The Future of Engineering Education: Where Are We Heading?

L. Gumaelius
KTH, Royal Institute of Technology
Stockholm, Sweden

Anette Kolmos
Aalborg University
Aalborg, Denmark

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ABSTRACT

The Nordic Engineering Hub has conducted a study on what engineering education will consist of in 2030. The study, conducted by universities in five different countries, focuses on the educational content and the pedagogical methods. Three major challenges have been identified as being crucial for the development of future engineering education: 1) sustainability, 2) digitalisation and 3) employability.

The first challenge is related to climate change and the 17 Sustainable Development Goals (SDGs) formulated by the United Nations (UN) that are vital for the future of the globe. The second challenge is derived from technology and science. With an expected increase in the use of new technologies, such as the Internet of Things and artificial intelligence, digitalisation will saturate all corners of society; it will also affect the engineering disciplines. The third challenge is about future conditions for employability, including the need for innovation and entrepreneurship.

For this study, professors from various engineering disciplines were interviewed with the aim of understanding their perspectives on how their discipline will be developed in the future, and what trends will dominate engineering education in 2030. The study adopted a phenomenographic approach, and, in this paper presents the initial analyses of the first five interviews. The initial analyses identify two categories: the importance of change and the role of the university. The discipline each interviewee belonged to is hypothesised to be an important factor for variations, an indication that will be followed up in future quantitative measurements. While the study is exploratory, the theory about tensions between the academic, market-driven and community-oriented modes within universities is used as a theoretical framework. The methodological approach is discussed, and it will be further emphasised during the presentation.

1 INTRODUCTION

Engineering education faces a variety of contemporary challenges that impact its future [1]. Society demands that engineers be capable of co-creating sustainable development. The importance of integrating sustainable development as a thread throughout all levels of education has been relevant for a long time, and, with the formation of the 17 Sustainability Development Goals (SDGs) [2] in combination with the contemporary climate debate, this is even more relevant to engineering education in 2030.

In addition to the challenge of sustainability, another challenge is posed by the industry demand for engineers who are experienced in project management and who have the ability to learn and adapt quickly, given that career paths will change more rapidly in the near future [1], [3], [4]. Therefore, future requirements for employability, including innovativeness and entrepreneurialism, constitute a second challenge addressed in this study. A third challenge is digitalisation, which requires engineers to have an increased understanding of systems and process skills that are integral parts of the Fourth Industrial Revolution [5], which has just arrived, in order to handle the forthcoming industrial challenges. The list describing the challenges that need to be considered in order for tomorrow's engineers to meet the needs of society can be long.

To meet those needs and achieve these goals, both content and pedagogical methods must be reviewed. However, combining the demands from all different directions might make it difficult to decide what to include in the future curricula in order to fulfil all the requirements an engineer will need to succeed in the future. Especially, it is expected that tensions will arise when employability and professional competences are as important as the ability to handle the SDGs and the new wave of digitalisation (www.nae.edu/File.aspx?id=43359) [4].

2 BACKGROUND

Jamison et al. [6] identified three university modes associated with tensions in the development of engineering education: the academic mode, with its emphasis on theoretical knowledge; the market-driven mode, with its focus on employability; and the community-driven mode, with its focus on civic society and sustainability [6]. These three modes are found in existing engineering institutions, and all three are needed to develop a future curriculum. However, the academic and the market-driven modes are the most dominant today, and, currently, tension exists between them. For example, with the development of artificial intelligence and the Internet of Things, which is essential in the market-driven (employability) mode, it is important to also develop the academic mode with new subdisciplines and interdisciplinary programmes to create a new hybrid academic mode [5].

Additionally, it is acknowledged that it is important for engineering students to acquire and learn to apply theoretical knowledge to realistic problems. Authentic problems also help students understand the range of industrial and societal practices they will encounter. Especially, the issue of employability has shifted the focus from the academic mode to a more market-oriented mode. In addition to the challenges previously mentioned, the industry requires engineers who have acquired employability competences, such as project management and the ability to learn and adapt quickly, given that career paths will change more rapidly in the near future. Therefore, these future requirements for employability, including innovativeness and entrepreneurialism, constitute relevant areas of development in engineering education.

The third important mode, sustainability, is a major issue in engineering education; it addresses the need to find solutions to climate change, the north/south relationship and the United Nation (UN) SDGs. This calls for new types of universities, such as ecological universities, with embedded social and civic values [7].

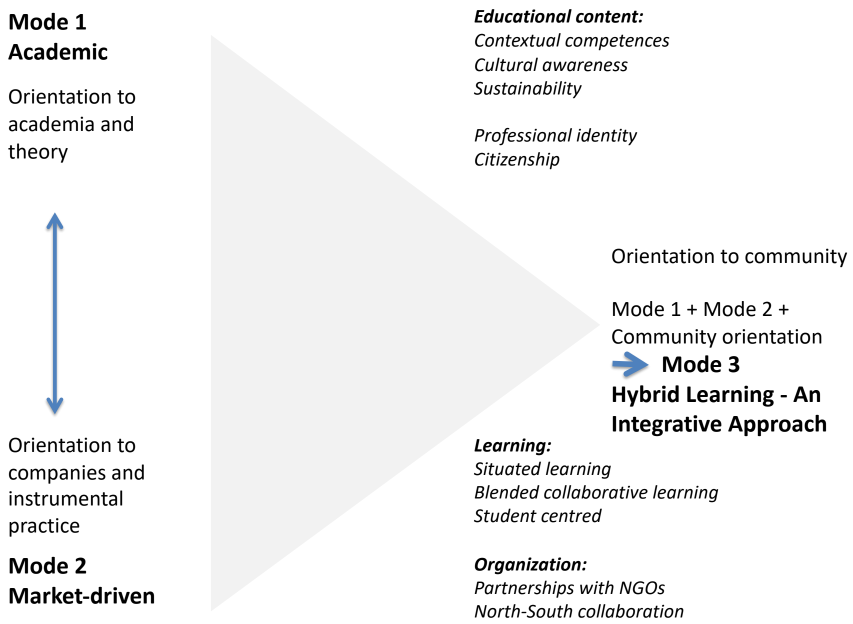

Fig. 1. Visual representation of the three university modes [6].

In the development of a three-mode education programme, based on an integrated, hybrid learning approach, the curriculum has to integrate or combine the various challenges with already existing development trends, such as: 1) student-centred learning, 2) contextual and practice experiences and 3) digital tools.

Student-centred learning methods encompass learning approaches in which students regulate their own learning processes. These methods include active learning, collaborative learning, team-based learning, design-based learning, inquiry-based learning, challenge-based learning and problem- and project-based learning (PBL). The general global trend indicates that accreditation is shifting away from content criteria towards learning-outcomes criteria. Thus, the focus is on both declarative content as well as competencies, including knowledge, skills attitudes and beliefs. The overarching trend is that education has shifted away from academic staff lecturing the students towards providing a more engaging and inclusive curriculum where students influence their direction of learning within a given academic framework. From a research point of view, there is clear evidence that student-centred learning activities have a positive effect on learning outcomes. In particular, PBL is a well-researched area; results indicate increased motivation for learning, decreasing drop-out rates and increased competence development. Increasing knowledge retention is another area in which PBL seems to have had a positive impact [8], [9]. Furthermore, PBL has been seen as a way to bridge the gap between engineering education and engineering work, thereby developing professional competences.

Conceptual and practice experiences represent an increasing educational trend that supports collaboration between private and public stakeholders. Collaboration with companies can occur in a variety of ways, ranging from being consultants or providing opportunities for students to observe practices to offering real-world collaboration and partnership experiences, where students work on solving identified problems. These collaborative projects give students a sense of the complex domain in which solutions emerge by engaging with the problem in all its real-world complexity. This trend also encompasses internships, where students are placed in companies while completing their studies to develop an understanding of the complex-problem situations in which they will be engaged after graduation. Normally, internships are regulated at a political level. In many countries, this has shifted from being a dominant part of the academic curriculum, with fewer internships and collaboration with external stakeholders, to a more practice-related curriculum, with more collaboration (also known as academic and employability drifts). The subject of internships is not a well-researched area in terms of documenting the students' learning outcomes. Positive outcomes have been reported regarding an increased understanding of future work, the application of academic knowledge and motivation for academic learning, but negative outcomes have also been reported, such as the lack of relating academic and practice, which is most often caused by the lack of facilitating the learning process in the workplace.

Learning with the help of digital tools (including the flipped classroom) is a relatively new trend that is still in its early phase. Massive Open Online Courses (MOOCs) and the flipped classroom are two of the icebreaking digital methods that aim at increasing the nature and quality of learning. MOOCs are unique in that they offer educational resources in a nearly 100% distance and virtual mode. The flipped classroom has influenced the development and quality of education by applying active learning and digital methods as alternative ways to present the learning content. Typically, the online part consists of a structured preparation, including videos, quizzes, reading or a collaborative activity, before the students and teacher meet in the classroom. The class is dominated by learning activities that prepare students for their assignments.

3 RESEARCH QUESTIONS

Each of above-mentioned educational trends has been applied in engineering education all over the world with various levels of success and various degrees of integration into the curriculum. Most often, the trends can be seen as “pockets” in the curriculum; they are rarely implemented at a systemic level.

In this study, we investigate the following research questions: How will these trends influence engineering education in the future? How will the trends influence academic research? Will there be a parallel development of research and education? What possible directions can be identified for engineering education in 2030?

4 RESEARCH PARTICIPANTS

Four professors at each of the five partner universities were selected to participate in a semi-structured interview [10]. The professors represent the following four engineering disciplines.

1. Biotechnology engineering
2. Mechanical (or industrial economy or production) engineering
3. Energy engineering
4. Civil engineering

The interviews were conducted by two people: one main interviewer and one representative from the university. On average, each interview lasted about one hour.

5 METHODOLOGY

A phenomenographic approach was chosen for this study because it provides an unconditional starting point for analysing the phenomenon, engineering education in 2030, based on the criteria presented by Ashworth and Lucas [11]. The study is exploratory; the interviewees were asked to give their personal perceptions of how they see the phenomenon and to also share how and why they developed those viewpoints.

One week before the interview, the interviewees were provided with the interview protocol, including the questions and short texts presenting the three contemporary challenges the informants were asked to reflect upon. The following questions formed the basis of the interviews.

1. How do you think the challenges (sustainable development, digitalisation and employability) affect the development of your discipline and the educational programme(s) you are involved in?
2. What do you expect the situation to be 10 years from now?
3. How do you prepare your students for the future using today’s educational resources?
4. How will students learn engineering in the future?
5. Are there other challenges ahead that we have not mentioned?

It should be noted that these questions were provided only as a guide for discussion; probing questions were used in each of the interviews to further elicit the interviewees' perspectives on the observed phenomeon.

The interviews were transcribed verbatim. In addition to analysing the transcripts, attempts were made to capture the moods and interpretations inherent in them, which can strengthen our interpretations. Analysis of the transcripts included identifying categories and addressing variations within the cohort of 20 participants representing the various disciplines and countries. This number of participants is considered sufficient to reach an acceptable level of trustworthiness.

6 RESULTS

The interviews with the faculty members were conducted in late spring 2019. For this first presentation of the preliminary results, five interviews were analysed, representing two of the five participating universities. In the initial analyses conducted to date, two more general categories were detected with two dimensions of variation in the respondents' perceptions.

Category 1: The importance of change. A large variation of perceptions was found regarding the importance of change in order to meet contemporary challenges. Some of the interviewees even expressed a reluctance towards change; they felt that ongoing trends might have a negative impact on the competence of future engineers.

For example, a chemical engineering professor said*: "...but I see the risk of actually the lack of competences in the future, because everyone is trying to be very generalist and broad. And that comes in some way in contradiction to being in-depth."*

This professor reflected on the need for deep content-knowledge in chemistry that is required to understand contemporary sustainability issues. At the other end of this variation dimension, we found professors that see the need for change in engineering education as being vital.

A mechatronics professor said: *"The future needs T-shaped engineers instead of I-shaped engineers; they need to have basic knowledge, but also knowledge in other areas, like safety, ethics ... there is enormous pressure on new technology of today– software can be hacked, which may be lethal … safety is very important."*

This professor claimed that engineers have to acquire better competence in some areas that have not been prioritised until now in order to contribute in future technology development. Both professors viewed the technical evolution as being extremely fast, and they noted that education needs to be adapted to the Fourth Industrial Revolution in the very near future. In this category, there is a trend in that the disciplines seem to be important factors in the variations that are noted. In the more science-dominated engineering disciplines, including biotechnology and energy, subject-specific core knowledge is highly valued. But, for disciplines that are closer to production, professors anticipate significant changes due to digitalisation and the Fourth Industrial Revolution.

Category 2: The role of future engineering institutions. As the interviewees discussed engineering education, they also reflected on the overall, future role of universities. This became the second category. Clear variations were seen in this category. At one end of this variation dimension, the interviewees thought that universities would adapt to societal change to as large extent as possible.

A civil engineering professor said: "*Yes, I hope it will evolve regarding the format. We are noticing that there is a clear demand for flexible learning…."*

This professor thought that engineering programmes, and the need for graduation, might disappear. Instead students/people will bring a file with them that provides information about the courses they have taken, and the file will be updated throughout their professional life.

However, some professors expressed a more passive role for universities in the future.

A biotechnology professor said: *"...the role may be more of quality control, in order to avoid faked facts etc.…"*

This professor saw the possibility that private actors would become educators, and because universities are slow to change, they will be left with more administrative tasks, such as quality control.

Several other trends deserve to be mentioned at this stage in the research. Sustainability is often seen as a challenge that has been on the agenda for a long time; thus, it is already rather well implemented. Professors in several disciplines expected education to take an even more holistic approach so students can address the sustainability challenge. Professors in other disciplines claimed that the trend of education being more holistic and broader for a single engineer may result in knowledge drainage within the discipline and in society; therefore, they did not regard it as the only solution.

One professor said: *"We see now an evolution where students become more and more generalists and less and less specialists. And I think that's also something that sustainable development has been striving for".*

The interviewees also had various thoughts about employability and the need for more innovative and entrepreneurial skills.

A civil engineering professor said: *"Innovation is our weakest point, meaning that the 'old' culture was, and still is, that the students want a job in a big company, where they do not need to care much about being an entrepreneur and establishing new companies. However, a change is seen, and this will definitely be important 20 years from now".*

Digitalisation is an area where the interviewees in all the engineering disciplines seem to agree that a change was needed. Some professors said that they do not yet have the ability to foresee the changes that will come, while others noted that their discipline is in the middle of this change and they already see a significant need for more digitalisation and programming in the educational curriculum.

7 DISCUSSION

The mode that is described as being the most important for engineering education in 2030 is the employability, market-driven mode. Many of the interviewees noted that reality-based problem solving will be used even more in engineering education in the future. The link with stakeholders is expected to grow, even though, as explained above, professors also see the risk of graduates not having the detailed knowledge they will need to succeed in their future career. In our analysis, the tensions between the three university modes that were described are clearly visible; the five interviewees expressed very different views on the priority of future academic quality and the need for market-driven education. It could be said that those tensions need to be emphasised when developing engineering education programmes. No perspectives should be neglected in an effort to arrive at a common vision of the development that all faculty can agree on. The hypothesis made after this initial analysis, which will be further investigated, is that those tensions are discipline-dependent rather than person/university-dependent.

The analysis did not find strong evidence for any anticipated development towards the community-driven mode at a university, although there were some indications of this as the interviewees remarked about society's influence on education.

In the Results section, it was mentioned that the interviewees identified different roles for the future of education at a university. Some of the professors expected to play a more active role than others. An idea for future analysis is to also include a question regarding engineering and its relationship to the future of society in order to identify a clearer picture of how the faculty views that relationship.

Although some preliminary results are addressed, this is a work in progress and the conference presentation will focus on the preliminary results as well as the methodology used. The advantage of using a phenomenographic approach is that it enables researchers to see variations and correlations. A disadvantage is that this methodological approach is rather complex; for example, many rules must be adhered to when using it, which can be difficult to follow.

By discussing these preliminary results and methodological approaches, we hope to increase the possibility that others will conduct similar investigations in other countries and/or at other universities. These studies would contribute by providing a comprehensive vision of how the engineering disciplines should evolve in the future to address the educational needs of engineers.

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