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# Fostering Automatic Control Students to Become Innovators

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**Abstract**: Today, innovation is a key word for many universities, as it constitutes an important part of most universities' public and scientific outreach task. Many universities are striving to increase the number of innovations generated at the university. A common method is to provide various support for research projects e.g.; providing researchers with information about international patent rights (IPR), offering administrative or financial help concerning patent applications, giving entrepreneurship and start-up support, etc. However, fostering innovators and entrepreneurs can start already in undergraduate/graduate courses, i.e. long before a student potentially reaches the research level. We believe that key factors for success in this matter are diversity and freedom. A course that strives to promote innovation capability must allow for students with different backgrounds and different curricula to meet and work together, and must allow for students to freely use their current knowledge within new contexts. This is generally not a setting provided in traditional undergraduate/graduate courses. This article describes the execution and outcome of an graduate course "international Market-Driven Engineering (iMDE)" in which diversity and freedom are key factors. The course is international and multi-disciplinary in terms of students, teachers and subjects. Graduate students with prior knowledge in automatic control constitute one important part of the course population. We believe that the diversity amongst the students, and their freedom when it comes to both innovation process and product, provides a promising platform in which seeds of ideas can grow into conceptual prototypes that build a solid foundation for full-scale innovations. On of the iMDE-projects, the Elderly Accessible Chair, or EA Chair, with its automated scanning and automatic seat-provider functionality, is one concrete example of this.

## 1. INTRODUCTION

The overall goal for most universities is presented as a set of three activities; education, research and outreach. Generating innovations is considered part of the outreach activities, and a high number of innovations generate a favorable reputation. At most universities, innovations are sprung from research projects and generated by researchers. However, innovations could also be based on new insights or market-discoveries, identified and explored by under-graduate or graduate students. Two key factors for this to happen are diversity and freedom. Undergraduate or graduate courses that allow for a large diversity amongst students and that allow students to freely synthesize on their current knowledge are rare. By allowing students in e.g. automatic control to meet with other engineering students and/or business students, and by allowing students in automatic control to apply their knowledge to current market needs, innovators could be fostered and new innovations generated.

This paper describes a new international and cross-disciplinary course that was developed in spring 2012 and held for the first time in fall 2012. The course is six (6) weeks long and held at Zhejiang University in China. The outcome of the course was 8 innovations manifested in terms of eight prototypes. One of the groups is currently applying for a patent in China.

The first section of this paper discusses innovations sprung from universities, and how these are generated. The next section presents various aspects of teaching and learning. The following three sections present the background, the aim and the outcome of the first iMDE course. The next to last section presents one of the innovations generated within the iMDE course, the EA chair. The EA-chair (Elderly Accessible Chair) is a chair only accessible for elderly people and it uses automatic control for access-control of the seat. The final section contains a discussion and a conclusion.

## 2. INNOVATIONS

The three key activities for most universities are; education, research and outreach. The education activity includes taking responsibility for programs and courses provided to undergraduate or graduate students, and the research activity includes providing support for PhD students, post docs and senior research personnel. The outreach activity is an umbrella term for promoting public awareness of science and making contributions to society (Wikipedia (2013a). During the last years, universities have put increased importance in supporting and promoting innovations. Today, some universities even have special hubs where researchers can get help transforming their research results to innovations, possibly resulting in new companies and products (LUIS (2013), Lund University). The hub could also e.g., help providing researchers with information about international patent rights (IPR), giving administrative or financial help concerning patent-applications, offering entrepreneurial and start-up support, etc. The innovations coming out from the universities are most often based on research results and generated by research personnel.

The term innovation can be defined as “the application of better solutions that meet requirements or needs” (Wikipedia (2013b)). Innovations could of course be sprung out of research, but could equally well be based on new insights or market-discoveries. The latter type of innovations could be generated by undergraduate or graduate students as well as by senior researchers. A key factor for successfully generating these types of innovations is diversity; a course that strives to encourage innovations must allow for students with different backgrounds and different curricula to meet and work together. “People who have the same background, skills, or location have little to exchange with each other. For this reason, diversity of the network is a critical ingredient for successful entrepreneurship (Sidhu (2013))”. Diversity is generally not found in traditional undergraduate/graduate courses, in which only students with the same curricular background are taught together. In addition, in most undergraduate/graduate courses the objective is to provide the students with, for them, new and more advanced knowledge, rather than apply and leverage/synthesize on the knowledge they already have.

Three important steps, working with innovations, are inspiration, ideation, and implementation (Brown and Katz (2009)). Automatic control is often a required knowledge in the implementation step since many technical solutions uses embedded systems and/or automation. Including control engineers in innovation courses is therefore advantageous.

## 2. TEACHING AND LEARNING

Generally speaking, teaching is interpreted as the act of helping someone to learn. In recent years, the discussions about teaching has shifted from “how to present and transfer knowledge from a teacher to someone else” to “how information and knowledge provided is perceived by the receiver”, i.e. from a teacher-student-transfer focus in which the subject is only the transported goods, to the student-subject-relation focus in which the teacher is only the medium used. This shift is illustrated in the didactic triangle in Figure 1.

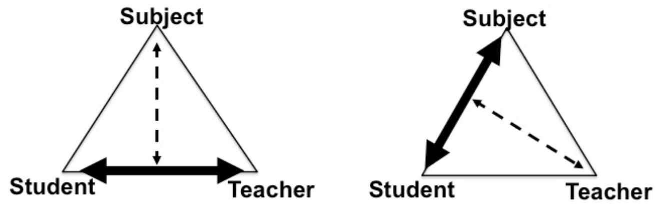


Figure 1: An interpretation of the Didactic Triangle showing a shift from the teacher-student-transfer focus (left) to the student-subject-relation focus (right).

The shift could also be illustrated in a teaching-style-dimensions diagram (Fox, 1983), see Figure 2. The “Transfer theory” placed in the upper-left corner is similar to the teacher-student-transfer focus whereas the “Growing theory” placed in the lower-right corner corresponds to the student-subject-relation-focus. Growing theory approach is more common to be used by teachers with more experience (Kugel (1993)). Growing theory approach is also preferred for students that are matured, which usually is the case in higher education.

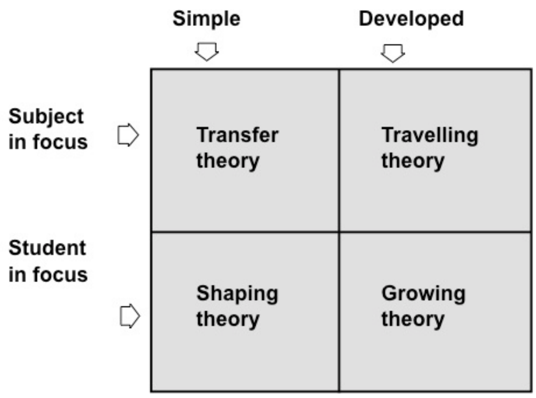


Figure 2: Teaching style dimensions diagram.

Five common but different perspectives of learning are (Säljö, 1979):

1. Learning as a quantitative increase in knowledge. Learning is acquiring information or ‘knowing a lot’.
2. Learning as memorising. Learning is storing information that can be reproduced.
3. Learning as acquiring facts, skills, and methods that can be retained and used as necessary.
4. Learning as making sense or abstracting meaning. Learning involves relating parts of the subject matter to each other and to the real world. Learning as interpreting and understanding reality in a different way.
5. Learning involves comprehending the world by reinterpreting knowledge.

In higher education, all five perspectives should be covered. The lower ones are preferably covered in the basic courses where base knowledge is taught, and the higher ones should preferably be covered in the more advanced courses as well as in professional life.

Learning situations, such as laboratories and/or projects could be set up in three different ways depending which of the five learning perspective that should be challenged. The learning situations also depend on how much of the expected result that is known a priori to students (learners) and/or teachers (Ahlberg et al (2010)), see Figure 3. The most challenging learning situation is visualized by the lower row.

| | Problem | Method | Result |
|---|---|---|---|
| Known to students and academics? | | | |
| Unknown to students, known to academics? | | | |
| Unknown to students and academics? | | | |

Figure 3: Three setups for laboratory learning situations.

## 3. iMDE, BACKGROUND AND AIM

### *3.1 Background*

The idea of setting up a joint course between Lund University and Zhejiang University was born in the fall of 2011. The subject for the course was decided to be “Innovations and Product Development”, being key words for both LU and ZJU. The pedagogical intention was to support the students learning in “relating parts of the subject matter to each other and to the real world” and “comprehending the world by reinterpreting knowledge”. The course was titled “international Market-Driven Engineering (iMDE)”.

The two universities already had agreements and activities regarding collaborations that the course could leverage upon. One such example is the Joint Centre for Innovation and Entrepreneurship (LU-ZJU JCIE), which is a platform that aims to help realize joint activities related to innovation and entrepreneurship. iMDE is a joint course, developed within the framework of LU-ZJU JCIE. The seed idea for the course was born in fall 2011, and the work of outlining the course and its content was intensified in the spring of 2012.

Diversity was one key factor, and the idea of having students with varying disciplinary background was therefore agreed. As a consequence, various disciplines at both LU and ZJU were also involved in the development of the course:

- LUSEM: School of Economics and Management, Lund University, Swede
- LTH: Faculty of Engineering, Lund University, Sweden
- SoM: School of Management, Zhejiang University, China
- ID and CSE: Engineering, Industrial Design (ID) and Department of Control Science and Engineering (CSE), Zhejiang University, China

Freedom was another key factor, and the idea of letting students work with each other in groups and freely synthesize on their current knowledge was therefore included in the course curriculum through a project.

The Swedish students, coming from LUSEM and LTH are already cooperating though the 2-year master program refered to as Technology Management (Johnsson and Nilsson (2008)) and (TM 2013). The Chinese students have not previously worked together.

### *3.1 Aim*

The iMDE-course should intertwine the two disciplines Technology and Management, in Sweden and in China, in four ways; Students, Teachers, Subjects and Cultures.

- Subject: the focus in the joint course is on Innovation and Product Development, a subject that is of great relevance from both technical aspects as well as economical and management aspects. The course contains lectures, field trips, and a project. The final examination is an oral presentation, a written report and a 3-minute film.
- Students: The course should be given to the 40 Swedish students from the Technology Management (20 from LUSEM and 20 from LTH) together with approximately 40 Chinese students (20 from SoM and 20 from the technical departments (ID and CSE).
- Teachers: Teachers from both Sweden and China and from both Engineering (LTH, ID and CSE) and Management (LUSEM and SoM) are involved in the lectures. A minimum of two teachers with different aspects of the subject are present at each lecture.
- Cultures: The cultural aspects of innovations, product development as well as project management and business behavior are covered in the course and practised in real life through the project.

The aim of the course is defined as follows:

*“The world is becoming more international and cutting edge knowledge in marketing as well as engineering in a global world is becoming a valuable asset on the job-market. There is a lack of people with skills in both fields with the ability to connect market needs and innovations with product development, especially in an international context. International Market Driving Engineering (iMDE) is aimed at providing these knowledge and skills.”*

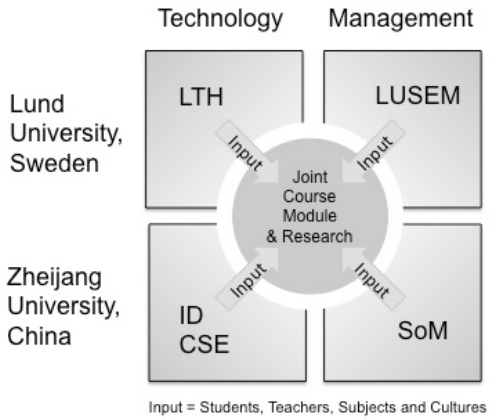


Figure 4: The collaboration model of iMDE.

The eight innovations are:

- Group 1; Naptop – sleep comfortably in public places on top of your laptop
- Group 2; Beddy Teddy – a teddybear for children connected to the parents' cellphone
- Group 3; iLock – maintain control of your computer while taking small breaks
- Group 4; SoLED Lights – a safety product for e-scooters
- Group 5; EAchair – elderly accessible (EA) chairs for public places
- Group 6; Onewake – waking the user up in a quiet way
- Group 7; EasySpace – everyday life recycling made easy
- Group 8; PoPo – a photo receiving phone making interaction with family members easy for elder people

## 4. iMDE – Outcome

The set of lectures provided the students with new knowledge and information regarding e.g. innovations and product development. The innovation process was described through the three stages (Brown and Katz (2009)); inspiration (e.g. looking for market needs), ideation (i.e. coming up with ideas solving the market need) and implementation (i.e. ways to implement and make prototypes of the idea). The innovation process was also covered from the aspects; desirability (market need etc), feasibility (product development), viability (business plan etc). In addition to the new knowledge obtained through the lectures, the students were supposed to combine and build on their own prior knowledge in their respective domains e.g. financial, management, automatic control, design etc.

The groups were divided into eight (8) teams, each one having members from both countries and all disciplines. In total there were about 8-10 members in each group (Nilsson et al (2012)). Some lectures were used to discuss cultural differences in innovation climates, project leadership and management. At the end of the course each group had six (6) deliverables, see table 1 below.

| | Deliverables.<br>At the end of the course, each group: |
|---|---|
| 1 | had developed a prototype manifesting their innovation. |
| 2 | could describe their potential customers and argue why the innovation was needed. |
| 3 | could present how the prototype should be built technically. |
| 4 | should understand the potential financial and market situation of their prototype. |
| 5 | had written a report presenting the innovation, including an executive summary in Swedish, Chinese and English. |
| 6 | had produced a short (3 minutes) film demonstrating the group's work process and their innovation. |

Table 1: Deliverables at the end of the iMDE-course.

## 5. iMDE – and Automatic Control

Automatic control systems are pervasive in today's society. They appear practically everywhere; in our homes, in industry, in communication systems, in all types of vehicles and in scientific instruments. Control systems are increasingly becoming mission critical, a failure in the control system will thus lead to a system failure. In spite of this, automatic control is not talked about very much. It is therefore appropriate to label the technology "the hidden technology". (Åström (1999)).

Automatic control emerged in the mid 1940$^{th}$ and is today about 60 years old. One of the earliest applications is known to be the centrifugal governor (Mayr (1969)), other early industrial applications include steam power, wind mills and textile mills. Automatic control was soon recognized as a very powerful technique that could be applied to many problems in diverse fields. Automatic control quickly received world-wide acceptance in industry and academia. Control groups were created in many companies, and new industrial enterprises specializing in control were established. Courses in the field were introduced at practically all engineering schools and a large number of textbooks were written (Åström (1999)).

Today most universities have courses in control, both basic control courses in which e.g. the core principles of feedback is explained, and more advanced courses such as non-linear control, adaptive systems, predictive control etc. Most of the courses are focusing on providing the students with, for them, new knowledge. There are also project courses in which the students can work on control problems associated with a practical device. However, most project courses only focus on the control problem itself versus on the whole application in which the control system constitutes only one (however, important) part. Traditionally, these courses only involve control engineering students. It is argued that it would be advantageous for the society to educate students who are capable of solving the whole problem, from conceptual design, to implementation and commissioning (Åström (1999)). This argument could be extended to include, not only the whole control problem, but also an holistic view of the complete system/product that the control system is part of. For this purpose, control engineering students would benefit from co-operation with students from other disciplines in some of their courses.

The iMDE course has its focus on innovations and product development. Due to the nature of automatic control constituting an important part of most today's applications and products, (hidden technology), it is considered advantageous to include control engineering students in the iMDE course.

## 6. EA Chair

The Elderly Accessible Chair, or EA Chair, is one example of a prototype that was developed by one of the eight groups in the iMDE course, fall 2012. The EA Chair is a chair aimed for elder people at public bus stops. The EA Chair comes with access-control functionality of the chair's seat so that only people with senior citizen bus cards, can access the seats. Control is used for the scanning of the senior citizen bus cards and for locking/unlocking of the seat itself. An animated picture of the EA Chair is shown in Figure 5 (right part of the figure).


Figure 5: EA Chair.

The diversity in the student groups assured that a broad set of knowledge was covered within the groups; automatic control, design, management, finance, etc. The students with a background in automatic control were responsible for designing the control system of the EA chair, see figure 6.

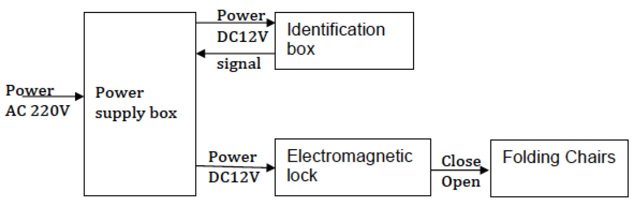


Figure 6: The control system of the EA chair.

The control system included an automatic scanning of the senior citizen's bus card and automatic seating-control. The control system of the EA chair was designed by three components;

- Identification box
- Power supply box, which contains a control chip
- Electromagnetic lock

The EA-chair's seat is shown in more detail in Figure 7. The scanning of the senior citizen's buscard is taken care of by the "armrest-like device" shown on the right side of the chair. The scanning device sends back a signal indicating if the card, that should be placed next to the scanning device, is a senior's bus card or not. If the signal is positive, the electromagnetic lock is given power and the chair is unfolded.

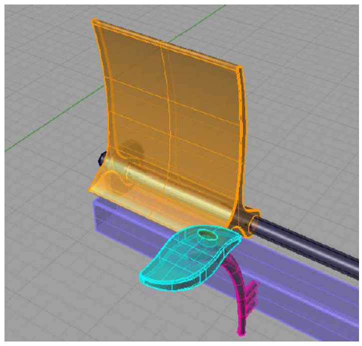

Figure 7: A detailed figure of the EA Chair.

The deliverables, compare table 1, from the EA Chair group are:

1) The EA Chair was developed using a CAD program. In addition a physical prototype was made from a simple wooden chair bought at IKEA and basic electric components.
2) Through brainstorming sessions, user studies and market observations, the group found out that the lack of available seats at public bus stops was an obstacle for many senior citizens. The public seats are often occupied or non-functional.
3) An electrical drawing of the scanning and automatic access functionality was included in the report.
4) The development of the product will need an investment of 1 million RMB. The best business model is considered to be a licensing model. If each chair is licensed for 500 RMB, the break even point was estimated to be reached within approx. 24 months.
5) Executive summary is found in Table 2 below. The executive summary is also available in Swedish and in Chinese.
6) The film, which is 3 minutes and 8 seconds, is available in m4v and mov-format and can be sent upon request to the authors.

The EA Chair has applied for a patent in China.

| Executive Summary EA Chair |
| --- |
| “In finding a need and thereafter translate it to a product that is viable on the market, this project aims to help the everyday life of elderly people. The challenges that are discussed in this report refer to the product development process on the one hand and the group process on the other.<br><br>The project is limited to the Chinese market. This scope is the basis for our observations and surveys that were conducted with elderly people in different situations. The approaches used for the ideation process are needfinding, brainwriting and a scoring. From a desirability perspective, we found that elderly are in need of a rest at bus stops, where it is difficult to find a free seat.<br><br>The product development process includes design and engineering, which resulted in a prototype. From a feasibility perspective, a chair with an attached control system to allow the elderly access to a chair with their senior citizens card was developed.<br><br>To make the prototype viable on the market, a business plan was produced. The business model is based on a tight partnership with bus stop manufacturers who will pay a license fee to produce our patented chair and even get the opportunity to achieve an exclusive deal. In this way, we will help our customer and partner to increase sales by being more competitive and simultaneously helping everyday life for the elderly people.<br><br>To conclude, the prototype together with the business plan enables the elderly to rest at bus stops and hence the identified need is solved.” |

Table 2: Executive Summary (also available in Swedish and Chinese) for the EA Chair.

## 8. Conclusion

Innovation is a key word for many universities, as it constitutes an important part of most universities’ public and scientific outreach task. Fostering innovators and entrepreneurs can start already in undergraduate and graduate courses. For this to take place, our experience is that the courses should include the two key factors diversity and freedom.

The course iMDE was designed to take these two key factors into account. The course was developed in spring 2012 and run for the first time in fall 2012. The outcome was eight innovations manifested as eight prototypes, whereby one is applying for a patent.

Swedish and Chinese students were working together; their background was either engineering or management and economics. This mix of students supports the diversity.

The students were working in groups of 8-10 students with a project. The groups could freely choose what to do in the project as long as it related to the theme “Helping every-day life”. The idea was to leverage on the knowledge the students already had, and complementing this with new knowledge about the innovation process. This course curriculum supports the students’ freedom related to the innovation.

The students with a background in automatic control constituted an important part of the course since control is included in many of today’s products. By letting the control students work both multi-disciplinary and internationally, with a project related to “Helping everyday life”, the iMDE course is “promoting automatic control for the benefit of humankind” (Ifac 2014).

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