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Kolmos, Anette; Holgaard, Jette Egelund; Clausen, Nicolaj Riise; Bylov, Stine Møller

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Transition from high schools to engineering education

A. Kolmos

Professor

Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University

Aalborg, Denmark

E-mail: ak@plan.aau.dk

J. E. Holgaard

Associate Professor

Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University

Aalborg, Denmark

E-mail: jeh@plan.aau.dk

N. R. Clausen

Research Assistant

Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University

Aalborg, Denmark

E-mail: nclausen@plan.aau.dk

S. M. Bylov

Research Assistant

Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University

Aalborg, Denmark

E-mail: s_bylov@plan.aau.dk

ABSTRACT

Pre-university engineering education has increasingly received attention to attract more students to engineering and make them better prepared to enter engineering studies at university level. Denmark is one of the countries that offer established high school curriculum that makes engineering the core identity of the school. In a longitudinal research project, the cohort of all Danish engineering students who were enrolled in 2010 has been followed. This study takes a quantitative approach to highlight the differences in preparedness for engineering students who have a background in respectively general high schools and professional oriented high schools where the technical high schools represent the most common pipeline. The study highlights differences when just entering the study and just before graduation. Findings indicate that students from the professional oriented high schools do experience themselves better prepared in relation to the conduct of experiments,

engineering analysis and tools, as well as in relation to process competences as design, problem solving and teamwork. The students from the profession-oriented high schools also find themselves better prepared in relation to business awareness. On the other hand, students from general high school programmes are more oriented toward ethics. After five years of study, the differences, however, are vanishing.

Conference Key Areas: Attractiveness of Engineering Education, Engineering Education Research

Keywords: Pre-university engineering education, technical high schools, transition

1 INTRODUCTION

There is increasing attention on pre-university engineering education in technology education circles to clarify the E in STEM (Science, Technology, Engineering and Mathematics) to support the technological development [1]. In some countries, specific pre-university engineering programmes have been established, and independent technical high schools have even been founded.

Denmark is one of the countries offering an established high school curriculum that makes engineering the core identity of the school as an alternative to the more traditional high school. In this paper, we take the Danish case as starting point to compare professional oriented high school programmes such as the technical high school programmes with more general high school programmes.

1.1 Denmark – a case with pre-university engineering programmes

In the Danish high school system, different types of high school degrees exist that are relevant for engineering education. These types of degrees can be divided into two categories, whereas the latter includes an explicit focus on technical competences:

- General academically-oriented upper secondary programmes, including the Higher General Examination Programme (STX) and the Higher Preparatory Examination Programme (HF)
- Profession-oriented upper secondary programmes, including the engineering-oriented programme, the Higher Technical Examination Programme (HTX), and the commercial-oriented programme, the Higher Commercial Examination Programmes (HHX).

In 2016, more than 61892 students were enrolled in Danish high schools, with 67% of the students enrolled at STX/HF, 18% at HHX and 10% at HTX [2]. In engineering education, however, an overrepresentation of students occur with a HTX degree, as they represent around 30% of the students [3].

For the professional oriented programmes, there are a considerable higher percentage of students from HTX who move to engineering education. For example, an account from the Faculty of Engineering and Science at Aalborg University shows that among students from professional-oriented programmes enrolled from 2012-

2016, 86,75% were from HTX and 13,25% from HHX. Thereby, the technical high school, HTX, constitutes an important pipeline to engineering education in Denmark.

The Danish technical high school was inaugurated in 1982 as an experiment and from 1995 it became a permanent addition to high school education [4]. The overall differences in the curriculum and the teaching and learning methodologies have been rather stable in the two types of high schools. The technical high school apply more problem and project based learning methodologies [5], [6], and has technology subjects aiming at engineering education, whereas the general high school education is more traditionally focused on a disciplinary approach and applying classrooms teaching.

1.2 Research question and methodology

Current research elaborates on the strengths and challenges of pre-university engineering education (see for example [1], [7], [8] for pre-university engineering education case stories). The question is however, whether professional oriented high school programmes are in fact increasing the preparedness for engineering education more than general high schools programmes, and if so, in which ways.

Not much research has been done on the differences between the two types of high schools and nearly nothing on the variations in the transitions from the two different systems to higher education. A Danish longitudinal study following 20 students in their transition from high school (including both HTX and STX) to higher education concludes that almost all students experience a gap between their expectations and their actual experiences with engineering and science education [9].

In this study, we compare students from the professional-oriented programmes (HTX/HHX) with general high school programmes (STX/HF) in order to clarify whether professional-oriented high school programmes actually produce students who assess themselves as better prepared for engineering studies.

The data is obtained from a longitudinal study starting out in the Programme of Research on Opportunities and Challenges in Engineering Education in Denmark, PROCEED, (2009-2013), followed up by the project PROCEED-2-Work, (2013-2018). PROCEED-2-Work has a more specific focus on the transition to and from engineering education. In these two projects, a cohort of all Danish engineering students (N=3652) is followed from their enrolment in engineering education 2010 [3], [10]. In this article, we will look at the transition from respectively STX/HF and HTX/HHX to engineering education based on the 2010 and 2015 data. The findings presented are based on frequency analysis as well as Pearsons Chi-square to be able to detect significant differences. All statistical analysis in this article were made using SPSS.

2 FINDINGS

In studying students preparedness, we have used the list of possible engineering skills developed in the Academic Pathways Studies of People Learning Engineering Survey (APPLES) prepared by the Centre for the Advancement of Engineering

Education, US [11]. According to Atman et al. [11], these items have been developed from the ABET criterion 3 programme outcomes list [12] and the National Academy of Engineering report, “The Engineer of 2020” [13]. The engineering skills items covered can be characterised as follows:

- fundamental skills in natural science, including science, maths and the conduct of experiments
- specific engineering skills, including engineering analysis and the use of engineering tools
- process competences, including problem solving, design, teamwork, creativity, communication and life-long learning,
- business-oriented skills, including professionalism, business knowledge, leadership and management skills
- contextual skills, including awareness of the societal context, global context, ethics and contemporary issues.

In the following, we present our findings on how prepared students assess themselves to be in this respect when 1) entering engineering education 2) being at the end of the study.

2.1 Perceived preparedness entering engineering education

Figure 1 show the frequency and significance level (* $p < .1$, ** $p < .05$, *** $p < .01$) in the 2010 data considering students, they felt well prepared to apply the emphasised engineering skills.

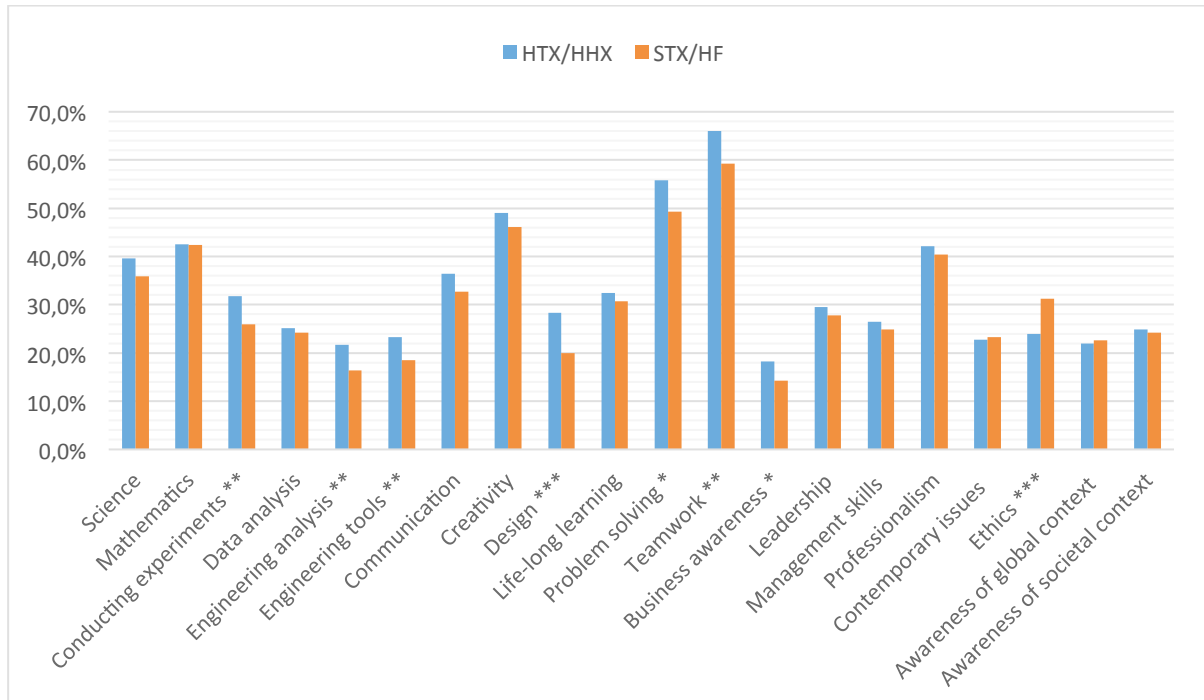


Fig. 1. Frequency and significance correlation(* $p < .1$, ** $p < .05$, *** $p < .01$), 2010 data (N=1241). The score show the percentage of students who felt prepared to apply the listed engineering skills.

For the specific engineering skills, including engineering analysis and the use of engineering tools, the students from HTX/HHX felt significantly better prepared. This result mirrors the HTX identity as engineering-oriented. For the so-called fundamental skills in natural science, the HTX schools have a higher sense of preparedness, although this difference is only significant for the “conducting experiments” item (**). These conclusions should be seen in relation to the admission requirements for engineering education including that students have attended high-level courses on math and selected natural scientific subjects.

For the process competences, students from HTX/HHX find themselves significantly more prepared in regard to design (***), teamwork (**) and problem-solving (*), whereas no significant difference occurs regarding communication, life-long learning and creativity. Thereby, the higher emphasis on PBL and the ability to “create” actual products at HTX does not seem to lead to a higher sense of preparedness considering creativity compared to students at the general high school. On the other hand, teamwork and problem solving elements of Problem Based Learning (PBL) are clearly reflected in the results.

Regarding business-oriented skills, including professionalism, business knowledge, leadership and management skills, there were only significant differences in regards to business awareness (**). The latter might be related to the increased possibility to focus on specific lines of professions in HTX/HHX schools. It is however notable that the considerable higher preparedness in terms of process competences are not aligned with the items related to business process, like business management and organisation.

For the contextual skills, students from the general education feel significant more prepared in related to ethics (**). On all other items (global context, societal context and contemporary issues), the students from the general education have a higher, but not significant, sense of preparedness.

2.2 Perceived preparedness at the end of the study

Table 1 presents the significant differences in preparedness in 2010, as presented in the previous section, compared to the account of significant differences in 2015,

	2010		2015	
	HTX/HHX	STX/HF	HTX/HHX	STX/HF
Conducting experiments	**			
Engineering analysis	**			
Engineering tools	*			
Design	***		*	
Problem solving	*			
Teamwork	**			
Business awareness	*			
Ethics		***		

Table 1. Significance correlation (* $p < .1$, ** $p < .05$, *** $p < .01$) in 2010 data (N=1241) compared to 2015 (N=1823). The data accounts for students stating that they felt prepared to apply the listed engineering skills.

As can be seen from table 1, the differences in the sense of preparedness have been evened out through the engineering study. In a critical perspective, this might be due to teaching based on the lowest common denominator, whereas a more positive mind-set could lead to assumptions about effective peer-learning and synergy in teamwork settings and situated facilitation of students. No matter the reason, attention to this alignment process could play a higher role in engineering education research.

But what can also be seen from table 2 is that HTX/HHX students are still feeling significantly better prepared to face design challenges at the end of the study compared to students from STX/HF. Based on previous PROCEED studies, Kolmos et al. [14] concludes that the Danish Engineering students does not emphasis design as much as their US peers. However, taking the tradition of Problem Based Learning (PBL) in Denmark into consideration, it is a possibility that students (and staff for that matter) conceptualise what others might call design processes in a PBL discourse. In other words, the processes of exploring potentials to solve problems or exploring problems to create solutions including the concern for societal as well as users needs, which is embedded in PBL incorporates design perspectives – but might not be characterised as such.

3 DISCUSSION

Henriksen [4] has used a qualitative approach to study whether the HTX technical high schools prepare Danish students for a future as engineering students. The conclusion from this study is that the ministerial framework constitutes a useful framework, but at the same time a call exists for a more in-depth discussion of the concepts ‘engineering’ and ‘technology’ and a recommendation to develop the pedagogical basis for students’ to work interdisciplinary and problem orientated even further. This is aligned with other prescriptive frameworks, as for example the Standards for Technological Literacy from the International Technology and Engineering Educators Society”, which have explicit emphasis on problem orientation and a multi-disciplinarily approach in grades 9-12 [15].

Taken into consideration the early inspiration from PBL at the Danish technical schools, they seem to have chosen an appropriate pedagogical starting point when we look at the high level of preparedness related to process-competences as teamwork and problem solving. However, in the merging of students with different educational background, it can be discussed whether to much emphasis on one educational model can in fact limit the cross-fertilisation of knowledge among students. A hypothesis could be that some students from the general high-school feel behind in relation to project oriented matter, whereas students from and engineering-oriented high school could be troubled by the broader system thinking and contextualisation embedded in engineering. The challenge is to empower the students to peer-learning activities and at the same time design study activities, which can create synergy of the different perspectives.

To design such study activities, staff need to be knowledgeable of the different perspectives they are to merge. Teacher collaboration in developing students’ study competences is essential [4]. But it might be easier said than done to train staff to embrace different cultures in a more systematic manner. Furthermore, the

awareness of the differences as well as the potential synergies in the two streams in the pipeline to engineering education highlighted in this study raises attention to the collaboration between staff at different high school levels as well as with university staff.

However to make this bridge, we come back to the need for a more in-depth discussion of the concepts 'engineering' and 'technology', or 'design' for that matter, and the need for staff training that enables staff to actually enter a such discussion. Based on Australian experiences, Thomson [16] concludes that the greatest challenge to STEM development is the lack of depth of teacher training in engineering education. On the other hand, it might also be argued that university staff needs a kind of training that enables them to move beyond own high school experience in order to understand what is at stake in the transition from high school to engineering studies.

4 CONCLUSION

In this study, we have used a quantitative approach to compare students from the professional-oriented programmes (HTX/HHX) with general high school programmes (STS/HF) in order to clarify whether engineering-oriented programmes in Denmark actually produce high school graduates that assess themselves to be more prepared to address aspects of engineering than others.

Findings indicate that the HTX/HHX students do have an easier transition to project work in engineering education as they have already been using it at the high school level. Furthermore, the HTX/HHX students are more oriented towards teamwork, design and also specific engineering analysis and tools. However, STX/HF students are better prepared to contextualise, which corresponds to the increasing focus on system thinking in engineering education.

At the end of the study, differences are however fading which leaves a discussion of the synergy of having different approaches in the pipeline to engineering education. But it also leaves a call for research on how to cope with the inevitable challenge of closing what might be rather diverse gaps between expectations and experiences when students enter engineering education.

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