ETALEE2018

IngeniørUddannelsernes
Pædagogiske Netværk

Exploring Teaching for Active Learning in Engineering Education

Aarhus University School of Engineering, November 29-30 2018

Book of Abstracts

DTU Technical University of Denmark

AALBORG UNIVERSITY DENMARK

SDU

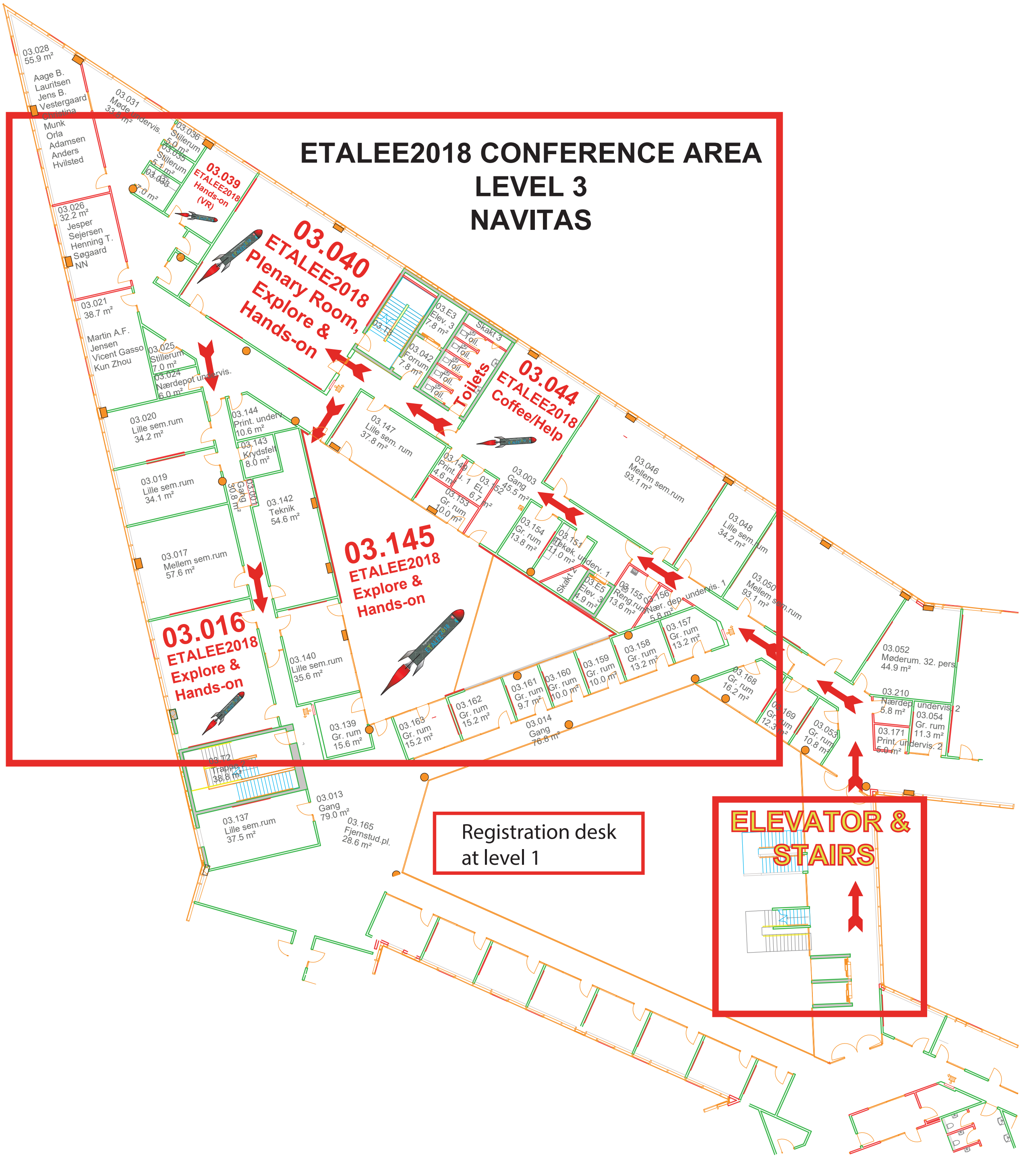
VIA University College

AARHUS UNIVERSITY SCHOOL OF ENGINEERING

Programme - ETALEE 2018

Thursday - 29 November 2018	
08.30 - 10.00	Registration - coffee and tea
10.00 - 10.15	WELCOME - room 03.040
10.15 - 10.45	Keynote - Olin College of Engineering - room 03.040
10.45 - 11.00	Coffee and tea
11.00 - 12.00	Workshops in groups - part 1 - room 03.040 (03.145)
12.00 - 13.00	Lunch - ”Kantinen” on level 1
13.00 - 13.55	Workshops in groups - part 2 - room 03.040 (03.145)
13.55 - 14.05	Short break
14.05 - 15.00	Workshops in groups - part 3 - room 03.040 (03.145)
15.00 - 15.45	Preparation of poster in groups with outcome from Workshops
15.45 - 16.00	Coffee and tea
16.00 - 17.30	Explore sessions - room 03.040, 03.016 & 03.145
19.00	Conference dinner at ”Centralværkstedet”

Friday - 30 November 2018	
09.00 - 09.45	Presentation of Posters from workshop
09.45- 10.10	Meeting in working groups for conclusions
10.10 - 10.30	Coffee and tea
10.30 - 12.00	Hands-on sessions - room 03.040, 03.016, 03.039 & 03.145
12.00 - 12.30	Ending session and good bye
12.30	Sandwich To Go



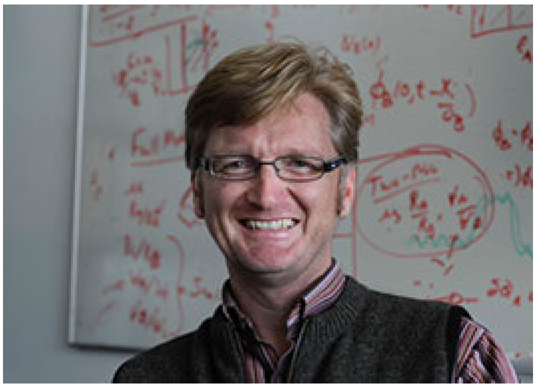
”eduroam”
or
”AU-Guest ” - just follow instructions on website

Table of content

	Page
Keynote - Olin College of Engineering	5
Explore: Instilling an -I can do it--attitude towards practical prototyping	7
Explore: How can assessment of reflective writing be carried out	10
Explore: Collaboration between two innovation courses enhances students understanding of organisational context	13
Explore: Collaboration between two innovation courses enhances students understanding of organisational context	13
Explore: Engineering Methodology Revisited	26
Explore: International Student Projects - How to make it happen	29
Explore: The Ultimate Challenge for Active Learning Design	40
Hands-on: Pursuing the good case for innovation learning	47
Hands-on: How to conceive the right problem - A method to reframe problems	50
Hands-on: Using virtual reality technology as an educational tool	53
Explore: Teaching Sustainable Systems design	55

Keynote: Olin College of Engineering - ”World leading strategies for teaching engineers – What and how”?

Thursday 10.15 - 10.45



John B. Geddes, Professor, Olin College of Engineering

Dr. Geddes is professor of applied mathematics at Olin College of Engineering. Since 2003 he has been fully engaged in building and sustaining this new engineering school. He has focused his attention on transforming education for engineers by developing project-driven, integrated learning environments for students. He is also dedicated to the development and mentorship of faculty at Olin and elsewhere. He is currently co-leading an effort to explore how Olin can help to shape the future of education.

Siddhartan Govindasamy, Associate Professor Olin College of Engineering.

Dr. Govindasamy has been with Olin College since 2008, where teaches a number of courses, including interdisciplinary courses spanning mathematics, mechanical, and electrical engineering. His interests include designing and developing student-centered, interdisciplinary learning experiences at Olin. With Dr. John Geddes and other colleagues, Dr. Govindasamy is currently working on a redesign of the early-stage engineering experience at Olin. He has also worked with a number of institutions internationally to redesign their engineering programs.

Abstracts/Papers
Explore Sessions
Thursday 16.00 - 17.30

	Explore session 1 Room 03.040	Explore session 2 Room 03.145	Explore session 3 Room 03.016
Thursday 16.00-17.30	**1) Instilling an -I can do it- attitude towards practical prototyping** **2) How can assessment of refective writing be carried out.**	**1) Collaboration between two innovation courses enhances students understanding of organisational context** **2) Engineering Methodology Revisited**	**IUPN networking group for Internationalisesation:** **Part 1 16:00-17:00** **International Student Projects - How to make it happen** **Part 2 17:00-17:30** **The Ultimate Challenge for Active Learning Design (Mathematics in Engineering)**
Author(s)	1) Emil B. Kromann, DTU 2) Kirsen From, DTU	1) Liv Gish, DTU Villads Keiding, DTU 2) Stefen K. Johansen, SDU	Part 1: Jens Myrup Pedersen, AAU Jacob Vejlin Jensen,AAU Part 2: Per Skafte Hansen, DTU
Chair	Ulrik Jørgensen, AAU	Mona Dahms, AAU	Aage B. Lauritsen, AU

Instilling an *"I can do it"*-attitude towards practical prototyping

Emil B. Kromann
Technical University of Denmark (DTU)
Dept. of Electrical Engineering, Denmark, EBKRO@dtu.dk

ABSTRACT

Keywords: *Prototyping, Bachelor curriculum, Mindset (as a learning objective)*
Type of contribution: *Explore session*

A recent survey predicts the following skills to become increasingly important for the Danish industry ([1] Danish Ministry of Higher Education and Science, 2018):

- The ability to collaborate (also across disciplines)
- The ability to develop new processes and products
- A general understanding of technology
- The ability to acquire new knowledge when needed

These findings underscore the existing notion that our economy hinges on the successful education of *collaborative problem solvers* and *tech-innovative thinkers*. Answering this educational need, DTU's innovation incubator (Skylab) features excellent prototyping workshops with skilled and welcoming staff – i.e. the ideal environment for our engineering students to team up and pursue their own innovative ideas, tackling acute technological problem solving in the process. I will present the new bachelor-level course *Biomedical Prototyping*, which harnesses Skylab as a learning environment to help students *see and seize* the plethora of creative possibilities at the interface of technologies ranging from *biology* and *optics* through *microcontroller programming* to *welding*. By instilling an "*I can do it*"-attitude, or, a *growth mindset* ([2] Dweck, 2008), the course aims to inspire students to pursue their own ideas, at their own initiative during their studies – thus, strengthening their qualifications and fitness to shape the future job market.

Figure 1. [DTU-Skylab, November 2017]. Thirty BSc-students have assembled their five separate prototypes into a single functioning unit: A confocal laser-scanning microscope.

Biomedical Prototyping is a 5-ECTS course, challenging its 30 participants with the collaborative construction of a high-tech instrument (a confocal laser-scanning microscope). Based on the participants' individual interests, they are split into five teams, each responsible for designing and building a specific part of the microscope. For example, one team may be asked to produce a fluorescent biological sample and a computer-controlled mechanism for positioning the sample appropriately relative to the microscope objective. As shown in **Figure 1**, the five teams assemble their products into a single (hopefully) functioning unit at the end of the course.

While this project/problem-based learning experience lets the participants hone their abilities to acquire new knowledge when needed ([3] de Graaff & Kolmos, 2003), I highlight three additional pedagogical elements, which are central to the course and its alignment with current needs for skill development: **(1)** The course eliminates competition and encourages *interdisciplinary collaboration* between participants, by giving each team a different challenge and a

clear motivation to communicate between teams. If the teams do not communicate, their five separate prototypes will not assemble into a functioning instrument ([4] Handelsman *et al.*, 2007). **(2)** The course encourages *creativity/risk taking* by basing assessment on each participant's grasp of the *prototyping process* rather than the quality of his/her *prototype-product.* Thus, allowing participants to experiment with new approaches *and* making the course inclusive of participants with limited hands-on experience. **(3)** At the end of each 4-hour course session, each team presents their concrete experiences in plenum. This knowledge-sharing and the ensuing feedback/reflection can give the participants a basis for improving their prototypes in the following session, setting in motion a series of engineering design cycles or (in a learning context) *experiential learning cycles* ([5] Kolb & Kolb, 2017): try → fail → learn → try again.

In an exam-situation, it is not straightforward to assess whether a participant's mindset has become better geared to "pursue his/her own ideas in practice". Thus, *constructive alignment* between this intended learning outcome and assessment is difficult to establish ([6] Biggs & Tang, 2011). Constructive alignment is sought with exam-questions like "what does this specific component of the microscope do and how could we improve its implementation?". An engaged participant will be able to *explain*/*evaluate* the prototype component and *synthesize* a *practical plan* for improving it. While this declarative and functional knowledge only allows to gauge a participant's *ability* to engage in practical prototyping, it does not reveal his/her attitude towards engaging. As outlined in **Figure 2**, course evaluations indicated profound learning outcomes. In this encouraging light, I now plan a deeper investigation of what, exactly, the participants are learning and how they fare with self-motivated practical projects in the future. Additionally, I will investigate the potential prospects of implementing a series of sister-courses at DTU, allowing to mix students from different engineering specializations between the courses.

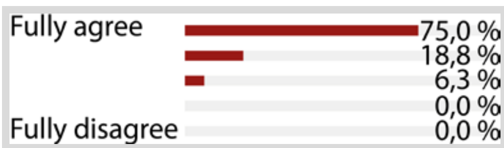


Figure 2. [2017, course evaluation] Responses to the statement *"I learn a lot in this course"*. 16 respondents.

At ETALEE 2018, I will kindle a discussion by posing a (maybe controversial) statement and a question: *Practical prototyping represents a highway towards developing a future-proof engineering mindset. Yet, too often, practical prototyping is hidden away in master-level courses and/or in not-for-credits extracurricular activities, which appeal more to students with an intrinsic "I can do it"-attitude than to students who need to develop that attitude. Why is practical prototyping not mandatory in the bachelor-level engineering curriculum?* I am excited to learn how the audience reacts to this statement. Likewise, I am excited to discuss other initiatives, which have used practical project-based prototyping at an early stage in the engineering curriculum.

[1] Uddannelses- og Forskningsministeriet (Udvalg om bedre universitetsuddannelser), *Universitetsuddannelser til fremtiden, Ref. 7.5.3 Virksomheders vurdering af fremtidigt kompetencebehov (pp. 199-200)* [Eng: Danish Ministry of Higher Education and Science, *University educations for the future, Ref. Chapter 7.5.3*], ISBN: 9788792572844 **(2018)**

[2] S.C. Dweck, *Mindset and math/science achievement*, Prepared for the Carnegie Corp. of New York-Institute for Advanced Study Commission on Mathematics and Science Education **(2008)**

[3] E. de Graaff & A. Kolmos, *Characteristics of problem-based learning,* International Journal of Engineering Education, Vol. 19, No. 5, pp. 657-662 **(2003)**

[4] J. Handelsman, S. Miller, C. Pfund, *Scientific teaching, Ref. The power of group learning (pp. 28-29)*. ISBN: 978-1429201889 **(2007)**

[5] A.Y. Kolb & D.A. Kolb, *Experiential learning theory as a guide for experiential educators in higher education,* ELTHE: A Journal for Engaged Educators, Vol. 1., No. 1, pp. 7–44 **(2017)**

[6] J.B. Biggs & C. Tang, *Teaching for quality learning at university (4th edition), Ref. 6. Constructively aligned teaching and assessment (pp. 95-110)*, ISBN: 9780335242757 **(2011)**

Assessing team skills: How can assessment of reflective writing be carried out effectively and relatively quickly?

K. From, DTU, Denmark, kifr@dtu.dk

ABSTRACT

Keywords – team skills, teamwork, reflection, assessment

Please indicate clearly the type of contribution you are submitting: ___ hands-on, _X_explore.

Teamwork has become a common way for teachers to ensure active participation in class. There is good evidence that this type of activation improves learning (Prince, 2004). At the same time team skills are important in the workplace. Engineers are expected to be able to work in teams. So in more than one way it makes good sense that students work in teams. But how can we ensure that our students become good team workers? And how can we assess them? These question will headline this explore session.

Dublin Institute of Technology (DIT) have implemented a very impressive framework for the development of team skills (along with other non-technical skills) (Duffy & Bowe, 2010). The framework is partly based on direct observation of students' *team behaviour*, and frequent formative feedback is offered to each students. This requires a low student-teacher ratio (Duffy & Bowe, 2010). But allocating this many resources to a course is not possible in all universities or programmes. So what can be done instead? Are there other ways of assessing behaviour than direct observation? Or maybe there are other parameters that could be assessed instead of behaviour?

In this project the following approach has been taken: Direct observation of behaviour is not possible, because one teacher cannot observe all students at once. But what *can* be assessed is a students' *knowledge of* teamwork, their *vocabulary* and *metacognition* in a reflective writing assignment to be submitted by each student individually. This is not exactly the same as being able to *do* good teamwork, but it – at least potentially – could motivate a person to actively change their behaviour accordingly.

The challenge, however, with reflective writing is that reading and assessment takes time. And this approach can only be viable if the time spent on assessment is reasonable. So the *first* step will be to test a rubric in order to see if is possible to complete assessment in a reasonable amount of time.

Another challenge is how to evaluate the overall framework – consisting of the learning objective, course content, and some theory – after each run. It is believed that the reflective writings will provide exactly those insights needed to be able to do that. In order to make it easier and quicker to extract these insights from the relatively large number of writings, the aforementioned rubric has been extended to include some extra questions about each students personal learning, team experience, and application of theory in the reflective writing.

So the research question at this time is: How can we assess reflective writings *and* evaluate the effectiveness of the framework after each run in an effective and relatively quick way, using an extended rubric?

Elements of this subproject

The overall framework is being developed within a course, '*Design, users, and ethics*' in the 1st semester of a Bachelor of Engineering programme at the Danish Technical University. The students work on a group project throughout the course. The groups are formed by the teacher.

The summative assessment method for the whole course is assessment of a group project report, the aforementioned short piece of individual reflective writing (up to 8000 characters incl. spaces), an oral group presentation (15 mins.), and individual oral exams (10 mins. each). The students are given an individual grade that is based on an overall assessment of all of the above mentioned elements.

One of the learning objectives in the course addresses team skills: The student must be able to: "Reflect on personal learning and contribution in a team process". A small part of the curriculum also addresses team processes in order to provide the students with some theory to apply in their reflective writings. Halfway through the semester the students are required to hand in the first piece of reflective writing for which they will receive general formative feedback. At the end of the semester they hand in the final piece of reflective writing which makes up part of the grade.

Research method

The rubric to be tested is an extended version of a rubric developed by Roseanne Birney (Birney, 2012) for the assessment of reflective writing. The extension that has been added are extra parameters so that the application of theory can also be assessed. Some extra 'boxes' has also been added below the rubric that allows for evaluation of the project: What do the students learn? Which challenges in the teamwork do they address? How do they understand the text they've read? And then some extra space for 'other insights'.

For this first test of the rubric the goal is to see whether it is relatively quick and easy to do the assessment *as well* as the evaluation so that each submission only has to be read once. 46 submissions are expected for this first run. So the method is simply to measure the time spent.

Eight hours for all 46 submissions would be a good time.

Before the ETALEE conference the rubric will have been tested once. The audience will be invited to discuss the results as well as the questions mentioned above.

Expected results

The expected result of this first test is a measure of the time spent on assessment and evaluation. There are many other questions that need to be explored in the overall project, but the results of this test will determine whether the chosen approach is worth pursuing at all.

REFERENCES

Duffy, G. & Bowe, B.: A Strategy for the Development of Lifelong Learning and Personal Skills Throughout an Undergraduate Engineering Programme, IEEE conference Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments, 2010.

Prince, Michael: Does Active Learning Work? A Review of the Research, p 223-231, Journal of Engineering Education, 2004

Birney, Roseanne: *Reflective Writing: Quantitative Assessment and Identification of Linguistic Features*, Phd Thesis, Waterford Institute of Technology, 2012

Collaboration between two innovation courses enhances students' understanding of organisational context

Villads Keiding
Technical University of Denmark, Denmark, vkei@dtu.dk

Liv Gish
Technical University of Denmark, Denmark, ligi@dtu.dk

ABSTRACT
The present paper presents the results of an experiment of close collaboration between two courses at the fourth semester at the bachelor programme 'Process and Innovation' at Technical University of Denmark. The two courses are Innovation and Knowledge Management (IKM) and Innovation in an Organisation Context (P4). Design-based learning has been used as a learning philosophy in both courses. The two courses shared six hospital cases at Herlev/Gentofte Hospital in the Region of the Capital of Denmark. The aim of the collaboration was to emphasize the students understanding of the organizational context in order to generate more value for the case-partners. Initially the students conduct an in-depth organisational analysis of a hospital department in the IKM course, followed by problem definition and an innovative process in the P4 course. The case partners answered with some variation that they recognized that the groups had taken the context into consideration e.g. economic and organizational issues and that it led to a more comprehensive understanding of the problem they solved, and to value creation in the proposed solutions. For some of the case partners the value generation did not primarily came from the final solution but from the initial analysis and inspirational discussions between staff members about the organisational context and situations from daily practice at the hospital. As an additional finding, this led us to explore the concept of *premature closure* of the problem definition. We concluded, that our actual framing of *design based learning*, based on Design Thinking and Double Diamond do not address the problem of *premature closure*. Based on literature we suggest a re-interpretation of design-based learning with "design as a hermeneutic practice" as its core.

Keywords – Design-based learning, innovation and design process, problem and context analysis, premature closure

Type of contribution: Explore

Questions for plenum:

1. We argue that a deep understanding of the context is important for identifying the right problem and developing relevant solutions. How do you teach students about a context (user and/or organisational context)? To what extent do you equip students with theoretical concepts prior to their work in the organization?
2. Premature closure is a well-known concept in medicine and also mentioned in literature about creativity (e.g. the Torrance test). How do you experience the concept of premature closure when teaching innovation?

I INTRODUCTION

In Open Innovation (Chesbrough 2006), it is widely accepted that the stakeholder's adoption of a new solution or a new value-offer is deeply dependent of the adoption to the actual context (Dopson et.al. 2008, Autio et.al. 2014). For the design engineer, getting the full picture not only from the perspective of users (von Hippel 2005) but also from multiple perspectives from other actors and stakeholders, analysing the organisational culture and ecosystem as a whole, is mandatory and maybe even a prerequisite for a value creating solution. The more complex the case, the more the need of context understanding is emphasized. At the bachelor-program Process and Innovation (PI) at Technical University of Denmark, it is a cornerstone of the education is to teach the students how to conceive problems in their context, hence postponing the problem definition. Conceive is also the first step of the CDIO framework (Crawley et al 2007).

Engineers are often viewed as technical problem solvers (Downey 2005) and it is a challenge for some students to leave their aim to solve problems, and just immerse themselves into the organisational ecosystem characterized by interaction by many professions, intense activity, demands of high performance, power play, politics, human emotions and technology. Sometimes we see students and project groups closing their eyes for an ambiguous context, avoiding the complexity of the process, just jumping to the safe zone of solving a given problem. As Hansen and Jørgensen (2011) coins it "Problem identification is not a simple desk research task as it often involves a multitude of actors having different or even not very well established ideas of what might be a good design result".

In the field of medicine, the phenomenon of jumping to conclusion too early, before all facts have been taken into consideration is labelled premature closure. Premature closure is also known from creative thinking, where it is mentioned in the Torrance Test (Almeida et al 2008) as a pitfall in creative thinking. Although, the label premature closure is not used in engineering design or innovation literature, we use it in this paper to denote the phenomenon of engineering students not maintaining the effort of exploring the context and incorporate the gained knowledge trough out the whole process. Thus, they arrive at a premature problem definition that consequently leads to a solution that might not accommodate the full picture of the need of the users and other stakeholders.

To emphasize the importance of an understanding of the wider context we have at Process and Innovation made an experiment, and re-designed and integrated two fourth-semester courses. By the re-design and integration, we support the students' exploration of the context of the particular case, before they define a problem and later develop solutions in an open design oriented innovation process.

The courses in the experiment are 'Innovation and Knowledge Management' (IKM) and 'Innovation in an Organisational Context' also called Project 4 (P4). Prior to the experiment the two courses were conducted in parallel throughout a semester, each with their own set of cases. Now IKM is executed in the first half of the semester, followed by P4. In the new design the courses share six hospital-cases, acquired through participation in the project CHI; Copenhagen Health Innovation (Link 2).

In IKM (5 ECTS) the students' objective is to make a cultural analysis of the case's organisational context. In the following course P4 (10 ECTS), the students must define a problem to solve and develop an innovative solution. In both courses, active learning is an integrated part that invites the students to learn and engage in theory, analysis and developing solutions.

II HYPOTHESIS

We argue that when the courses aim at providing the students with a deep understanding of a complex organisational context it is more likely that the outcome of the innovation process can be implemented and will create value for the stakeholders in the case. We also argue that the exposure of the students to a complex reality in the setting of design-based learning, where students takes almost full responsibility for the interaction with the organization, supported by relevant theoretical concepts, do facilitate deep learning about innovation and the importance of adoption to context, theoretically and practically.

III THEORETICAL TEACHING FRAMEWORK

The theme of this year's Etalee conference is active learning. In the two courses discussed in this paper, we use design-based learning to actively involve the students in their own learning process. Each of the two courses apply a different span of specific methods to support active learning. However, they do share the same case and the same student-teams throughout the semester. We define active learning as the students' active involvement with the organisational context and its actors and a design-based learning process that is also a design oriented innovation process, driven by students.

Design-based learning

The rationale for choosing a design-based learning framework is that it nurtures intrinsic motivation in the students and that it reminds very much of what the students will meet in real life when they graduate as Process and Innovation engineers. Design-based learning grows from problem-based and project-based learning, however, different emphasis is put on its content. Gómez Puente et al (2011) argue that the design of artefacts, systems and solutions in project-based settings are central, whereas Richard K. Miller (2014) (Link 1) argue that in design-based learning the problem have not been defined yet, thus the student needs to define the problem. Moreover, framing the problem is one of the most overlooked aspects of education according to Miller, which also corresponds to the claims of Hansen and Jørgensen (2011). It has therefore also been difficult to find papers exploring the problem definition aspect of design-based learning. The four central design-based learning elements applied in our two courses are: 1) Authentic cases, 2) Students work in project-teams, 3) Students follow a design based innovation process i.e. they iteratively investigate the context, define a problem and materialise a solution, 4) The teachers' dominant role is to act as facilitators and provide formative feedback. We will elaborate on the elements in the following.

1) Authentic cases

The concept of authentic learning was proposed by Herrington et al (2006) and relates to real-world situations involving complex problems and their solutions. Whittington et al (2017) argue that assignments with real-life relevance make students more motivated to learn and give them a more positive approach to their study. Working with authentic cases expose the students for real-world situations, it becomes meaningful for them to engage in the case, and it prepares them for their later professional careers.

2) Students work in project-teams

Design-based learning does not necessarily prescribe that the design process is conducted in a project-team, however, most design processes involve more actors. Working in project-teams also reassembles real life situations because this way of organising innovation in both the private and the public sector is widespread. In a project team, the members get familiar with the different development phases of a project team (Tuckman 1965). Furthermore, they need to cooperate, divide tasks between them and develop project management skills.

3) Students follow a design process

The students' objective of the P4 course is to conduct an innovation process. The students must "*analyse the company context, [...] identify and define a relevant problem [and] develop a solution"* as the course description explains (Link 4). At fourth semester students have experience with various innovation models presented at previous semesters. In P4, a merge of Design Thinking (Doorley et al 2018) and Double Diamond (The Design Councils 2005) is presented as a framework for the course-design and as a recommendation to the students, who have a lot of freedom to design a process appropriate for their particular case. See figure 1. Design Thinking methods with heavy focus on users and use context help the students design their data collection i.e. interviews, observation and workshops. The Double Diamond makes the students aware whether they should diverge or converge in their work process. We set the restrain that a problem should be defined no later than three weeks before the final submission.

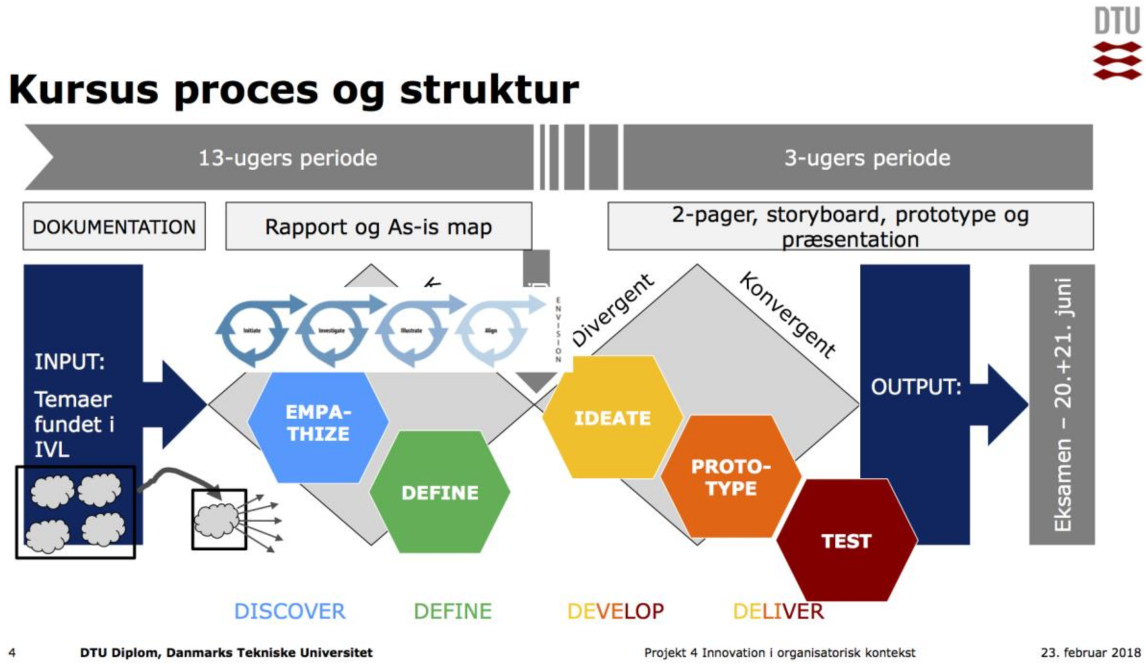


Figure 1: The design process visualized at the first lecture at P4

4) The teachers' dominant role is to act as facilitators and provide formative feedback

Puente el at (2015) argue, "The role of the teacher is to facilitate the learning process and coach and supervise students in DBL assignments". The teacher's task as a facilitator is also to take design for granted in design-based learning, to prevent premature closure, achieve a deep adoption to the context and to keep the wheel of the design-process spinning to gain knowledge all the way, until times is up.

As teachers, we need to prepare and support the students' entrance into the arena of the case. We must consider what is an appropriate theoretical toolbox, what process models should be suggested, and what deliveries or explications could facilitate the process. Furthermore, we need to manage the initial contact with the involved case-owners in the companies and set up and align expectations. Sometimes company management expect students to solve given problems from day one, so the case-owners also need to understand the importance of exploring the context and let the students take responsibility for the project.

IV THE CONDUCTED EXPERIMENT

Access to authentic cases

Access to the cases has been provided through the teachers' participation in CHI (Copenhagen Health Innovation), a project that aims to create collaboration between the healthcare sector and universities. Before semester start, CHI provided us access to hospital management at Herlev/Gentofte Hospital. We were allowed to contact all departments with an introduction letter sent by email. Six departments of 16 possible agreed to participate as case-partners.

Learning design

The IKM course follows a strict lecture structure where the students at each class apply a theory (selected by the teacher) to analyse the case. Each lecture is structured as a workshop with a number of activities supporting active learning: Student presentation of curriculum, facilitated dialogue in class, team exercises and group presentation. After each lecture, the groups documented and collected their work in a portfolio. After six and a half weeks, all groups summarized their findings in a poster session, showing "a comprehensive image of the organisation". A report reflecting on the impact of the theoretical concepts on the innovation process were submitted after 13 weeks and presented and defended at an individual oral exam.

Innovation in an Organisational Context is organised as a project's course that alternates between pitches made by the student-teams and supervision. The starting point for Innovation in an Organisational Context (after 6.5 weeks) was the descriptions and analysis of the group's case made in Managing Innovation and Knowledge Management. For the final assessment the students handed in a report, an as-is map, a storyboard, and a two-page executive summary. At the final oral group exam, they also presented a prototype.

V DATA COLLECTION

We have conducted five qualitative semi-structured interviews with representatives from five of the six involved hospital departments. Table 1 shows how many and who were present at the interview in each department, as well as the length of the interview. We did not get any interviews at Department F, however, the group working there have continued collaboration with the Department and is in this moment of writing working with employee driven innovation in the Department.

Table 1 Overview of interviewees and interview duration

Department	Participants	Length of interview
A	Head of Department	35 min.
B	Head of Department and Head of Unit	55 min.
C	Head of Department	36 min.
D	Innovation consultant, employee 1 and employee 2	49 min.
E	Head of Department, Head of Unit 1, Head of Unit 2, Production manager, Area manager	47 min.
F	No interview	

The interview guide was comprised of five overall themes of questions: 1) background information of the interviewees, 2) perceptions of the students' behaviour in the department, 3) the students' influence on the daily routines, 4) the chosen problem and solution, and 5) the collaboration between the hospital department, students and university. The interviews were conducted two month after both courses have ended, were audio-recorded and transcribed.

Our hypothesis is that by providing the students with a deep understanding of a complex organisational context it is more likely that the outcome of the innovation process can be implemented and will create value for the stakeholders in the case. To operationalise and validate this hypothesis we have formulated three questions we will examine our empirical data with:

- Were the students seen as relevant actors by the organization?
- Were the students, from the perspective of the organisation, able to adapt to the actual context?
- Did the proposed solutions consider the context, and how did it affect the perceived value creation?

We have used these questions for analysing our interview transcripts, however reformulated them into three corresponding codes: 1) The interviewees' perception of the students, 2) the interviewees' perception of the students' investigation of the organisational context, and 3) the interviewees' perception of the proposed solutions and value creation for the department. Both authors read the transcripts, and noted the coding in separate work logs. Afterwards we created a shared document with empirical examples of each coding category and discussed the meaning of them.

In addition to the interviews, the authors have also observed the students throughout the semester including their mid-term pitches and presentations, supervision and exams. Furthermore we have read their final reports and assessed work-portfolios, prototypes, storyboards, graphical representation of the as-is situation (as-is map) and the executive summary. We also consider our own slides form the introduction lesson as data. However, we have not made a systematic analysis of this data. We thus mainly base this paper on the interview analysis. At the end of the semester, we also made an evaluation of the course together with the students about how they perceived the collaboration between the two semester courses and the sharing of cases. This data has neither been the primary data for this paper.

VI EMPIRICAL FINDINGS, ANALYSIS AND DISCUSSION

In the following, we present the analysis of our empirical data in the four categories: "The students as actors"; "Adaption to the actual context"; "Solution and value creation" and "Additional finding: Closure in the design process" We will discuss alongside presenting the results and analysis.

The students as actors

First of all, in general, the students behaved themselves and acted polite and respectful to everyone. The interviewees describe them among other things as "polite", "engaged", "structured" and "creative". They paid very well attention to the fact that they are invited into a world of others, and conscious about not to disturb more than necessary. They are "good ambassadors", as one stated, and with "a good approach to inquiring without being judgmental". We as teachers will not take the credit of our students' good behaviour, but just note that it seems that the students have acted appropriate facing the sudden experience of being in the intense and complex world of a hospital. We will not further discuss to what extend the initial introduction to healthcare at IKM and P4 have supported this.

We also got the feedback that the students appeared structured, were good at communicating with their contact-persons at the hospital as well as other employers, and good at presenting for the stakeholders during the process. The interviewees mentioned the inquiring attitude several times as a sign of real interest in understanding what was really going on. Although we and our contacts at the hospital were aware that the experiment would somehow be time consuming, the students were pushing the limits. Asked whether the time consumption was acceptable one answered; "That was okay, but you could not have asked for more".

Educating trainees from many different medical processions is an integrated part of the daily work at hospitals, and working with students is a well-known part of the daily routines. Having non-healthcare professionals such as engineer-students or business school students in the department is somehow different: They do not take part in the daily routines, instead they observe, analyse and eventually propose solutions. Asked what can be expected from an engineer, one answered “a practical structured approach”. Answers to the question what could be expected from our students and from their participating as a case in the courses came out more differently: Some departments tried to prompt the students to work on a particular problem, others just wanted “a glance from outside” and apprised the explorative approach. In short: The students acted differently from what the departments are used to. They are perceived interdisciplinary, serious, explorative and structured. To let engineer students into the department takes resources, but in general, the effort pays off.

The analysis of our interview shows us that the students have made a good impression in the departments and they have made an effort to study the organisational context they have been placed in.

Adaption to the actual context

We were curious about how the departments perceived the process. What was it like to be under the analytic lens? What was it like to participate in a design based innovation process, emphasizing a deep understanding of the organizational context?

In most of the departments, the analytic part was recognized as relevant and necessary. One department; Department D, does not have direct interaction with patients, but are instead supporting the rest of the hospital, and facilitating processes across the organization. Employees here are familiar with the organisational perspective, and found the students “analytic approach” and the initial “cultural screening” obvious. In contradiction to what we experienced in the other departments, the cross disciplinary perspective brought in by the students were not perceived as something that created new value, but although acknowledged as something of importance in order to facilitate changes and innovation in the hospital. Only, most of the matters of interest suggested by the students were rejected as something of a larger complexity that could not be dealt with within the limited span of time.

In Department A, the Head of Department claimed the right to control organisational explorations and was surprised to be object for an organisational analysis. “We do a lot of work with employee satisfaction and management assessment. If more analysis should be done, I would prefer to be in charge”, the Head of Department said. The perception is that “one cannot do a proper analysis in such a short time”. Later in the same interview a bad experience with students from a business school were revealed, where the students “not at all grasped what's going on”, apparently, “because they have not spent enough time on it”. We have no detailed knowledge about the particular example, or the methods and theory applied, but much later in the interview, the manager indicated that our students’ observations and application of theoretical concepts actual did build a sufficient understanding of the organisational context: "They tried to go beyond, to talk about economics and costs while developing a device".

In Department A, time spend on archiving biological samples is an important matter. The students suggested a registration system that uses cameras to automatically log paraffin blocks with tissue samples when archived. The matter was suggested by the students on a backdrop of ten weeks of presence at the department, and chosen by the manager as well as the porters in consensus at an event where the students presented more optional matters. The suggested solution was judged as very relevant, realistic, and affordable: “They had an eye on the economy”. Also, the manager elaborated on a situation in the process where the students proposed several matters to choose from and noticed, “both the hospital porters and I chose the same solution as such, so it was very good. Then they have somehow hit it".

This analysis shows that the matter of understanding the organizational context, is perceived as important and accepted as something of value in the process, but to see it as an integrated part of the innovation process is somehow new. It emphasizes the need of methodological alignment prior the cooperation.

Solutions and value creation

In the table 2, we have listed the concrete results achieved in each of the participating departments. We have included Department F, even though we do not have any interviews with them. The quoted descriptions in the table refer to the “executive summery” submitted by the students to the departments at the end of the project.

Table 2 Overview of the proposed solutions in each of the six departments.

Department	Proposed solutions and experienced value creation
A	“Real Time Tracker: A registration system that uses cameras for automatically logging paraffin blocks with tissue samples when archived.” The solution proposal is now part of the department's project pipeline, but second in line compare to other projects, e.g. an internal construction project.
B	“Digitized Registration of Substrate Samples” The head of department support the proposal: "I have given a green light [...] with the estimated economy we would really like to use the product that was presented". The group have formed a start up company and wish to continue the project as a supplier. No progress has taken place since hand in of the project report.
C	"SafeHeat": A new concept for the mattress for the operation table with built-in electric heating. According to the department manager, the proposed solution is relevant, well communicated, at it will create value if implemented, but realization will require involvement an external partner from the industry. Therefore, realization is not realistic.
D	“Notification System for Special Patient Meetings": The yield is better patient treatment and better collaboration between departments and the department D during the implementation of a new concept for patient meetings. The notification system requires a change in the regional digital healtcare platform, called ‘Sundheds Platformen’, a complex and notoriously buggy and time-consuming system still under implementation. Involvement of the hospital's IT department is imperative. Realization is not considered realistic.
E	"Timesaver” A collection of proposals for streamlining food delivery by optimizing the use of elevators for employee and visitors. Several suggestions have been implemented. Others are in progress. The effect is measurable. There are now fewer delays in food delivery, compared to a registration in December 2017.
F	“Flow Guide: A digital tool that helps employees to navigate in organizational processes and connect with the right departments in connection with project start-ups”. The collaboration between the group and the department continues in the form of a new project where the students are experimenting with employee-driven innovation.

The list shows proposed solutions from six departments, where as we have conducted interviews in all but (F). Summarized one proposal (B) has led to measurable value creation. In two cases (A and C) the departments find the proposals feasible, they are willing to invest some limited economy in the finishing and implementation but no steps have been taken since end of the course. In two cases (D and E) the departments do not consider realization realistic. In the last case (F) the department manager agreed to let the students try to realize their proposal and a new project was formed. The scope of the new project is not to implement the developed solution, rather to do experiments and gain new knowledge about the conditions for employer driven innovation in the department.

Value creation in an organization is not only measured on how likely a solution is to be implemented. In some departments value generation did not primarily come from the final solution but from the initial analysis and inspirational discussions between staff members about the organisational context and situations from daily practice at the hospital.

In Department E the students presented a solution to optimize the complex matter of food supply and transportation at the hospital, suggesting a range of hands-on interventions, some approaching the matter with communication techniques and strategies, other with simple tracking technologies, addressing employees as well as visitors. During the process, the students had a lot of interaction with the organisation, not only by observing but also by doing experiments. At our interview, the top manager as well as four middle managers had decided to participate and spent time. They have had a good experience working with the students, and recognized that the students' work did create value. The students were perceived as an important resource to deal with problems, that was well known, but not taken care of because of lack of resources, and because "people has got a little exhausted [and] there were a sense of discouragement". Our respondents felt inspired by the methods and the mind-set of the students and one felt that "now, the organization is more mature". Some of the concepts suggested by the students are already implemented and the outcome can be measured: "There are fewer delays than there has been in December, so it's only on a fraction now, where there are delays". Dealing with delayed food supply has, as we were explained, a huge economical impact, since delayed food to patients causes delayed operations. As one from the departments put it; "Never before I had anyone from outside looking at what's going on in the department from a technical, organisational or psychological perspective. That is new to us [and] it is my impression they had a very good understanding that is, whatever the case is, it doesn't take a quick-fix, it's more complex". Another said: "There are many actors and many dependencies so it became a really complex task [...] but they had actually identified the complexity." "The solution was very simple" one said during one of the interviews. This could be true to most of the feedback we got on the suggested solutions.

I Department B, the solution was well received when presented in the department: "People were amazed when the students presented the program they had made where the employees themselves were allowed to scan the things with these barcodes, and they could see how it just came online. There they were very excited". The project was intended to continue with the students as suppliers to the department, as they have formed a start-up. Although, as we speak, no action has been taken to realize the solution. It seems to be difficult to advance without the official framework provided by the courses.

In Department D, a consultant put it this way: "We ourselves had been around a lot of it". Later when the students' value creation was discussed in the interview, it was stated that: "basically, there was not much of a result". But, to deeper understand the culture and cross organisational praxis of the department, the students were assigned to two particular employees, former nurses, now consultants, and joined them at two minor change management projects, where the aim was to implement new tools and procedures. For the students it was an eye opener to experience how the consultants worked, how they were perceived in the departments where the implementation were meant to take place, and all the difficulties they met. The students ended up suggesting a very simple solution to notify the health care professionals prior to a specific kind of patient dialogue meetings. Both in Department D and in the department where it was meant to be implemented, it was appraised as simple and relevant, as "They had some really nice ideas", but hence conceptual strong, the proposal was also "rather unrealistic". Unfortunately, it conflicted with IT protocols and regulation. Although the students did not match the level of understanding of the context in the department, some organisational learning took place; "...we became even more aware of the importance of the fact that there is a professional knowledge and how the network is important".

One could argue, that even in the cases where the proposed solution did not create value, focus on exploring and understanding the context was not the problem. Rather the case is that the global context of a hospital is overwhelming and constantly expanding, as you work your way in, so, if a value creating proposal should be developed, diving into the context of the IT-infrastructure is just the next step. Defining what problem to solve beforehand would be a premature closure.

Additional finding: Closure in the design process

The fact that the experienced value creation in the six departments is very different leads us to question weather the process of the six groups has been different to the same extend. To exemplify, in case D, where a measurable result was achieved, the group did a lot of experiments and interventions in the departments, all along the process, and in the end their proposals was about organizing and communicating primarily with the mean of physical signs in the department. In case C, the group chose the operation table with built-in electric heating as their scope. We do not have data to tell at what point in the process, the scope was decided on, but it directed the group into a product development process that did lead to a result that could only be applied with a comprehensive development process, substation resources and the involvement of external industrial actors.

It drag our attention to the design based learning framework, as it was communicated with the Double Diamond model and the Design thinking model merged in one visualization (Figure 1), and to ask if it has provided the groups with an appropriate theoretical support.

Since the general learning strategy of the two courses is design-based learning, and the two innovation models both exemplify innovation processes based on design, we find it relevant briefly to discuss the concept of design and the design process in relation to premature closure.

The Design Thinking model as well as the Double Diamond model emphasizes the importance of knowledge creation early in the process. The first phase of design thinking is named ‘empathize’ and the double diamond the process starts out with a ‘discover’-phase, similar to the ‘conceive’ phase from the CDIO standards for engineering education (Crawley 2007). Unfortunately, this do not necessarily prevent premature closure. Both in the case of design thinking and the double diamond, the second phase is named ‘define’, a term that can lead the less experienced student to the misconception that ‘define’ means that exploration of the context has been sufficient and thereby is ‘closed’.

Looking back in literature to understand the basics of design processes reveals that learning theory and design theory are intertwined. In 1984, Kolb published his model for experiential learning; the hermeneutic learning circle. The year before, Donald Schöen (1983) published the book ‘The Reflective Practitioner’. Both are influential to modern learning theory, also experience-based learning and in particularly design-based learning. Both are dealing with the same matter, that is, the emergence of something; knowledge, skills, concepts or ‘solutions’ in a process of experimenting or ‘making’, altering with reflection. In the perspective of Kolb and Schöen the design process could be understood as a situated knowledge-producing hermeneutic practice (Jahnke 2013). Bryan Lawson, architect and design theorist, published in 2005 a hermeneutic model for the design process suggesting three actions; analysis, synthesis and evaluation, altering repeatedly with the duality of ‘problem’ and ‘solution’ as the pivot. According to Schöen and consistent with the concept of design-based learning; “there are no problems to be solved, only problematic situations to engage in, characterized by uncertainty, disorder and indeterminacy” (Schön 1983 p 15), because, as Lawson adds; “Problem and solution emerge together” (Lawson 2006). A suggested solution is no more than temporarily stabilized - or closed - state, action, routine or artefact.

With the basic design process defined as a situated knowledge-producing hermeneutic practice, the Design Thinking model and the Double Diamond model will be ‘2. order models’, that could help the practitioners (e.g. the students) to focus and organize their effort along the design process. But there is a risk, that the models can drag attention from the core of the process that is the emerging problem and solution, and the need for deeper knowledge about an expanding context that raise in the process.

In figure 1 the hermeneutic design process is hinted with four small circular icons shown below the textbox; “Rapport og As-is map”. As a consequence of our reflections in this paper, and to prevent the premature closure, we aim to emphasise “design as a hermeneutic practice” in the new learning design and the way it is communicated.

VII CONCLUSIONS

Since we cannot compare our data from the semester in question with previous semesters (because we do not have interviews from previous semesters’ case-owners) we cannot conclude that the collaboration between the two courses have enhanced the students’ understanding of the organisational context compared with previous semesters. However, our study do show that all of the student teams have made a great effort to investigate the context and that both the case-owners and the teachers and examiner had the perception that the students understood the context they engaged in really well.

We conclude that the emphasized focus on understanding of the context have made sense to the students and also have paid off with respect to the departments experienced value creation. Our data and analysis indicate that design based learning is a relevant framework to stage a deep understanding of context. However, our additional finding indicate that the particular framing of design based learning with the use of the Double Diamond and Design Thinking visualized as one image (figure 1) in combination and the project teams extended autonomy to their own interpretation of the design process have not provided the students with the optimal theoretical support. In our future learning design, we will experiment with a hermeneutic oriented design framework, communicated in a more stringent fashion.

ACKNOWLEDGEMENTS

We would like to acknowledge the involved departments at Herlev/Gentofte Hospital for giving the students access to their departments and using their precious time to be observed and answer questions.

REFERENCES

Almeida, L.S., Prieto, L.P., Ferrando, L., Oliveiraa, E., & Ferrandiz, C. (2008). Torrance Test of Creative Thinking: The question of its construct validity. *Thinking skills and creativity*, 3, 53-58.

Autio, E., Kenney, M., Mustar, P., Siegel, D., & Wright, M. (2014). Entrepreneurial innovation: The importance of context. *Research Policy*, *43*(7), 1097-1108.

Crawley E.F., Malmqvist, J., Östlund, S., Brodeur, D.R & Edström, K (2007). R*ethinking Engineering Education - The CDIO Approach*, Springer.

Chesbrough, H. W. (2006). *Open innovation: The new imperative for creating and profiting from technology*. Harvard Business Press.

Council, D. (2005). The ‘double diamond’ design process model. *Design Council*.

Dopson, S., Fitzgerald, L., & Ferlie, E. (2008). Understanding change and innovation in healthcare settings: reconceptualizing the active role of context. *Journal of change management*, *8*(3-4), 213-231.

Doorley, S., Holcomb, S., Klebahn, P., Segovia, K. and Utley, J. (2018). *Design Thinking bootleg*, dSchool, Stanford University

Gómez Puente, S.M, van Eijck, M. & Jochems, W. (2011). Towards characterising design-based learning in engineering education: a review of the literature. *European Journal of Engineering Education*, 36(2), 137-149.

Hansen, C.T. & Jørgensen, U. (2011). The challenge of conceiving: Approaches to problem identification and framing. Proceeding of 7th International CDIO Conference, Technical University of Denmark, Copenhagen.

Harrington, J. (2006). *Authentic learning environments in higher education*. IGI Global.

Jahnke, M. (2013). Meaning in the Making. *Business & Design Lab, HDK, School of Design and Crafts, University of Gothenburg*.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development* (Vol. 1). Englewood Cliffs, NJ: Prentice-Hall.

Latour, B. (1999). Circulating reference: Sampling the soil in the Amazon forest. Pandora's hope: Essays on the reality of science studies, 24-79.

Lawson, B. (2006). *How designers think*. Routledge.

Schön, D. A. (1983/2017). *The reflective practitioner: How professionals think in action*. Routledge.

Tuckman, B. W. (1965). Developmental sequence in small groups. *Psychological Bulletin*, *63*(6), 384-399.

Verganti, R. (2009). *Design driven innovation: changing the rules of competition by radically innovating what things mean*. Harvard Business Press.

Von Hippel, E. (2005). Democratizing innovation: The evolving phenomenon of user innovation. *Journal für Betriebswirtschaft*, *55*(1), 63-78.

Whittington, C., Anderson, T. & Conner, A. (2017). *Embedding authentic practice based learning in engineering undergraduate courses*. AAEE2017 Conference, Manly, Sydney, Australia.

INTERNET RESOURCES

Link1: Richard K. Miller (2014), Olin College https://www.youtube.com/watch?v=yzM9_DamVP0, accessed 2 Otc. 2018

Link 2: Copenhagen Health Innovation: http://copenhagenhealthinnovation.dk/, accessed 12 Oct. 2018

Link 3: Knowledge and Innovation Management: http://kurser.dtu.dk/course/62L26 accessed 12 Oct. 2018

Link 4: Project 4: Innovation in an organisational context: http://kurser.dtu.dk/course/62040 accessed 12 Oct. 2018

BIOGRAPHICAL INFORMATION

Villads Keiding has a background as a designer and holds a master degree in Design from KADK. He is associate professor at Center for Bachelor of Engineering Studies at Technical University of Denmark, teaching at the bachelor programme Process and innovation. He is involved in teaching and innovation projects within creativity, innovation and design processes.

Liv Gish has an engineering background and holds a PhD degree in innovation management from Technical University of Denmark. She is currently assistant professor at Center for Bachelor of Engineering Studies at Technical University of Denmark, teaching at the bachelor programme Process and innovation. She is involved in teaching and innovation projects within entrepreneurship, innovation and organisational analysis.

Engineering Methodology Revisited

Steffen Kjær Johansen
SDU Engineering Operations Management, University of Southern Denmark, Denmark, skjo@iti.sdu.dk

ABSTRACT

Keywords – engineering science, engineering knowledge, engineering methodology, methodology of the Humanities

Please indicate clearly the type of contribution you are submitting: ___ hands-on, _X_ explore.

Though difficult to define and demarcate precisely, it is a fact that engineering science encompasses a multitude of other sciences or aspects thereof. In fact, engineering science is so varied and broad that it is difficult to imagine sciences that do not, in one way or another, bear impact on it. This observation should come as no surprise; after all, the engineer has always relied on all sorts of inputs for "making things work". It may also be of little surprise that the tendency of such interdisciplinarity seems to become more and more pronounced; after all, our societies become more and more complex thereby increasing the demand for complex engineering solutions (Christensen & Ernø-Kjølhede, 2006). A bit more surprising perhaps, and possibly also debateable, is the observation that interdisciplinarity also seeps into engineering science in an altogether different manner. Because of pressure from society at large, the engineer of today is no longer just a technology-creator; the role-model for an engineer today is an innovation-creator. This subtle shift instigates a radical change in the approach to engineering science and to the conception of what it means to be an engineer.

One can create technology without caring much for end-user needs and wants: technology remains technology even if no one is interested in using it. Creating innovation is a far more daunting task in as much as end-user needs and wants must be taken into account: innovation only becomes innovation when end-users adopt it (Frederiksen & Knudsen, 2017). Because this shift towards innovation-creator stems from pressure from society at large, it is literally everyone concerned with engineering that is affected by it. The innovation-creator is no longer the odd one out among engineers; he or she is the norm. Discovering end-user needs and wants is not a task that traditionally has befallen engineering science or the natural sciences for that matter; it pertains to sciences inherently situated within the Humanities. This new dimension to engineering science must generally be heeded by anyone who wants to excel in engineering, and this again implies that engineering training programs must pay due attention to it. In other words, engineers must be trained in the science methodology of the Humanities.

The paper and presentation begins with a discussion of the knowledge-categories pertaining to various scientific fields. I will end this discussion by contrasting knowledge within the natural sciences to knowledge within the Humanities emphasizing in particular the pertinence of the various sub-fields of engineering science. To do so I apply the following demarcation principle: all sciences based on laws of physics belong to the natural sciences whereas the rest are taken to be human constructs and to belong to the Humanities. Clearly a demarcation principle like this needs to be justified and I will adopt a scientific-realist position to do so (Musgrave, 1988).

I will then discuss how knowledge within the natural sciences is well-defined in the sense that the meaning of it is precisely given and invariably laid out by the specific theory to which it pertains. This has the consequence that knowledge can be shared essentially without risk of misunderstanding (provided, of course, that the persons involved in the knowledge-sharing actually understand the natural scientific theory at hand). In the Humanities, however, this is not the case. The human-construct aspect opens up for (mis)interpretation wherefore knowledge-sharing becomes a precarious activity where considerable time and effort must be spent to achieve shared understanding (even if the persons involved in the knowledge-sharing at the outset are familiar with the context).

Then I will go on to discuss the differences in the knowledge-generation methodologies of the natural sciences and the Humanities. This discussion will emphasize the impact of meaning, as discussed above, on the methodologies adhered to by the two knowledge-domains, respectively. Thus I discuss why the hypotetico-deductive method becomes the archetype of natural scientific methodology and contrast this to the Hermeneutical spiral, the methodological archetype of the Humanities.

Lastly I will discuss the impact of the differences in knowledge-generation methodology on the *knowledge-sharing* (or pedagogical) methodologies of the two knowledge-domains. I will end up arguing that much knowledge and many concepts within today's engineering science are best learned through experiential methods. This again implies that traditional engineering teaching methods are not fit for this purpose if the students are to acquire deep knowledge.

Throughout the presentation, I will use Newtonian mechanics and the concept of innovation as exemplars of the two knowledge-categories.

REFERENCES

Christensen, S. H., & Ernø-Kjølhede, E. (2006). Reengineering Engineers: Towards an Occupational Ideal of Bildung in Engineering Education. In J. Christensen, L. B. Henriksen, & A. Kolmos (Eds.), *Engineering science, skills and bildung* (1 ed., Vol. 1, pp. 209-232). Aalborg: Aalborg Universitetsforlag.

Frederiksen, M. H., & Knudsen, M. P. (2017). From Creative Ideas to Innovation Performance: The Role of Assessment Criteria. *Creativity and Innovation Management, 26*(1), 60-74. doi:10.1111/caim.12204

Musgrave, A. (1988). The Ultimate Argument for Scientific Realism. In R. Nola (Ed.), *Relativism and Realism in Science* (Vol. 6, pp. 229-252). Dordrecht: Springer Netherlands.

International Student Projects
How to make it happen

Jens Myrup Pedersen and Jacob Vejlin Jensen
Aalborg University, Denmark, (jens@es.aau.dk, jvje17@student.aau.dk)

ABSTRACT
The students we educate today are going to work in a globalized world: Even if located in one country, often work is done in diverse teams that spans background, cultures and geographical borders. An important way to prepare our students for this globalized workplace is to have students working exactly this way, making projects with students from other countries and with other backgrounds. However, this is easier said than done, even if good intentions are present: Different traditions on project work and collaborations, different formal and informal requirements, timing, accreditation and simply managing these complexities. In this paper, we present an approach to overcome these challenges in a setting of mixing physical and virtual collaboration, along with the evaluations received from students, teachers and industrial partners. We discuss the challenges we have identified, and how these can be overcome. The paper is inspired by experiences from the Erasmus+ Strategic Partnership EPIC (Improving Employability Through Internationalization and Collaboration), which is a flexible framework for collaborative student projects. It targets university teachers and supervisors and other staff working with internationalisation such as program responsible and international coordinators. Conclusively, the value of student collaborations across cultural and academic differences involving both partners from industry and academia is demonstrated. Challenges associated with the proposed approach of EPIC are outlined and a proposal for refining the concept to overcome said challenges is presented.

Keywords - Problem Based Learning, Student Projects, Internationalisation, Cross-Disciplinary.
Contribution – Explore session.

I INTRODUCTION

The students we educate today are going to work in a globalized world: Even if located in one country, often work is done in diverse teams that span background, cultures and geographical borders. An important way to prepare our students for this globalized workplace is to have students working exactly this way, making projects with students from other countries and with other backgrounds. This can happen in the same physical location, but it can also be taken to another level by students collaborating on e.g. mini projects, semester projects or thesis projects even if located in different places.

The need for students being able to work in diverse environments and being able to understand real-world problems is clearly identified in the Agenda for the Modernisation of Higher Education (European Commission, 2011) – a new and updated Agenda is currently being written, but this focus on transversal competences is unlikely to change. Previous projects in the field such as the COLIBRI project (Pedersen et. al, 2017), (COLIBRI website, 2018) has also demonstrated how students, staff and industrial partners all see a strong value in training such skills through joint student projects. In the COLIBRI project, during the last year 93% of the students found that participating in the course had made them better prepared for the international labour market (to a moderate or major extend), and 79% of the students found the course had made them better prepared for the national labour market (to a moderate or major extend).

The EPIC project, Improving Employability Through Internationalization and Collaboration, (EPIC website, 2018) is a 3-year Erasmus+ Strategic Partnership, where a flexible framework for setting up and carrying out student projects is explored. Compared to previous projects in the field, the main difference is that these student projects are carried out within existing study regulations, and do not require special arrangements and dispensations. While being scalable, flexible and "doable", it does give some additional practical and pedagogical challenges which need to be addressed (e.g. in terms of group formation, projects starting and ending at different points in time, as well as reporting and evaluation).

In this paper we explore how this can be done concretely, given the opportunities and limitations in the Danish engineering educations, in the whole process of such projects: From getting the initial idea, to matching students and forming groups, to virtual, physical and blended collaboration during the semester and finally evaluation and exam. The goal of the paper is to inspire the participants to do more international student projects and to introduce concrete tools for how this can be done. We also want to demonstrate the hypothesis, namely that such projects are valuable for students and in fact also possible to carry out even within existing studies.

II THE SETTING

As mentioned before, the EPIC project is a 3-year Strategic Partnership funded by the European Commission through the Erasmus+ Programme, running through 2017-2020. Among the partners are eight universities and two companies, spanning over seven countries and geographically representing most of Europe. During the first year, 25 students participated from seven of the universities (AAU contributed the most students since an AAU-group of five students participated, while others contributed just a few students).

The idea behind the project is to develop ways to set up student projects across educational institutions, usually also involving collaboration with companies representing various industries, i.e. through having students working on real-world problems they define. Moreover, the project will deliver materials to support all aspects of the project work: From documenting benefits for the collaborating companies, to methods for setting up the project work, and to teaching and training materials for both students and teachers. However, this paper focuses on how to set up the project work.

The three year duration of the project allows for three independent yearly cycles, where each cycle runs from September to August, and includes preparing the projects, executing the projects during the spring semester, and then evaluating the previous year before developing for the next. New students are selected every year. The goal is to develop methods and materials that can also be used after the project is finished, and therefore it is important that the developed framework for setting up student projects is flexible enough that no hand-held solutions are needed in how legal aspects are handled, and that it is also not too expensive with respect to travelling.

These different aspects of the project work are discussed further in the following sections of the paper. The models and approaches described all reflects upon how it was done during the first yearly cycle of EPIC, but also discusses considerations for changes in the second year.

III PREPARING THE PROJECTS

Setting up student projects across multiple educational institutions spanning over different geographical boarders is more challenging than setting up the projects in just one institution.

One set of challenges is the practical challenge with respect to e.g. different times of semesters, different duration/workload to different students, different learning objectives and other formal requirements, and different ways of conducting exams. From the beginning, we wanted to avoid all hand-held solutions and dispensations from existing legal frameworks, as this is not scalable/sustainable. Therefore, the process was designed so that:

- All reports and documentation are handed in to the home university of the student and examined and graded according to their regulations. The only additional requirement from participating in EPIC as a student is that all students are required to also submit a joint final report, describing both academic achievements and reflections upon the learning processes involved. This also ensures that all work done in EPIC is properly and formally recognised with ECTS points in their local universities.
- The timing of the projects also follows that of the home universities: Since semesters start and end at different dates, a natural consequence is that not all members of the project groups start/stop at the same time. In practice, most students start the spring semester around February 1, which results in an almost synchronised start, while the ending dates are more spread but also less critical for the collaboration.

Figure 1 describes four different models for project setups. Model 1 is an extreme case with a minimal amount of cross institutional collaboration, where the students work on a joint problem but with separated theses and individual reports. This model is fitting for a project where local university regulations and other complexities created by the diversity of the group, has heavy influence and hinders closer collaboration. Model 4 is an opposite extreme case, where cross institutional collaboration is a leading aspect through all parts of the project. This project model requires of the students to delegate contributions to and responsibilities for the joint thesis through evaluation of individual qualifications. Obstacles caused by communicative challenges, academic or cultural differences and general disagreements are expected to occur, but the philosophy of EPIC, is that these obstacles resembles situations in the global labour market and ultimately helps to better prepare the students. Models 2 and 3 offer group variants dominated by a combination of shared and individual elements contributing to the flexibility of EPIC.

In all cases, the students will also finish with a joint report describing both academic achievements and reflections on the learning process.

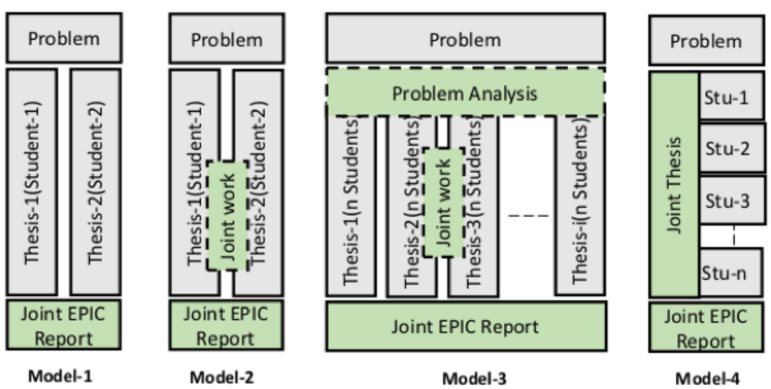


Figure 1: The four different models for joint student projects

The other set of challenges is related to the matching between interests of the industry, students' interests, students' backgrounds, and academia interests. We found this to be rather challenging, in particular due to a number of observations:

- There are different timings of topic/project selection processes in the different institutions, and sometimes these processes make it hard to handle situations where a project cannot be confirmed at their selection deadline. For example, the deadline for alternative options might be closed by the time all students in EPIC have indicated their project wishes. As an example, students from one institution had to choose their master thesis topics in early December and have them approved before Christmas. On the other hand, students from another institution would usually not select their topics until the beginning of the semester.

- On the other hand, it was not possible for us to guarantee students that they could work on a specific topic until we knew that a sufficient number of students would choose these (in particular, we wanted all projects to have students from at least two different countries).
- One complexity that we have not really resolved deals with traditions in some countries, where students are often paid for collaborating with companies on e.g. master thesis projects. In this case, the company often has some procedures for accepting students, e.g. applications or interviews. In EPIC we have decided not to take hand of this. We also do not have a universal view on IPR/publication rights, but leave this to the involved institutions; However, the report produced especially for EPIC is made publicly available.

In practice, this was handled by defining a process, where each institution would team up with relevant companies (sometimes also across institutions) and propose project proposals together. Once these were published, students could apply to participate in EPIC with a prioritized list of topics, which would give us some flexibility in ensuring which projects to run. We would then confirm to the students as soon as there were students from more than two countries who had selected a project, and in the case of projects with students from only one country we would discuss with the teachers of the institutions that had not yet selected their students whether we would be almost certain to have applications for these topics. While being somewhat cumbersome to administrate, it actually worked out well, even in the case of uncertainties and last-minute changes that always happen. However, it was also a process that somewhat violated some of the usual procedures for project selection and group formation in the involved institutions: For example, for Computer Engineering students at Aalborg University, the group formation and project selection process is always taking place on the first day of the semester, where all students on the same semester meet, are introduced to project proposals, and then have to form the groups based on some requirements to minimum and maximum group sizes: As a general rule, no group is formed before all groups are formed. This dynamic is changed a lot when one group is formed months ahead, and before alternative project proposals are even known.

Another challenge with the process described is that the time from “idea” to “project realisation” becomes quite long. The dialogues with companies take place already in September-October, while the project does not start until February. This is a much longer process than in Aalborg University, where the ideas for spring project proposals are usually defined shortly before the semester start, e.g. December or January. For this reason, and also to accommodate other good ideas, it was also possible for the institutions to define projects through a “fast track”, where students could be matched to a good idea – for example, when it turned out that master thesis students from both Aalborg and Riga where working on similar topics, they could also benefit from becoming part of EPIC.

In this paper we will not deal so much with the other aspects of preparing the stakeholders (students, teachers and company representatives) to the project work, but just mention that this was done through e.g. a set of online materials that all were supposed to follow before the project itself started.

IV THE PROJECT WORK

In this section we will present how the projects were carried out. Figure 2 provides an overview of this process: Each yearly project cycle in the EPIC collaboration involves a mixture of physical and virtual collaboration. The project work as such is inspired by the Aalborg model for Problem Based Learning (Kolmos et. al, 2004), but adapted to the different setup and contexts.

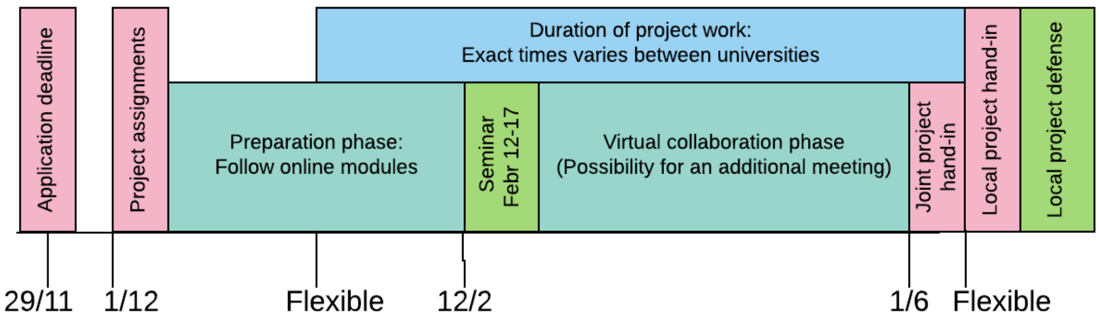


Figure 2: Timeline for the project work during the first year of EPIC

As can be seen in Figure 2, the project start is flexible – something that reflects the different semesters in the different countries. In principle, the project assignments were supposed to be in place by December 1, but in reality, this was not always possible and in fact the last students were confirmed around February 1. The online modules we mentioned previously would be the first part of EPIC that the students experience. These are partly focusing on teamwork and project management of diverse and virtual teams, and partly on content that is expected to be relevant for all the students.

In the next step, all participating students physically meet up with each other and representatives from all academic and industrial partner institutions, at an introductory seminar. The purpose of this seminar is that all project groups leave with a clear vision for the structure of the work to come, their responsibilities towards each other as well as the requirements for the academic work related to their respective local universities and their part-taking in the EPIC project. During this period students are instructed in tools relevant to problem solving and online communication, with purpose to supply everyone with the necessary toolbox before the online collaboration phase starts. This involves workshops and lectures within themes as effective use of online communication tools, file sharing and parallel development methods.

The next part is virtual: Throughout this the students are provided with both academic and industrial guidance, to ensure real-life-perspective and fulfillment of requirements for both perspectives. Depending on the group model chosen to fit a specific project group, the collaborative aspects differ in many areas. All four models have the initial problem definition phase and the final joint EPIC-hand-in as obligatory. But the perspective taken on the online collaboration phase differs greatly depending on the model in use. For model 1 and model 2, the actual project work is directly in parallel and the involved students primarily acts as sparring partners working on the same problem. Model 3 and model 4, depends on more on in-depth collaboration, with either a joint problem analysis phase followed by tightly connected project work, or a joint process from beginning to end. In the first year of EPIC the size of groups ranged from two students working together on their thesis projects, to 9 students from four different universities working together. In the latter case, the students were all working at different levels (from 2nd semester to 6th semester) and different amounts of ECTS (from 8 to 25). Table 1 provides an overview of the groups and themes of the student projects of the first year. Needless to say, the format of group work was very different in these different cases.

During the virtual phase, all groups had the possibility to arrange an additional physical meeting with the Erasmus+ funding. However, due the Erasmus+ funding rules it is a requirement that such a visit comprises of at least five working days, which can make it hard to fit into a schedule that also includes other courses. The groups would meet at different times and places, so that each group could fit it into their project plans and schedules, and it would be held in one of the institutions involved in the project – also to minimize travel costs. The plan for the week was made by the groups together with supervisor(s) to fit their needs – much of the value being the ability to sit and work together for a week. Three of the groups chose to do so, and as described below found this to be very beneficial for the project work. We would add that especially for the larger group, this additional seminar was crucial for the successful completion of the project.

Table 1: The projects carried out during the first year of EPIC

Topic/Research area	Leading University	Students involved
E-Commerse (food logistic)	Stavanger	3
Facility Management	Bydgoszcz	3
Logistic	Hamburg	2
Honeyjar (malware studies)(4 subgroups)	Aalborg	9
Mobile app for funding research	Atene Kom (company)	2
Security for IoTs	Riga	3
Energy Dash Board	Saxion	3

The joint project hand-in deadline was set to be June 1, as around this time the first students have to deliver their projects to the home universities. This choice also means that some students with a later local hand-in date would have additional time to work on their parts. In reality, this was administrated with some flexibility, so a suitable deadline was negotiated for all the groups. The joint EPIC report was assessed and led to the students receiving an EPIC certificate in addition to the recognition of the work at their home universities.

V EVALUATION AND RESULTS

Throughout the yearly cycle, both quantitative and qualitative evaluations were carried out among students, teaching staff and company representatives. This section presents some of the most interesting results and observations related to the project work. We also present some of our own observations which are well in line with the comments received from both students, teachers and companies.

First of all, we will present some of the quantitative evaluations received. The general evaluations from the students are presented in Figure 3, and the general evaluations from the teachers in Figure 4. The scores are on a scale from 1-5, where 5 is the highest level of satisfaction. We see that most students are very satisfied and believe the EPIC project has been good for their studies and career. This is confirmed in additional more detailed questions, which we have not included here due to space limitations. The responses from the teachers are similarly positive.

The students also evaluated the mobilities, both the initial project seminar and the additional blended mobility that three of the groups had. This was done on a scale from 1 to 4 (“bad” to “excellent”) and the results are presented in Figures 5-6. In general, the students are happy with both seminars: In fact, all students found that both seminars helped them with the project work to an either good or excellent extend. However, it is remarkable that on most parameters the second mobility (which is not mandatory) receives higher scores than the initial mobility (which we consider to be mandatory). We believe this is largely due to the fact that the students after working together online, and after working with the subjects for some time, are better prepared for the academic activities. Both authors of this paper were present for the second seminar of the large group (Honeyjar) and can confirm that it was a very productive week: The ability to discuss face-to-face, and to use whiteboards for discussions, was of extreme value. Also, the fact that the students were together, being able to focus on the project for a full week without other interruptions was part of the positive experience.

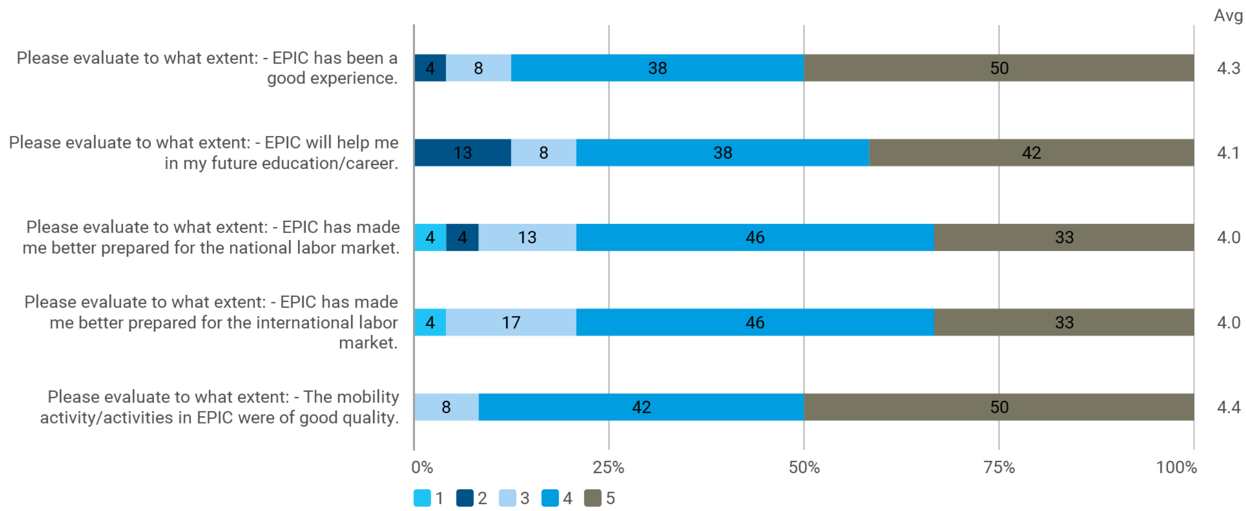


Figure 3: Students evaluation of EPIC year 1. The scale is 1-5, where 1="Not at all" and 5="Very much".

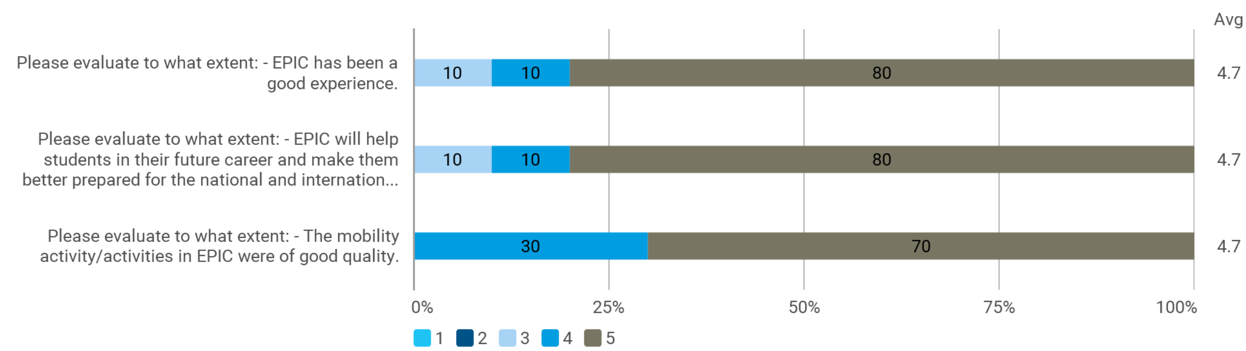


Figure 4: Teachers evaluation of EPIC year 1. The scale is 1-5, where 1="Not at all" and 5="Very much".

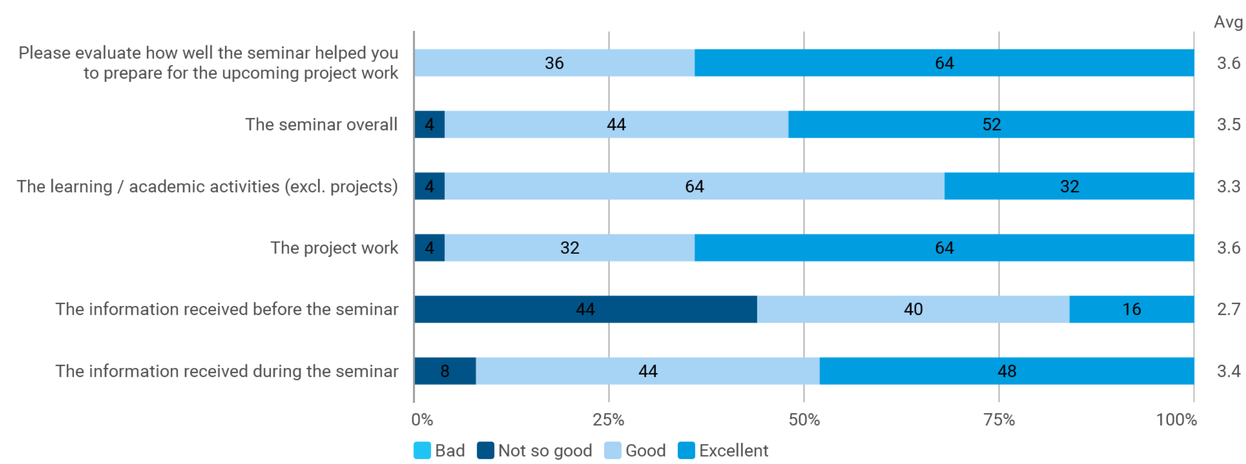


Figure 5: Students evaluation of the project seminar (the average is based on a 1-4 scale, 4 being excellent).

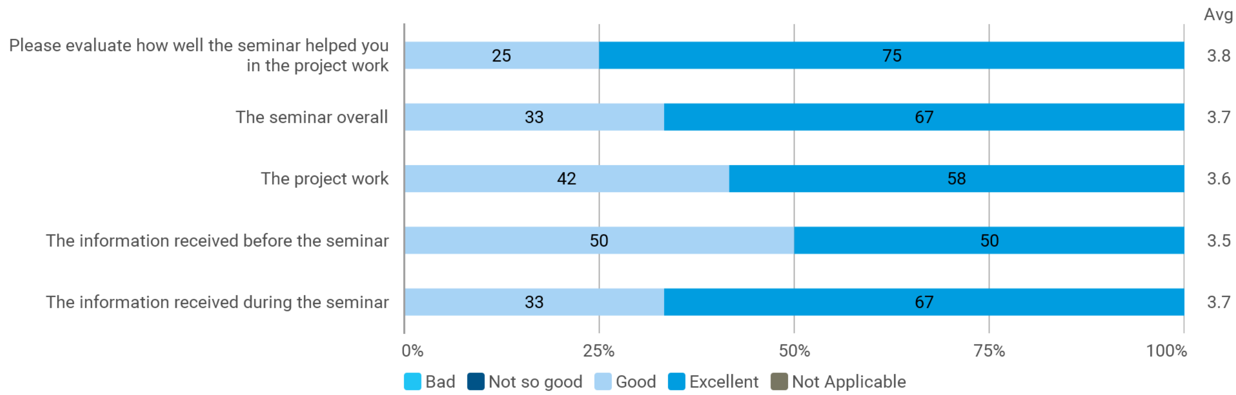


Figure 6: Students evaluation of the second blended mobility (not all students participated).

Based on the qualitative comments received in the evaluations, as well as our own observations, we would like to add the following comments:

- Staying within existing study regulations come with advantages in terms of sustainability and scalability: This can actually be done also outside of our Erasmus+ Strategic Partnership, and even when the project is over and the funding no longer available. It also ensures that the students receive recognition and ECTS points for the work done, which is what really makes it an integrated part of their studies. On the other hand, some of the projects especially in larger groups, also give the students some additional work related to project planning and setup: While this is exactly what provides the students with competences related to real-world problem solving, international collaboration, and interdisciplinary work, this does take time away from the disciplinary academic learning. It varies from country to country to what extend these learning objectives are counted and assessed during the evaluation of the work, and we could wish that these were more formally included in the learning objectives to ensure recognition – otherwise, students who simply aim for good grades might not find these learning activities attractive.
- The project seminar denotes the kick-off of the project. By starting "from scratch" it ensures that the groups have a common understanding of the project scope and goals, and supervisors from both academia and industry can help defining the right scope from the beginning and clarify any uncertainties. Initially, it also seemed that all groups got a good start of the project, and left the seminar with clear visions and plans. However, very often the first part of the project period would be to study the background and context of the problems to work on, and in many cases this new knowledge resulted in a need for adjusting content and time plans. It turned out that these adjustments could be difficult to do based on virtual collaboration. Therefore, it should be considered if enabling the students to be better prepared for the project seminar would help them in ensuring that they can leave the seminar with a more robust scoping and plan. We also saw in the evaluation of the project seminar that satisfaction with the activities increased day by day: We find this to confirm that it was during this week the students really found out what the project was all about, suggesting that a better preparation would have been beneficial.
- Some groups found that the different supervisors would try to get them to work in different directions, and also observed that the objectives of EPIC were not always aligning with the objectives of the project to be delivered at their home universities. While this is in line with the above point on staying within existing study regulations, it could demonstrate a need for clarifying more precisely the different roles of the different supervisors (company supervisor, local supervisor and EPIC supervisor). On the other hand, having supervisors with different points of view can also be a strength as the students are presented with different perspectives.
- Finally, we note that despite the challenges identified both students, teachers and company representatives are overall showing a high degree of satisfaction with the project.

On a final note, we would like to present some of the quotes from the student evaluations, which both demonstrate the value of doing international student projects, but also highlights some points that could be improved, especially when it comes to the role of the industrial partners.

- "Initiates like this are a great way for students to explore different cultures and work with people you would've otherwise never worked with. Thank you."
- "EPIC on a whole was a great experience, I had developed an eye for industrial problem solving. The only suggestion from my side is that, please make sure that the industry is willing to assist the project completely and also make sure a clear project proposal is identified before taking up the projects."
- "I am happy to partake in this project, I had the exposure to finally apply what I learnt in school. This is the best experience since I started studying in Europe. However, there should be more commitment from the organisations student works with, these companies should provide as much as possible information to the students and the student should be added to the companies' in house research team."

VI DISCUSSION AND CONCLUSIONS

The diversity brought by the globalization involves challenges of cultural and academic proportions. Establishing a collaboration across geographical and virtual boarders creates communicative, professional and humane challenges. Applying these challenges to a collaboration involving industrial partners and the established educational environment, where differences in local university regulations and predefined deadlines is inevitable, requires a well-structured approach. The complexity brought as a result of diversity resembles the global labour market. EPIC acts under the philosophy that introducing students to real-world challenges early in their educational careers is an important step in preparing them to enter the global labour market.

Collaborating across cultural and academic differences requires a structured methodology for effectively managing the project work. In pursuit of addressing the diversity while creating a solid framework for students to base their project work on, the EPIC partners have developed four proposals for structuring the group-based project work. All models take point of departure in Problem-Based learning methods, which requires of the students to locate a problem worth solving and in collaboration with academic and industrial supervisors develop a thorough strategy for the consequent work.
In this paper we have demonstrated the value of having students working on projects across countries and disciplines. We have also outlined some of the challenges that comes with this approach, especially when working with the constraints that we want to stay within the limitations of existing legal frameworks without dispensations and hand-held solutions. The models introduced are flexible and pragmatic and shows that it is possible to overcome the challenges identified.

During the next years we will continue polishing the models, especially focusing on the following aspects:

- Making the students better prepared for the first seminar, so they can get an even better start on the project work. As a first step, it is necessary to have all students on board at an earlier stage, and also to appoint supervisors early on. This will make it possible for the supervisors together with the company/companies to identify relevant materials that the students can study on beforehand, so they have more background knowledge when showing up for the project seminar. We believe this will support having more qualified discussions on content during the seminar, reducing the need for re-scoping later on).
- Another effort to improve the project start is to create a booklet describing the profile of all participants, both teachers, students, and company representatives. By introducing this prior to the

project seminar it becomes possible for the students to be not only prepared on the academic aspects, but also on the profiles in the groups. Also, it will provide a useful overview of the profiles of different teachers, so the students can identify relevant profiles for questions and inputs both during the seminar and for the rest of the project period.

- We will work on equipping the supervisors better to take on the supervisor role(s) with a special focus on the roles of the different supervisors from companies, local universities, and the EPIC supervisor. It is our experience that terms like "project work" and "supervisor" can have very different meaning in different educational contexts, and while we do not think these should be standardized some common agreements about supervision would be beneficial: Especially, we should equip both supervisors and students to be explicit about wishes and expectations to each other.
- Finally, we will also try to adjust the process for project selection, as to make it more structured and with less ad-hoc solutions. The main idea is that students instead of selecting specific project proposals can select to work within a theme, where each theme consists of a number of different project proposals. This will allow some more flexibility when assigning students to projects. On the other hand, we also want to remain flexible and able to adjust to specific wishes from students and companies.

ACKNOWLEDGEMENTS

We would like to thank the European Commission for supporting the EPIC project through the Erasmus+ Programme. All mobility activities were funded by Erasmus+, and thus participation in the project was free of charge for the students. We would also like to Thank Koojana Kuladinithi from Hamburg University of Technology for providing Figure 1 in this paper.

REFERENCES

COLIBRI website (2018), http://erasmus-colibri.eu, last visit 14-11-2018.

EPIC website (2018), http://epic.agu.edu.tr, last visited 14-11-2018.

European Commission (2011): *Supporting growth and jobs – An agenda for the modernisation of Europe's higher education system.*

Kolmos, A., Fink, F. K., Krogh, L. (2004). *The Aalborg PBL Model: Progress, Diversity and Challenges.* Aalborg University Press

Pedersen, Jens Myrup ; Lazaro, José ; Mank, Lea ; Eichhorn, Vanessa. (2017) *Blended Learning and Problem Based Learning in a multinational and multidisciplinary setting.* 6th International Research Symposium on PBL: PBL, Social Progress and Sustainability. red. / Aida Guerra ; Fernando José Rodriguez ; Anette Kolmos ; Ismael Peña Reyes. Aalborg Universitetsforlag. p. 535-546 (International Research Symposium on PBL).

BIOGRAPHICAL INFORMATION

Jens Myrup Pedersen is Associate Professor at Department of Electronic Systems, Aalborg University. In addition to his research in the fields of computer networks and cyber security, he has a strong interest in Problem Based Learning, especially in international and interdisciplinary contexts, and in digitally supported learning. He has been coordinating a number of Erasmus and Erasmus+ projects and is currently coordinator of the EPIC project.

Jacob Vejlin Jensen is a student of Computer Engineering at Aalborg University, Aalborg, Denmark. He is actively involved in the EPIC project, first as a student, and after that as a student helper. He has acquired experience with international studies, Problem Based Learning, and cross disciplinary work. In EPIC he was part of the 9-person group working with Honeyjar (malware studies).

The Ultimate Challenge for Active Learning Design?
Turning a calculation-only repetition course into an active learning experience

Per Skafte Hansen, associate professor, M. Sc., Ph.D.
Technical University of Denmark, Denmark, psha@dtu.dk

To Iben

ABSTRACT

Keywords – active learning design, reflective practice, repetition course, re-examination

Intended for an “explore” session.

1. Background

For the past five years, the author has been in charge of providing material for a preparation course for students about to enter re-examination for the mathematics course 01005 held in August: At the Technical University of Denmark, the general first-year course 01005 *Advanced Engineering Mathematics 1* provides 20 ECTS points worth of calculus, linear algebra and vector analysis to bachelor students. 01005 comprises weekly lectures, weekly training sessions (one supervised, the other not), 7-8 home assignments, a 3-week project course and two exams. Some students fail the final exam in June and are thus eligible for the re-examination.

Originally, such students were simply offered a 4x4 hours ‘marathon calculation’ challenge at the DTU premises, prior to the re-exam. Thus, the author assembled and arranged individual exam questions from previous years, grouped according to subject and selected to provide a suitable degree of difficulty, gradually increasing and with a mild decrease at the end, meant to reinforce the students’ feeling of progress. In other word: This ‘marathon calculation’ almost exclusively provided operational drilling, the only pedagogical aspect of the material being the attempted easy-hard-easy curve. Quite apart from being in keeping with “folk psychology” – you feel better about working on a set of tasks if your latest attempt was a success – it tallies with the concepts of perceived *self-efficacy* as motivation (Choi 2005) and the more general *flow* (Csikszentmihalyi 1990).

This ‘marathon calculation’ is now a complete miniature course, 01003, still with 4x4 supervised hours of student work taking place at the DTU premises. However, based on the experience from previous years, the author has felt the need to provide material for preparation-before-the-preparation, as it were, seeing that each ‘marathon day’s selections of old exam assignments are not released until the morning of the session in question. (This has been a decision from the very beginning, primarily based on the observation that it is much more efficient to dole out instructions if every student around a table is working on the same problem).

In 2017, some ‘preparation-before-the-preparation’ material was provided, which made use of the *worked example* principle (van Gog et al, 2011). This material was based on problems the students had met – and presumably worked on – during the term. Although not quite the overwhelming success the author had perhaps wished for, positive reactions from participants suggested an enhanced version; thus, in 2018, an all-out attempt was made to stimulate active learning in what might otherwise seem a rather stale experience, the students simply trying to solve as many problems as possible and asking very specific how-to questions.

Many of the activities one might wish to engender are *a priori* ruled out; and the students are motivated and focused, yes, but somewhat reluctant to let ‘fancy ideas’ disturb them. The following is a brief review of what was done or attempted, what was not (or currently not possible), what succeeded and to what extent, and what is contemplated for seasons to come.

2. The possibilities

Surprisingly, there appears to be no hard-and-fast definition of *active learning*. The author is inspired by the monograph Active Learning Creating Excitement in the Classroom (Bonwell et al 1991) which in its introduction has the following broad formulation:

> …students must do more than just listen: They must read, write, discuss, or be engaged in solving problems. Most important, to be actively involved, students mast engage in such higher-order thinking tasks as analysis, synthesis, and evaluation (Bonwell et al p 5)

to which should be added observations and practical experiences such as those reported in (Hansen 2004) and (Hansen 2017). In particular, the concept of *structured action learning*, which is gradually taking shape – and briefly discussed below – probably best describes what was and will be attempted in the mini-course 01003.

So, the challenge was to make the students every now and again look up, lean back and *reflect upon* and *discuss* what they were doing and learning, time pressure notwithstanding. Two separate goals can be identified: to convince students that this is worth their while; and to provide material to stimulate thoughts and discussions and a forum in which to place answers – and deeper questions.

The tools available comprise an LMS (DTU Inside) with the usual capabilities of such a tool, most notably a built-in wiki with which many – but not all, as it turned out – of the students are familiar; rooms with blackboards and AV equipment; and access to a CAS tool (MapleSoft's Maple©) used throughout the two-term teaching of 01005 and capable of producing interactive notes and related material.

In August 2018, a last-minute higher-level decision placed the students in rooms *without* blackboards and AV, thus reducing the actual possibilities. This decision was logistically motivated and need not influence the further development described below.

3. Making use of the tools

In preparation of the course, the author completed an analysis of the task at hand and produced new material accordingly. Both the analysis and the outline and templates of the material was heavily influenced by previous experiences. The decision to include elements of active learning grew out of this work, motivated by the growing amount and the ever more evident structure of the result. In a sense, the material invited new thinking as it became clear that an effort was needed to help the student make the most of what was offered.

The resulting material can be described as follows:

The 72 subjects: From the weekly 'menus' of 01005 problems, which the students solve prior to the home assignments, a total of 72 subjects were selected and arranged. These were pivotal to everything that followed, so care was taken to achieve balance in term of relevance and difficulty.

A complete list of the 72 would be out of place here; but a few can be mentioned to give the reader a feel for what was attempted. The overarching concepts were Calculus, Parameterization, Integration and Vector Calculus. Note: This is not entirely the order in which the topics are taught in 01005; but since all material is – in principle, at least – familiar to the students, and since Parameterization (not taught separately in 01005) is known to be a stumbling block, this division seemed appropriate. The topic of parameterization was subdivided thus:

- Graph of function of one variable. Graph of function of two variables. The interplay and differences between a function graph, a parameterized curve and a solution curve of an equation
- Parameterized curve in 2 and 3 dimensions. Parameterized planar segment. Parameterized surface.
- Parameterized function graph in 2 dimensions. General cylinder. General surface of revolution.
- The sphere. Spherical sectors. Spherical caps.
- Volume between surface descibing graphs of function of two variables and the coordinate plane.
- Substition in function. Substitution in vector field.

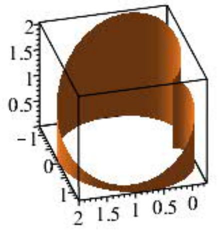
The semi-interactive notes: With the 72 as headlines, notes (4 parts comprising 18 subjects each, divided into 6 groups of 3, as illustrated by the example) were written directly in the CAS tool used, making use of the ‘folding editor’ facility, the responsive 3D- figures, code for the students to modify, experiments with and copy-paste and colour coding of warnings, remarks and solution procedures. The author makes use of ‘document mode’, so the notes resemble ordinary text book material. A .pdf-version is also provided.

Later version (planned) will further emphasise interactivity, as the CAS tool offers a plethora of possibilities. However, such enhancements can easily become decorations, not used by the students and hence of little value (but time-consuming to produce). Presently, the above results in something like fig. 1:

$xc := t \to \cos(t)\cdot(1+\cos(t)) : yc := t \to \sin(t)\cdot(1+\cos(t)) :$

$zp := t \to -\frac{1}{3}\cdot xc(t) - \frac{2}{3}\cdot yc(t) + \frac{4}{3} :$

plot3d([$xc(t)$, $yc(t)$, $zp(t)\cdot u$], $t = 0..2\cdot\pi$, $u = 0..1$, *scaling* = *constrained*, *style* = *surface*, *color* = "Chocolate", *orientation* = [75, 60, 0])



Skråt afskåret cylinderflade

2.3.3 Parametriseret omdrejningsflade

I de fleste opgaver benytter vi en konvention af formen:

- Der foreskrives er parametriseret plan *profilkurve*, beliggende i xz-planen med x-værdier ≥ 0
- Denne kurve roteres 360° - altså 2π - om z-aksen

Vi kan derfor koncentrere os om denne type og som afslutning betragte andre varianter

Profilkurven tænkes givet ved $(x(t), 0, z(t))$, $t \in \mathcal{P}$, hvor $\mathcal{P}$ er et reelt interval. Parameterfremstillingen for fladen kan derefter skrives

$$\begin{bmatrix} \cos(\theta) & -\sin(\theta) & 0 \\ \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} x(t) \\ 0 \\ z(t) \end{bmatrix} = \begin{bmatrix} \cos(\theta)\, x(t) \\ \sin(\theta)\, x(t) \\ z(t) \end{bmatrix}$$

med $\theta \in [0;2\pi]$. Bemærk, at denne fremstilling er helt generel, men at vi nu benytter parameterintervallet $[0;2\pi]$, snarere end $[0;1]$. Hvis vi insisterer på et interval af formen $[0;1]$, kan vi skrive parameterfremstillingen på formen

Figure 1, an example from the semi-interactive notes written for 01003

Figure 1 shows the code-like commands, a responsive 3D figure, the 'folding' document structure (the triangle before the section number 2.3.3 allows the entire section to be collapsed into a headline only), the use of colour for highlighting textual elements and the writing of mathematical formulas.

Problems for preparation and for the marathon: The preparation-before-preparation problems were copy-pasted from the weekly 'menus' used in the main course, 01005 and suitably re-arranged. Typically, these are much smaller – i.e. less time consuming – than even the smallest individual questions in the exam assignments used in the marathons. They are directed at one specific aspect of an already narrowly identified topic and were, in earlier versions, supplemented by *worked problems* of the same nature. This augmentation was abandoned in 2018, mostly for lack of time, and will be considered in future versions. As mentioned above, Marathon 2 was wholly devoted to the subject of *parameterization*, a decision much applauded by the students who had found this to be a thorny issue.

Apparently, the students' use of the preparation-before-preparation problems was very uneven, as some students were otherwise engaged on workdays (the marathons taking place in weekends). To this, one can probably only answer that the entire course 01003 is voluntary – but the whole structure of the course should be better described to the students in advance of the Marathons.

The solution challenge: The selected preparation problems and exam assignments were uploaded to the course LMS, one set per marathon day, the preparation problems in advance, the assignments on the day. A special folder was provided *for the students to upload their proposed answers*, thus introducing the first true 'active learning' part of the enterprise. Much goading was needed before this actually started rolling, but suggestions did appear and more followed, even if the hoped-for avalanche remained a modest snow fall.

A total of 11 files containing around 6+6+3+9+7+7+11+16+7 70 answers (one file was corrupted, and many files contained answers of highly varying degree of detail and precision). A much better way of providing further feedback must be developed to support this part of the course. On the whole, however, it must be considered a success.

The wiki: A wiki was provided for the students, with two special (groups of) pages:

- The FAQ: Students were encouraged to upload questions to a FAQ page. They were also encouraged to provide answers, but shied away from this, leaving the task to the 'service centre' (the present author)

- The round table discussions: For every three assignments in the 'marathon' sets, two questions for reflection were asked and the groups encouraged to upload their best answers. This, fortunately, was a success, again modest, but sufficient to provide meaningful clues to further activities

The questions actually asked by students were mostly very narrowly directed at specific assignments:

> Q: Er der nogen der har en idé til hvordan man løser opg3F: Niveaukurver og gradienter. Jeg har sat udtrykket for funktionen lig med c: x^2-2*y = c og dernæst isoleret for y så udtrykket bliver: y = (x^2/2) - (c/2). Men her går jeg i stå.

The question is: How do I solve assignment 3, question F? The answer, provided by the author, points out that the solution offered as part of the question is essentially complete.

The wiki clearly provided a tool for the students to reflect and ask; but as for answering each other's questions, the students shied away. The reason may well be that the students haven't established sufficient self-confidence, even if they are not afraid to publish answers to the set question (cf. The solution challenge).

Fortunately, the round table discussions led to some reflections and gave the author – and, it is hoped, the participants – some insight into to the deeper aspects of the concepts covered by the course. An example of the discussion subjects and the answers uploaded are:

1. Hvorfor betyder det noget for parameterfremstillingen, at der kræves en normalvektor i en bestemt retning?

   Svar til 1:

   Det betyder ikke noget for parameterfremstillingen at normalvektoren skal vende en bestemt retning, da man kan vende sin tangentvektorer efter ønskede fortegn. (Fordi at normalvektoren skal have et bestemt fortegn på z-koordinaten. Omløbsretningen er vigtig for fluxen.)

(The question is about the connection of the choice of orientation of the boundary, the direction of the normal vector and the sign of the integral in computing the flux. The answer shows the group's attempt to express this connection in their own words).

The 'unit operations': After each chapter of the notes, the author identifies those 'mathematical unit operations' one must master to be able solve problems of the kind described. Each students group could thus summarize the solution of a problem using a sequence of these unit operations.

This part of the total effort was a partial failure as the students did not have blackboards at their disposal and thus could not make use of the 'unit operations' originally intended, viz. as a kind of stenography in summarizing how they had they had solved a given assignment. Examples of 'unit operations':

- It is a unit operation to describe (x, f(x)) as parameterized by x
- It is a unit operation to describe ((x, y, f(x, y)) as parameterized by x and y
- A 9-step process leading to a parameterization of a curve and its accompanying tangent plane can be resolved in unit operations

etc. With no practical outcome it is hard to assess the value of this idea; but the author feels that 'more research is needed', anyhow.

The wiki eventually contained 12 'deep' questions on the FAQ, some with elaborate illustrations; and there were 17 round table discussions. There was also a substantial number of emails to the author, some of them transferred to the FAQ. Altogether, this shows that the students are serious about these new possibilities and that active learning is possible even under these somewhat trying conditions.

Other than the above, it must be mentioned that the author provided a continuing stream of comments and cheeruppance via the LMS messaging service. The students appear to have received this in a positive spirit.

4 Overall results 2018 and further ideas

85 students were enlisted, an automatic process, i.e. students must explicitly sign themselves out. Around 50 students showed up for the marathons, the number varying as did indeed the composition of the group.

Around 80% of the enlisted students passed the exam (precise numbers have not been revealed, presumably to avoid the formation of rumours pertaining to the difficulty of the course). Participants' evaluation of the efforts and results of the four days and of the material provided were positive: On a scale from 1 to 5 with 1 as the lowest, the question "Did the course help you?" has 1 student giving it the mark 3, 4 the mark 4 and 10 the mark 5. (Other questions, mainly concerned with the study activity, are answered in accordance with the descriptions given above). Of the 12 comments, 11 are unconditionally positive, 1 contains only wishes for future versions. This is in line with results and comments from previous years, which have helped forming the 2018 version.

The course can be said to represent a *structured action learning* approach: Given its constraints with respect to time and space, it presents a rather firm outline and limited freedom in terms of e.g. goal setting (Latham and Locke, 1991). It nevertheless provides an opportunity for the students to do much more than simply solving as many of the assigned problems as possible. Goal setting in general, and in particular the question whether students have a clear mental picture of the difference between *learning* goals and *achievement* goals (Cianci et al, 2010) will be central issues in future versions of this miniature course.

5 Conclusion

The title may claim more than can be granted, but the message remains: Even a miniature course with practically no other purpose than to bring as many students as possible safely over the last hurdle between them and a very well-defined operational goal – passing a specific exam by mastering certain mathematical calculations – can benefit from the methods and philosophy of active learning. Introducing such methods within narrow confines has required a bit of ingenuity, and not everything attempted has met with success. It is nonetheless the author’s hope that the efforts described here may inspire similar – or vastly different – experiments.

Acknowledgements

The author would like to thank his colleague and co-instructor, Iben Sig Buur Bækgaard, for her effort to make 01003 2017 and 2018 successful and for her many constructive ideas and comments as the course developed.

References

Bonwell, Charles C., and JamesA. Eison. 1991. *Active Learning; Creating Excitement in the Classroom*, ASHE-ERIC Higher Education Report No. 1, Washington, D.C

Namok Choi, *Self-efficacy and Self-Concept as Predictors of College Students’ Academic Performance*, Psychology in the Schools, Vol. **42(2)**, 2005

Cianci, A. M et al, *Achievement Goals, Feedback, and Task Performance*, Human Performance, **23**:131–154, 2010

Csikszentmihalyi, Mihaly (1990). *Flow: The Psychology of Optimal Experience*. New York: Harper and Row

Hansen, P.S., The secret of Action Learning, *Proc. 4th International Workshop on Active Learning in Engineering* (© SEFI-ALE), 2004

Hansen, P.S., *Death by x and y – a mathematician’s lament*, ETALEE 2017

Latham, G.P. and G. Locke, *Self-Regulation through Goal Setting*, ORGANIZATIONAL BEHAVIOR AND HUMAN DECISION PROCESSES **50**, 212-247 (1991)

Abstracts/Papers
Hands-on Sessions
Friday 10.30 - 12.00

	Hands-on session 1 Room 03.040	Hands-on session 3 Room 03.145	Hands-on session 3 Room 03.039	Hands-on session 4 Room 03.016
Friday 10.30-12.00	**IUPN networking group for Innovation:** **Pursuing the good case for innovation learning**	**How to conceive the right problem:** **A method to reframe problems**	**Using virtual reality technology as an educational tool**	**IUPN networking group for Sustainability:** **The challenge of teaching sustainable systems design**
Author(s)	Steffen K. Johansen, SDU Hanne Løje, DTU Villads Keiding, DTU	Claus Thorp Hansen, DTU Sara Grex, DTU Hanne Løje, DTU Pernille Andersson, DTU	Claus Melvad, AU	Ulrik Jørgensen, AAU Andrés Valderrama, AAU
Chair	Leila Schmidt, VIA	Jørgen Røn, SDU	Pernille Andersson, DTU	Mona Dahms, AAU

Pursuing the good case for innovation learning

Steffen Kjær Johansen
SDU Engineering Operations Management, University of Southern Denmark, Denmark,
skjo@iti.sdu.dk

Hanne Løje
Center for Bachelor of Engineering Studies, Technical University of Denmark, Denmark,
halo@dtu.dk

Villads Keiding
Center for Bachelor of Engineering Studies, Technical University of Denmark, Denmark,
vkei@dtu.dk

ABSTRACT

Keywords - real-life cases, intrapreneurship, innovation, learning

Please indicate clearly the type of contribution you are submitting: _X_ hands-on, ___explore.

Background

Innovation projects are rapidly becoming an integrated part of study programmes in Denmark (DEA, 2014) and in other countries (Zhang *et al*. 2013). Government and society at large expect students to be able to transform gained knowledge into business, i.e. value creation, and innovation is seen as the method to accomplish this. This expectation is a relatively new phenomenon. Innovation courses have, for at least a couple of decades, been available to students of especially economics and to some extent engineering. Traditionally those students were taught innovation theory with little or no practical components. This has changed radically. Today innovation courses are very hands-on with very strong elements of experience-based learning. At times these courses are purely entrepreneurial in the sense that students are asked to develop a business plan from scratch. There is a growing realization, however, that most students will end up in existing companies; in other words, they will not become full blown entrepreneurs. The innovation courses are therefore shifting from *entrepreneurial* courses to *intrapreneurial* courses.

The most progressive intrapreneurial courses ask the students to innovate within a company framework, i.e. with real companies' real-life innovation projects. In such settings, where the otherwise somewhat difficult innovation concept comes alive, the students gain practical experience with real-life innovation and value creation (Løje *et al*.2017). The students are typically presented with a project framework that stipulates the area of innovation interests, any solution constraints pertaining to it and other details important to the students (e.g. expectations regarding data sharing and level of involvement with and by company representatives). The project framework, in our experience, turns out to be a very subtle thing to work with. We have often faced the paradoxical conclusion that projects with project frameworks that we deemed very good in fact were not so good and vice versa.

A project can be successful from the point of view of any one of the three primary actors, i.e. of the students, the company or the teacher, but not the others. A project which e.g. leaves the company dissatisfied by proving the premises formulated by the company wrong through concluding that no solution is possible within the given constraints can be a result of a well facilitated process and lead to deep learning and top grades for the students. A project in which e.g. a company feel deeply inspired by something proposed almost accidently by a group of students may not result in a satisfactory level of reflection on behalf of the students resulting in a poor learning outcome and a low final grade. A project can e.g. leave a company satisfied by providing the expected delivery and result in satisfied students who have experienced a process which have not forced them outside their comfort zone but at the same time leave the teacher with a feeling that deep learning was not achieved.

The question arises if it is at all possible to design a project framework that guaranties satisfaction for all three primary actors. Designing the project framework is typically a task that befalls the teacher and a company representative, and this process is by nature highly complex. It implies aligning views on innovation and expectations of outcome, and this is not achieved at a particular moment in time; it is ever an ever-ongoing process. We may have to relinquish the idea of having a fixed project framework from the start of the course and onwards and accept the dynamic nature of the project framework design process and allow for it to change throughout the entire course.

Because of the above, we teachers need to shift focus from optimizing the concrete project framework, presented to the students at the course start, to optimizing the entire project framework design process spanning from the very first company contact to the last student has left the exam room and maybe even after that. What, then, makes that process a good process that will leave all primary actors satisfied in the end? This is the question that we want to explore in this hands-on session.

Hands-on session

The authors will first introduce the research question outlined above and describe why this is both relevant and important and which dilemmas we see (10 minutes). Then the participants will be grouped and asked to discuss questions formulated in advance by the authors. The groups will have time to discuss the group members' own experiences with real-life company innovation teaching and what the good case for innovation learning is (20 min). The group session will be followed by a plenary summing-up session (10 min). Then the groups will continue the discussion but now focusing on designing the good 'project framework design process'. At the end of the session, the groups will present the results of their discussions and this will be followed by a plenary discussion, evaluation and conclusion (20 minutes). The authors will facilitate the discussions throughout the session.

Expected outcomes

The expected outcomes from the session is more knowledge about and ideas for the development of the project framework design process for working with companies in relation to innovation courses. The authors will continue with the development of such a framework, which can be used in courses at our own universities but also at other educational institutes. Furthermore, the framework will be described in relevant papers for engineering education.

References

DEA (2014). Fra forskning til innovation – om virksomheders brug af erhvervsrettede forsknings- og innovationsordninger entreprenørskab på universiteterne – fra vision til hverdag https://dea.nu/sites/dea.nu/files/dea_-_entreprenoerskab_paa_universiteterne_-_fra_vision_til_hverdag_2014.pdf

Løje, H., Andersson, P. H. and Grex, S. (2017). Improving innovation and multidisciplinary competences among bachelor of engineering students, Proceedings of the 45th SEFI Annual Conference 2017, pages: 380-388, 2017, Brussels. Presented at: 45th SEFI Annual Conference, 2017, Angra do Heroísmo

Zhang, F., Kolmos, A., and De Graaf, E. (2013), Conceptualizations on Innovation Competency in a Problem- and Project-Based Learning Curriculum: From an Activity Theory Perspective. International Journal of Engineering Education, vol 29, No1, pp 3-16

How to conceive the right problem: A method to reframe problems

Sara Grex Center for Bachelor of Engineering Studies, Sarg@dtu.dk, **Hanne Løje**
Center for Bachelor of Engineering Studies, halo@dtu.dk, **Pernille Hammar Andersson**
Learning Lab DTU, pea@llab.dtu.dk, **Claus Thorp Hansen**
DTU Mechanical Engineering, ctha@mek.dtu.dk, Technical University of Denmark

ABSTRACT

Keywords **-** facilitation, innovation processes, reframing, problem definition

Please indicate clearly the type of contribution you are submitting: __x_ hands-on, ___explore.

Background

The number of innovation and entrepreneurship activities in engineering educations are growing (Rae & Melton, 2016). Innovation and entrepreneurship activities can be categorized as being "About", "For", "Through" or "Embedded" (Pittaway & Edwards, 2012). Even if different forms of innovation and entrepreneurship activities in engineering educations exist, they all have in common that the innovative process is by nature iterative, where problem understanding including conceiving the right problem to solve are central activities (van Boeijen et al., 2014; Hurmelinnea-Laukkukanen & Heiman, 2012).

During their education engineers and engineering students are trained in solving well-defined problems. The problems might very well be complex, technical advanced and hard to solve, but students learn methods and approaches to tackle this type of problems. However, innovation activities are characterised by solving open problems, i.e. problems where there does not exist an infallible procedure that leads the engineer to a satisfactory solution (Eekels & Roozenburg 1990). When confronted with an open problem it is not trivial to figure out what the right problem to solve is (Wedell-Wedellsborg 2017). If you are stuck on a problem, it often helps to look at it from another perspective and try to find out what are the causes of the problem. This is an important competence to support engineering students to develop. Reframing can be one of several useful methods how to tackle problems to be used in Engineering Education. The point of reframing is not to find "the real problem" but to see if there is a better one to solve (Wedell-Wedellsborg 2017). It is important to be aware of that problems typically are multi-causal and can be addressed in many ways. Wedell-Wedellsborg (2017) has proposed seven practices for effective reframing:

1. **Establish legitimacy**. All in the group should know the method and accept to use it.
2. **Bring outsiders into the discussion**. It can be a good idea to get an outsiders perspective on the problem and ask them to come with inputs.
3. **Get people's definitions in writing**. Very seldom, a group of people can agree on one idea. Therefore, it can be valuable to have each idea on paper.
4. **Ask what is missing**. Often people pay less attention to what is not described. Therefore make sure to ask explicitly what has not been mentioned.
5. **Consider multiple categories**. Ask the invited people to identify specifically what category of problem they think the group is facing and then try to suggest other groups.
6. **Analyze positive exceptions**. Look when the problem did not occur – by asking what was different about those situations? By exploring such positive exceptions sometimes called bright spots, which can often uncover hidden factors whose influence the group may not have considered

7. **Question the objective**. Focus on the objectives of the different parties involved. First clarify all the objectives and afterwards challenge them in order to uncover hidden objectives.

Reframing can be a powerful tool for engineering students to tackle open problems in a more qualified way. Besides reframing, as a method to handle problems in a better way, it can also be useful to teach engineering students how to do field research and how to meet customers, users and other relevant parties, e.g. maintenance persons. It is neither thinking nor testing alone, but a marriage of the two that holds the key to radically better results in problem solving (Wedell-Wedellsborg, 2017).

Hands on session

Introduction

The method "Reframing" will be introduced and examples of how it can be used in teaching activities in an innovation context will be presented. (10 minutes).

Hands-on activity

The next step will be to conduct a reframing exercise with the focus "*How to ask the right question and solve the right problem*". The participants will be grouped into smaller groups. Each group will get a problem/challenge to which they apply the reframing method by Wedell-Wedellsborg. At the end of the session, there will be wrap up of the discussions. (60 minutes)

Discussion and conclusion (20 minutes)

In the last part of the session, the participants will discuss the result of the hands-on activity and share their experiences within this topic of problem solving.

Expected outcomes/results

The expected outcome from the hands–on session is creation of new experiences for workshop participants on how to use the reframing method as an example to find the right problem to solve. The participants will be provided with ideas to use in their own teaching.

References

Eekels, J. & Roozenburg, N.F.M (1990) "Preface" in "EVAD – Evaluation and Decision in Design" (Eds. N. Roozenburg & J. Eekels), Edition Heurista, 1990.

Hurmelinnea-Laukkukanen, P. & Heiman, B. (2012). Finding the right problems to solve: value creation unpacked. Baltic Journal of Management, 7 (3), 238-250)

Pittaway, L. & Edwards, C, (2012) Assessment: examining practice in entrepreneurship education, Education + Training, 54 (8/9), pp.778-800,

Rae, D. & Melton, D.E., (2016). Developing an entrepreneurial mindset in US engineering education: An international view of the KEEN project. The Journal of Engineering Entrepreneurship, 7 (3), 1-16

van Boeijen, A., Daalhuizen, J., Zijlstra, J. & van der Schoor, R. Delft Design Guide. BIS Publishers (ISBN: 97890 6369 327 5)

Wedell-Wedellsborg, T. (2017). Are you solving the right problems?. Harvard Business Review, 76-83

Using virtual reality technology as an educational tool

Claus Melvad, Christian S.V. Sørensen, Christian I. Brahe
Aarhus University School of Engineering
Denmark
cme@ase.au.dk

ABSTRACT
Virtual reality, simulation, mastery learning, gamification, virtual learning environment

Please indicate clearly the type of contribution you are submitting: _X_ hands-on, ___explore.

Practical experience in the workshop is an important part of the mechanical engineering education. Knowledge of machining capabilities, and especially limitations, is essential when designing new hardware. The industry often requests engineers with more practical experience and better workshop skills. Aarhus School of Engineering faces the problem of facilitating practical workshop training for the growing number of students. Due to a lack of the required capacity of workstations and staff, only about 15% of students are able to participate in the workshop class.

Immersive virtual reality lets a user experience a virtual world via a head mounted display. The user is able to interact with the environment using controllers and receive feedback via visuals, sounds and haptics. This allows students to handle virtual object and work with expensive and dangerous machinery unsupervised, and even at home. As an additional benefit, the virtual world facilitates a framework for immediate and customized feedback for each student. Each individual controls the amount of repetitions, the pace and difficulty of the exercises.

The simulation aims to address the need for additional workshop experience by simulating a complete workshop virtually. By integrating the virtual workshop as a part of the course Production-technology all students will get a better understanding of the machining trade. Research shows multiple indications of how VR can be a powerful educational tool (Dinis, 2017), and gamification can serve as a compelling motivator (Eleftheria, 2013). The project will also serve to increase the interest in the practical skills among youths, and function as an appetizer for the technical educations.

The method for learning outcome evaluation will be *efficient learning desing* and *mixed methods research design* (Cresswell 2017). This purpose of this evaluation is both a) to enhance the program as well as b) form a general study of the specific potential for learning using VR.

This workshop will contain information on the general state and use of VR. Afterwards the short presentation, you have the opportunity to try our demo for *Craftio* and form your own opinion about the opportunities using this technology for learning.
Join us to experience and discuss the opportunities of VR learning:

- Highly controllable environment
- Gamification as a means for motivation.
- Mastery learning, flipped learning and experiential learning with VR

REFERENCES

Fábio Matoseiro Dinis, Ana Sofia Guimarães, Bárbara Rangel Carvalho, João Pedro Poças Martins, *Development of Virtual Reality Game-Based interfaces for Civil Engineering Education,* 2017, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7943000&tag=1

Chantzi Athanasia Eleftheria, Plessa Charikleia, Chatziparadeisis Gkanas Iason, Tsakalidis Athanasios, *An Innovative Augmented Reality Educational Platform Using Gamification to Enhance Lifelong Learning and Cultural Education,* 2013, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6623724

Cresswell & Clark, *Designing and Conducting Mixed Methods Research*. Sage Publishing, 2017.

The challenge of teaching sustainable systems design

Ulrik Jørgensen,
Dept. of Planning, Aalborg University, Copenhagen, Denmark
uljo@plan.aau.dk

Andrés Valderrama,
Dept. of Planning, Aalborg University, Copenhagen, Denmark
afvp@plan.aau.dk

ABSTRACT

Keywords – sustainable design, systems design, systemic change

Please indicate clearly the type of contribution you are submitting: ___ hands-on, _X__explore.

Background

The authors of this paper work at Aalborg University offering the educational program Sustainable Design Engineering. At the same time, we are researchers at the Centre for Design and Innovation for Sustainable Transitions. These two institutional affiliations reveal our normative purposes: we are committed to support processes of transition towards sustainability through design at various scales. Our effort, thus, imply facing several challenges central to the analytical content of this paper.

Explanation

We present the program Sustainable Design Engineering, where Science and Technology Studies theories are a core element among design and engineering approaches. Our main claim is that existing product centred and short-term oriented solution tools and knowledges are inadequate for system design in a transition perspective. To become so, design should be upgraded in order to tackle controversies and engage in proposing how to navigate conflicting matters of concern and partial systemic clashes with a long-term scope.

Set up

In the workshop we will present results from a student project developed during the second semester of 2016 to illustrate the type of decisions the students take and the difficulties they face. The project in question dealt with the planning of a new neighbourhood that was to be built in the island of Amager, about 3 km from the city centre of Copenhagen as part of a long-term development of Ørestad, a new part of Copenhagen.

Expected outcome

Workshop participants will be invited to discuss the conclusions of our studies.

REFERENCES

Directions in the Sociology and History of Technology. Cambridge, MA: MIT Press

Geels, F. W., Berkhout, F., & van Vuuren, D. P. (2016). "Bridging analytical approaches for low-carbon transitions". *Nature Climate Change*, *6*(6), 576. https://doi.org/10.1038/nclimate2980

Majoor, S. (2008). "planning ideals in a neo-liberal context, the case of Ørestad Copenhagen". *International Planning Studies*, 13(2), 101-117.https://doi.org/10.1080/13563470802291978

ETALEE2018

DTU Technical University of Denmark

AALBORG UNIVERSITY DENMARK

SDU

VIA University College

AARHUS UNIVERSITY SCHOOL OF ENGINEERING