Combining engineering and teacher education – ideas and experiences from Chalmers University of Technology

Samuel Bengmark, Torbjörn Lundh, Philip Gerlee

1 Introduction

A successful educational system is essential for the future welfare of Sweden. Without competent young people entering the workforce our nation will find it difficult to compete with the rest of the world. Educational success is dependent on well-educated and skillful teachers. Unfortunately, Sweden has an increasing shortage of teachers, especially in STEM subjects, who can educate and inspire new generations to become engineers.

As a response to this problem, Chalmers University of Technology, as one of two universities in Sweden (Cronhjort & Geschwind, 2020), offers a double degree in engineering and education. In school, these graduates work as teachers with insights into applications of mathematics and being role models for engineering studies. In industry, they add valuable pedagogical competence, needed in an increasingly technologically advanced, and knowledge-intensive, industry.

The double degree program at Chalmers has been successful in several ways. In a national evaluation of mathematics teacher training programs, Chalmers' program was assessed as being of high quality (UKÄ, 2020). The graduates that choose to work in the industry find the breadth of the combined education, and especially leadership and pedagogical skills, important factors for their success as engineers (Cronhjort et al., 2020). The number of first-choice applicants is growing and is now around 100 per year.

2 Questions

This text aims to describe some of the main ideas behind Chalmers' combined engineering and education program, and how these ideas have worked

in practice during these first ten years. This will be done by answering the following question: Which ideas behind the design of Chalmers double degree program in engineering and education has been of special value in the implementation of the program, and what value have they added?

3 The big five

We will elaborate on five ideas behind the program design that have proven to be of great value.

3.1 Master Teachers

Skilled upper secondary school teachers are engaged in the program, called master teachers. This idea is inspired by Uteach (Marder, 2020). The master teachers contribute with knowledge about best practices and relevant insights into the teachers' reality. They are active in several courses, not least the master teachers contribute profoundly to the students' development during practicum, by having a continuous dialogue with the students via logbooks.

The master teachers participate in admissions interviews and then recurrently interact with the students, follow their development and provide feedback, both in the courses and at an annual development interview with each student. The students greatly value the master teachers' knowledge and constantly ask for more time with them.

A master teacher works 20-40% of full-time at Chalmers. Every year, a new master teacher is contracted for three years, through his or her school, hence still being fully employed at their regular upper secondary school. This system allows new teachers to take advantage of the competence development that the time as a master teacher offers. The master teacher alumni unanimously say that their time as master teachers was a period of great development for them. Reflecting on the students' teaching, formulating feedback, regularly discussing with university faculty, and preparing lessons for these students, leads to new ideas and deep insight about teaching and their practice.

The downside for Chalmers, of having experienced master teachers leave after three years, is compensated by the inspiration and insight that new skilled master teachers add to Chalmers. The master teachers are also involved in developing the program, both in developing courses and by being part of the program advisory board.

3.2 Many entrances, one exit

The student enters the studies as a regular student at one of Chalmers engineering programs, at that state maybe only aiming to become an engineer. After three years of study, i.e. a first cycle, the student can continue in a second cycle, to study one of Chalmers master's programs. The student normally has about 10 different master's programs to choose between, depending on which engineering program the student has studied in the first cycle.

To get a double degree in education and engineering the student must choose the master's program Learning and leadership. This program is one of the broader master's programs at Chalmers, accepting students from many different engineering programs. There are hence several possible entrances to Chalmers' double degree program, but only one exit, see Figure 1. As teachers, the graduates will be eligible to teach two subjects in upper secondary school, mathematics, and either chemistry, physics, and technology depending on which engineering program they have taken in the first cycle.

An advantage of this system is that the students can delay their choice to study education. We hear how the students at the Learning and leadership program have found an interest in teaching during the first cycle while helping their peer students, or working as an instructor for students in upper secondary school. This implies that Chalmers educates students to become teachers who did not choose teacher education when applying to tertiary education.

There is also an option for in-service engineers who later in life want to add a degree in education. For them, Chalmers offers a one-and-half-year version of the Learning and leadership program that excludes the master thesis project (Kompletterande pedagogisk utbildning, KPU). Hence, a mix of younger engineering students and older, experienced, engineers study together at the Learning and leadership program. This mix is appreciated by the students and adds important perspectives at seminars and in discussions.

3.3 Interviews

Personal admission interviews are used as part of the application process to the Learning and leadership program, i.e. between the first and the second cycle. The interviews have two goals. Firstly, to help the applicants to understand the goals, content, and structure of the program and what is expected of them. For example, we discuss the fact that there will be a shift in the form of knowledge they will study, i.e that knowledge in education and leadership is different and communicated differently compared with knowledge in technology, mathematics, and natural sciences.

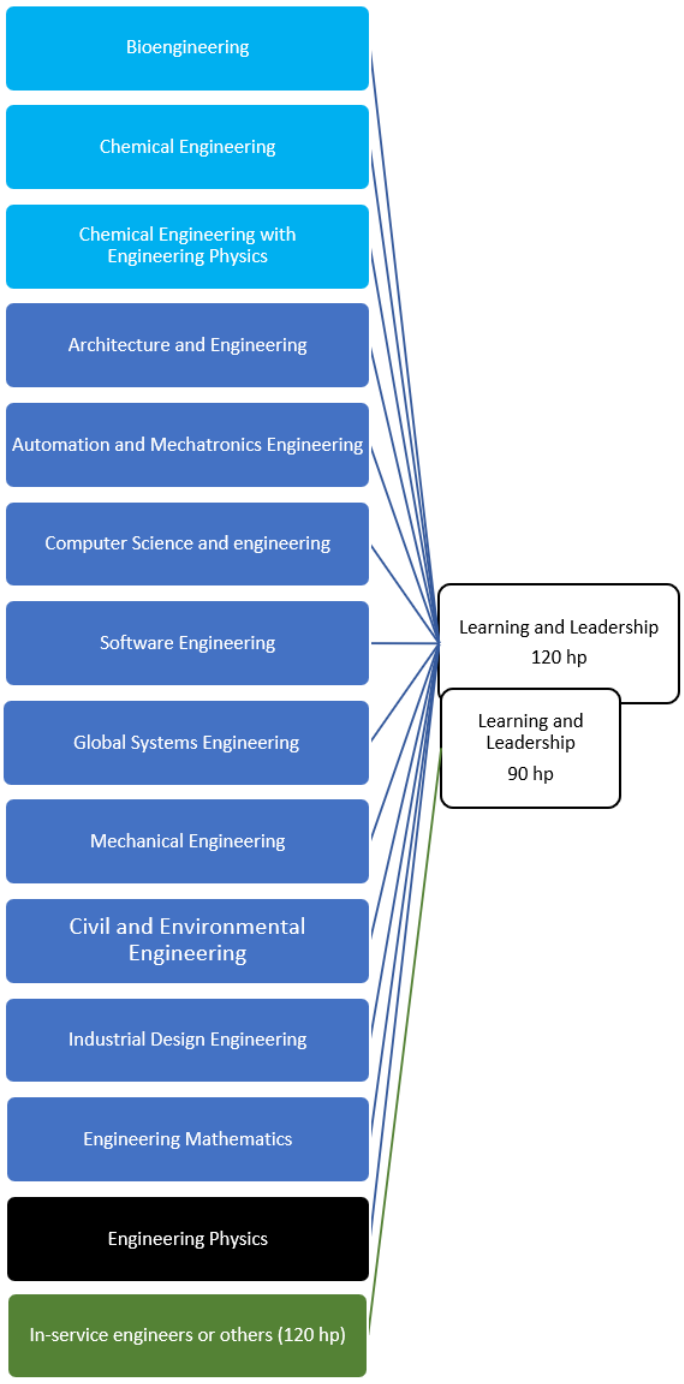

Figure 1: Many entrances but one exit, and admissions interview in between. Teaching subject combination depends on which engineering program the student has studied. The color-coding shows the teaching subject of the students, besides mathematics: light blue = chemistry, blue = technology, black = physics, and green = varies depending on background.

Secondly, the interviews aim to determine whether the applicant has a reasonable chance to complete the studies. As the students will have their first practicum, teaching in school, just ten weeks after entering the Learning and leadership program, each student has to have a reasonable ability to communicate and interact with learners. At the interview, the student is valued independently by three interviewers on five aspects: pedagogy, leadership, motives, self-reflection, and subject background. In the spring of 2020, about 82 interviews were conducted leading to 34 students being enrolled.

There is some research evidence that a selection process is positive for teacher efficiency. A meta-study by Klassen and Kim, 2019 shows a small but significant ($r=0.12$, $p<0.001$) overall effect size. At Chalmers we have noted several other, short-term, effects. The students express that being chosen makes them better appreciate the opportunity to study the double degree program. They think the interview gives a better understanding of what the studies entail. Both these aspects are reasons to why there are few dropouts (approximately 7%). Furthermore, the group dynamics among the students is considered exceptionally good, which both the students and the teachers partly attribute to the fact that the students are selected through interviews.

3.4 A competency model

In Sweden, there are 12 national objectives for the engineering degree and 24 national objectives for the subject teacher degree, some of which are composite, i.e. consisting of several different goals. To make this manageable a competency model has been developed and used in the design of the combined engineering and education program av Chalmers (Pettersson & Bolldén, 2020). The model, described in detail in (Bengmark, forthcoming), consists of three main competencies, Learning Cultivation Competency, Leadership Competency and Subject Competency, which are in turn divided into three sub-competencies each, see Figure 2.

Coherence, based on a common, clear vision of good teaching, grounded in an understanding of learning, and that permeates all coursework and clinical experience, is the number one principle for good educational design according to Ingvarson et al. (2014). The competency model has been used as a mean to accomplish this. For example, the program design matrix, which links the separate course goals to the overall goals of the educational program (Malmqvist et al., 2006), emphasizing the progression in each competence within the program (Bengmark, 2014).

The competency model is also used by teachers to motivating the course content, or content in the specific lessons, to the students. The model for

Figure 2: The hierarchical nature of the model for teaching competencies used at the double degree program at Chalmers University of Technology. See (Bengmark, forthcoming) for details.

teaching competencies is also very useful for the student, as a road map on what competencies to develop. On some occasions, during the program, the students are asked to reflect on their development within each of the competencies in the model.

3.5 From work skills to further development

The Learning and leadership program starts with a focus on practice, i.e. to learn to master established methods and tools to create lessons and manage groups. In the first courses, the students weekly teach in front of their peers, master teachers, and university teachers, and are given feedback. The methods and tools learned and practiced in that stage prepare the students for their first practicum that starts a few weeks later. According to practicum supervisors, the students are well prepared in their first practicum. The stu-

dents are happy to have practical knowledge and it makes their encounter with a real classroom less stressful and confusing. When comparing what in their education alumni think has benefited them the most in preparing them for their current professional needs, the alumni from Chalmers more frequently highlight their preparation in practical teaching methods in comparison to the other teacher education alumni (Bengmark et al., forthcoming).

Later, at the end of the first year of the Learning and leadership program, the students study theories and models of learning. At that stage, the students are familiar with some established teaching methods and have experience from classrooms, which they can link to these theories and models. Hence, the practical methods and tools do not only facilitate the students' entrance into teaching but are also used as a foundation on which the students can develop improved practices, using theory.

4 Final words

We invite other universities, not least those that already educate engineers, to take part in solving the shortage of STEM teachers. Chalmers' experience has shown that, by offering a double degree in engineering and education, new groups of students can find their way into the teaching profession. By sharing the five design ideas that have been found most valuable in the implementation at Chalmers, we hope somewhat pave the way for other universities, and inspire them to start a program combining engineering and education.

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