of your own personal state<sup>19</sup>.

In order to train these competencies it was decided to create a four week *preject* phase (a small pre-project before the actual project phase) where focus is on knowledge creation in a divergent phase<sup>20</sup>. In this phase great emphasis was put on creating a learning space through social relations. Knowledge mapping exercises, teambuilding, Jungian Type index, visits at each disciplines home workshops, together with introducing innovation tools such as the business model canvas, scenario planning, design thinking etc. was ingredients to stimulate this. However, in order to also create a bridge between the creative early stages of innovation and the more for engineers familiar prototype-development stages, the Build element of CDIO pedagogical framework<sup>21</sup>, it was decided to leave the remaining nine weeks to the project part.

All Bachelor of Engineering educations at The Technical University of Denmark work with the CDIO framework. Conceiving, Designing, Implementing, and Operating Systems in the Enterprise, Societal and Environmental Context. Conceiving covers opportunity identification to high-level or conceptual design. Designing includes

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<sup>12</sup> Amo

<sup>13</sup> Høytrup

<sup>14</sup> Darsø

<sup>15</sup> Darsø

<sup>16</sup> Nonaka, Reinmoeller, & Senoo

<sup>17</sup> S. Sarasvathy

<sup>18</sup> Bandura

<sup>19</sup> Bandura

<sup>20</sup> Darsø 2012

<sup>21</sup> Crawley & Lucas, 2011

aspects of design process including prototype building. Implementing includes test and verification as well as design and management of the implementation process. Operating covers a wide range of issues from designing and managing operations<sup>22</sup>. It argues an equal emphasis on the building blocks of: Technical Knowledge and Reasoning, Personal and Professional Skills as well as interpersonal skills.

As the frame is set for the inter-university work, the cooperation with the SME's also needs to be formalized. It is discovered that the haunt for IPR, often is seen as the obstacle for open innovation. Having the adequate tools and the right mentality is found to be the true requirements for creating an innovation setting.<sup>23</sup>

### **3 SME COOPERATION – ATTRACTING, INVOLVING AND DELIVERY**

The work with the SME's have been split into 3 chapters where attracting is about the dilemmas found with the recruitment of companies, involving is describing dilemmas in the execution phase, and delivery is about dilemmas found in the triangle between university, student and SME.

#### **3.1 Attracting**

There is generally a big flow of incoming requests of support from SME's to the Technical University of Denmark. The problems they present do not necessarily fit into a standard semester schedule, and some companies wants to have support without spending too much of their own time on the students. The latter prohibiting the fulfilment of the learning goal of learning in an authentic setting. It was therefore recognized that it is necessary to consider how to attract the right SME's to the elective course. Based on former experiences the selected companies where therefore briefed about the expected workload for the students on a 10 ECTS credit course, and what kind of results could be expected.

In order to stimulate the commitment it was agreed to request a sponsorship fee for the service offered. This decision was taken knowing that it potentially would exclude some of the SMEs purely from a financial perspective.

##### **3.1.1 Product ownership**

In the cooperation between universities and companies intellectual property rights (IPR) often present a challenge. What if the students invent something amazing while working on this project? In the development phase of the course two different traditions regarding IPR that split the faculty in half where identified. One belief that can be called the designer approach is that students do the intellectual work and should own all rights and the other that could be called the business approach is that students would not be able to create anything without the context and knowledge of the company so the rights should belong to them. The former arguing for 100 % IPR rights to the student and the latter 100 % IPR rights to the company.

In interviews with representatives from SME's it was learned that one of the largest barriers for collaboration is the idea that "the university steal our IPR". So the dilemma was at the same time provide a reasonable scheme for the students as well as not to scare away the companies; and not least encourage all partners to put in their bests efforts not being afraid to "give away IPR". The pragmatic solution,

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<sup>22</sup> Crawley & Lucas, 2011

<sup>23</sup> Deschamps, Macedo, Eve-Levesque



inspired by the Product Development Project at Aalto University, became to draw upon the national law material stating the rights of an employee. The law sketches out a process where the employee (in this case the student) owns the rights to an invention, but the company owner has the rights to demand these rights against a fair compensation. The University has chosen to create a standard contract including the above mentioned IPR approach as well as a non-disclosure agreement, to ensure a fair agreement for both parties.

### **3.2 Involving**

Apart from the financial part it is also important that the faculty sets the frame for the cooperation as the learning objectives and the goals for the company most likely have some differences. In a learning process a failing prototype isn't necessarily a lousy project, because in an innovation process it is just as important to close doors as opening doors. This means that a great part of all the innovations projects started will be closed, whereas the SME most likely require a working result, as the financial impact on the SME, if failing, can be significant.

As a frame setting part there is in the elective course scheduled in a number of interactions with the company, where the first one covers an expectation adjustment between supervisor, company and students. The prescheduled slots describe the minimum interaction the company should have with the students (it has however been noted that the students in praxis have had more frequent contact). It can be concluded that the expectation adjustment suit as a management tool, but doesn't resolve the paradox between learning objectives and the company goals.

### **3.3 Delivery**

#### ***3.3.1 Company requirements vs. radical innovation***

For the sponsorship fee the company will in the end of the project receive a business presentation, a prototype, and some technical information for the continuation of the project

This however has a build-in potential problem that the pressure to deliver, limits the risk willingness and thereby the potential for creating radical innovation. This is further stimulated by the students drive to create a concrete solution fast, and is therefore a further driver towards incremental innovation. On the other hand it can be a motivating factor that the students will have a prototype to present to a real company, and it also emulate the time pressure in a real setting.

#### ***3.3.2 Student obligation vs. University image***

Another issue found is that the relation to the company is essential, not only for the students, but also for the supervisor, and finally the reputation of the university. The students are not legally obligated to stay on the course, which means that students can drop out impacting the expectation from the company.

Even though there is not given any promises for results, it is found that the pressure for a successful collaboration is transferred to the University/supervisors rather than to the single student groups.

Based on experiences, the enrolment requirements for the students to the course is currently being changed, and for planning of mandatory courses it would be essential to have a system set in place to handle dropouts.

#### 4 EVALUATION/ASSESSMENT

Results of the first run of the course shows that the students has identified that the interdisciplinary cooperation adds value to their innovation and broaden their view on engineering. As the projects have not been concluded we are not able to say anything about the innovation height of the projects. However In micro-sized companies the interdisciplinary teams might close gaps in competences, and as a natural effect, add benefit to the SME.<sup>24,25</sup>

To give the students arguments in relation to the company and allow them to act as intrapreneurs, it has been identified that it is necessary to force them to use the lectured innovations tools. By doing that they are able to give the company a more structured and organized feedback. The elective will as a result next time require hand in assignments in the beginning of the course.

The course is vulnerable due to the company collaboration and the reputation at stake. The students' sense of obligation is therefore extremely important. The elective will as a result on next semester be more focused on that matter in the recruitment and be more firm towards student that do not perform. The SME will receive an invoice on the agreed sponsorship fee after the preface, when the supervisor is confident that the students are committed.

The companies have shown a great flexibility. They have seamlessly adapted the tasks to fit the students' motivation and interests. They have shown a high level of ability to use these interests creating new opportunities for the students and the organisation. With this approach showing a high level of improvisation or in other words the ability to act effectually<sup>26</sup>

#### 5 CONCLUSION AND RECOMMENDATIONS

The first round of the elective course has brought valuable learning for the future rounds. Early indications show that is possible to engage with SME's without jeopardizing the learning outcome by creating a structure that manages the expectations in the three phases of attracting, involving and delivering.

Highlight learnings are:

**Be aware of time to market deadline for the companies** → It has been possible to recruit companies with the given frame (the cost, the engagement, the focus on learning outcome). Getting closer to the delivery deadline it has however been evident that the company deadline in terms of time to market has higher priority than the learning outcome. For that reason the company's time to market urgency (for future elective courses) has been specified to be at least 1 year to reduce the pressure on the students and allow innovation.

**Charging a sponsorship fee – raises the commitment from company and University** → Unlike anticipated, charging a small amount has not become an issue when recruiting the companies. Rather, or maybe as a result of this, they have been very engaged in the process and provided all the knowledge the students have asked for in a timely manner. If the fee can and should be greater could be discussed.

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<sup>24</sup> Henneke, D., & Lüthje, C.

<sup>25</sup> Justesen, S.L

<sup>26</sup> Sarasvathy, S. D.

It is still emphasized that the students should lead the innovation and the supervisor should act as supervisor only. Initiatives around recruiting and invoicing are taken to make that strategy viable.

**Interdisciplinarity adds value to the students** → Though theoretically supported, we have not yet been able to conclude that Interdisciplinarity is a benefit for the SME, but as a positive side effect the students has found the diversity extremely motivating. Seen from a CDIO syllabus point of view, it is found reasonable to introduce interdisciplinary work on 5<sup>th</sup> semester, and by that preparing the students for their future responsibilities.

## REFERENCES

- [1] King, J. E. (chair). (2007). *Educating Engineers for the 21st Century*. London: The Royal Academy of Engineering.
- [2] Liebenberg, L., & Mathews, E. H. (2010). Integrating innovation skills in an introductory engineering design-build course. *International Journal of Technology and Design Education*, 22(1), 93–113.
- [3] Crawley, E. F., Malmqvist, J., Östlund, S., & Brodeur, D. R. (2007). *Rethinking Engineering Education: The CDIO Approach* (p. 286). Springer
- [4] Biggs, J., & Tang, C. (2011). *Teaching for quality learning at university*. New York: McGraw-Hill.
- [5] European Commission. (2013). *SBA Fact Sheet 2013*.
- [6] Darabi, F., & Clark, M. (2012). Developing business school/SMEs collaboration: the role of trust. *International Journal of Entrepreneurial Behaviour & Research*, 18(4), 477–493.
- [7] Christiansen, N. M., Ulrich, M.-M., & Pontoppidan, M. L. (2013). 62063 Course description SME Innovation and Intrapreneurship. Retrieved from <http://www.kurser.dtu.dk/62063.aspx?menulanguage=en-GB>
- [8] Kirketerp, A. L. (2010). Pædagogik og didaktik i entreprenørskabsundervisningen i de videregående uddannelser i et foretagsomhedsperspektiv. Syddansk Universitet
- [9] Read, S., Sarasvathy, S. D., Dew, N., Wiltbank, R., & Ohlsson, A. (2011). *Effectual Entrepreneurship*. *Journal of General Management* (Vol. 36). Routledge.
- [10] Sarasvathy, S. D. (2001). Causation and effectuation toward a theoretical shift from economic inevitability to entrepreneurial contingency.. *Academy of Management Review*.
- [11] Fayolle, A., & Gailly, B. (2008). From craft to science: Teaching models and learning processes in entrepreneurship education. *Journal of European Industrial Training*, 32(7), 569–593.
- [12] Amo, B. (2010). Corporate entrepreneurship and intrapreneurship related to innovation behaviour among employees. *International Journal of Entrepreneurial Venturing*.
- [13] Høyrup, S. (2012). Employee-Driven Innovation: A phenomenon, concept and mode of Innovation. In *Employee-Driven Innovation*.
- [14] Darsø, L. (2012). Innovation Competency - An Essential Organizational Asset. In S.



- [15] Høyrup, M. Bonnafous-Boucher, C. Hasse, M. Lotz, & K. Møller (Eds.), Employee-Driven Innovation. Palgrave.
- [16] Nonaka, I., Reinmoeller, P., & Senoo, D. A. I. (1998). The “ ART ” of Knowledge : Systems to Capitalize on Market Knowledge, 16(6), 673–684.
- [17] Sarasvathy, S. (2010). What Makes Entrepreneurs Entrepreneurial?, 1–9. HBR Case
- [18] Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191–215.
- [19] Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191–215.
- [20] Høyrup, M. Bonnafous-Boucher, C. Hasse, M. Lotz, & K. Møller (Eds.), Employee-Driven Innovation. Palgrave.
- [21] Crawley, E. F., & Lucas, W. A. (2011). The CDIO Syllabus v2 . 0 An Updated Statement of Goals for Engineering Education. *Engineering Education*, 24, 1–4
- [22] Crawley, E. F., & Lucas, W. A. (2011). The CDIO Syllabus v2 . 0 An Updated Statement of Goals for Engineering Education. *Engineering Education*, 24, 1–4
- [23] Deschamps, I, Macedo, M, G, Eve-Levesque, C, (March 2013), University-SME Collaboration and Open Innovation: Intellectual-Property Management Tools and the Roles of Intermediaries, *Technology Innovation Management Review*
- [24] Henneke, D., & Lüthje, C. (2007). Interdisciplinary heterogeneity as a catalyst for product innovativeness of entrepreneurial teams. *Creativity and Innovation Management*, 16, 121–132.
- [25] Justesen, S. L. (2007). Navigating the paradoxes of diversity in innovation practice: A longitudinal study of six very different innovation processes. In practice. Copenhagen Business School.
- [26] Sarasvathy, S. D. (2008). *Effectuation: Elements of Entrepreneurial Expertise*. Sciences New York, 2010, 1–23.