Chapter 11
Double Degree Programmes in Engineering and Education: Two Cases from Swedish Technical Universities

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11.1 Introduction

Technical universities are characterised by their focus on science and engineering subjects and programmes. These areas show considerable continuity over time but are also subject to renewal. As shown in Chap. 2 in this volume, some of the classical engineering programmes in mechanics, electronics, chemistry and the built environment have later been complemented by programmes in new areas, such as information technology, computer science, and biotechnology. However, as discussed in other parts of this volume, technical universities also host other academic disciplines—including from the humanities and social sciences—allowing them to integrate a broader base of knowledge and skills into engineering curricula. In some cases, such as 'industrial engineering and management', the integration of the social sciences has been taken one step further, currently representing one of the most sought-after programmes in Sweden. The topic of this chapter, how combined teacher training and engineering programmes were introduced at the two leading technical universities, should be seen in that light. However, the institutional priorities and strategies are not the whole picture. The Swedish policy background needs to be understood as well.

In recent decades, there has been a shortage of teachers in the STEM subjects in Sweden, with the situation becoming more challenging in recent years (Ahlbom and Alpman 2015; Skolverkets lägesbedömning 2017; Universitetskanslersämbetet 2015). In an effort to improve this situation, a new type of education offering two degrees—one in engineering and one in education—was introduced in Sweden in

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L. Geschwind et al. (eds.), *Technical Universities*, Higher Education Dynamics 56,
https://doi.org/10.1007/978-3-030-50555-4_11

2002.[1] This was instigated as a cooperation between KTH Royal Institute of Technology and Stockholm Institute of Education, and was supported by a governmental decision regarding this specific case, offering some financial support. The programme was prolonged by half a year compared to other engineering programmes. Today, the study time in other engineering programmes and corresponding teacher-training programmes is the same as for this combined course. This combined programme has become dominant in the field of teacher education in STEM-subjects in Sweden (KTH Annual Report 2011; Lärarförbundet 2014). A similar programme was created in 2011 at Chalmers, designed as a master's programme, also leading to degrees in engineering and education.

In this chapter, we consider how two technical universities handled the introduction of non-technical curricula in their degree offerings. We focus on the motives for commencing these two programmes, and on investigating attitudes towards this new activity. We also examine how the necessary competence was acquired. Two strategies are demonstrated in the cases included in this study. Competence can be acquired by building new groups or departments within the technical university, or by engaging in cooperation with others. We also examine how these programmes have been integrated in the organisations, which is connected to how the programmes are viewed. This study is based on contemporary documents, discussion articles, and interviews with people who were involved as either initiators or programme directors. We compare similarities and differences between the two studied cases.

11.2 The Programmes

The programmes included in the study are both taught in Swedish. It is common for teacher education programmes to be taught in the national language. At KTH and at Chalmers, courses in the later years of study in engineering programmes are normally taught in English.

The name of the programme at KTH is '*Civilingenjör och lärare*' (in English, Master of Science in Engineering and in Education, here abbreviated to CL). In the beginning, this was an engineering programme with a specialisation in teaching. The programme is a continuous, five-year programme (300 ECTS). Since it began, it has been in cooperation, first with the Stockholm Institute of Education and then with Stockholm University (SU), when the former university was integrated into SU. Other engineering programmes at KTH are composed of a bachelor programme and a master's programme following the Bologna 3 + 2 model, but this is not the case for CL. Mathematics is a dominant subject in the programme, and all graduates have mathematics as their primary teaching subject in their degree in education. The programme at KTH has a unique structure. The first year of study is common for all

[1] Similar programmes exist in other countries, e.g. Finland, Germany, Greece and Israel.

students in the programme, after which students choose one of four specialisations: physics, chemistry, information and communication technology, or energy and environmental technology. Work-placed learning (teacher practicum), courses in pedagogy, and other courses regarding teaching and learning are present in all years of study, with their major practicum session (year 4) being completed in an upper secondary school. The majority of courses in the teaching subjects are studied together with corresponding engineering programmes at KTH. In 2017, there were 481 applicants to the programme, of whom 98 applied for the programme as their first choice. Some 60 students were accepted (26 women and 34 men). Of those students who graduated, approximately 30% are employed in schools, 60% in business, and about 10% at universities.

The programme at Chalmers is called '*Lärande och ledarskap*' (in English 'Learning and Leadership, MSc progr', here abbreviated to LL). The name describes what distinguishes this programme from other engineering programmes. It is a two-year master's programme (120 ECTS). With some exceptions, applicants are welcome from most bachelor programmes at Chalmers, and those admitted to the programme come from a diversity of academic disciplines. Students having a relevant bachelor's degree can obtain two master's degrees: one in engineering and one in education. For the degree of education, possible teaching subjects are mathematics and either chemistry, physics, or technology (pre-engineering)—depending on what bachelor programme the student has studied before. In general, technology is the primary teaching subject. In some cases, the student is required to have studied certain optional courses in order to obtain two teaching subjects. Two skilled and experienced teachers—called 'master teachers' ('mästarlärare')—from the upper secondary school are employed by Chalmers and involved as teachers in many courses on the programme. In 2017, there were 10 students admitted to the programme. Applicants are interviewed in order to select skilled and motivated students. In addition, there are students from a 90 ECTS Bridging Teacher Education Programme ('kompletterande pedagogisk utbildning', KPU) on the courses, totalling nine admitted students for 2017. Thus, a total of up to 20 students are registered on the courses. Of the graduating students, approximately 40% are employed in schools, and 60% in business.

11.3 Methodology

The study was based on documentary studies and interviews with five key individuals involved in starting the programmes, some of whom are well known by the authors. Two of the interviewees took the initiative to start the CL and LL programmes at KTH and Chalmers, respectively, and three have been programme directors both at the beginning of the programmes and for many years since. At KTH, the programme directors remained in their position for about 10 years. At Chalmers the interviewed programme director is still in this position.

Interviews were transcribed and served as the primary data source for content analysis (Cohen et al. 2011). Both latent and manifest content was considered. Separate analyses were performed for both institutions, and data were labelled and categorised regarding the reasons for starting the programmes, and either perceived or experienced difficulties. Categories were generated directly from the interview material. After interrogating the data from both KTH and Chalmers, the following categories were established:

Categories regarding motives

(a) Worries and a sense of urgency regarding future recruitment of students to engineering education
(b) To influence the content of teacher education
(c) To create competition
(d) Personal interest and experience
(e) To contribute to meeting the needs of society
(f) Positive side effects for the technical university
(g) Existing examples

Categories regarding concerns and difficulties

(a) Concerns regarding number of applicants and economy
(b) Concerns regarding weakening of the engineering content
(c) Concerns regarding retention and demands on students
(d) Concerns regarding the teaching subjects
(e) Concerns regarding difficulties to cooperate
(f) Differences regarding epistemology

Within each category, data from KTH and Chalmers were compared. Similarities and differences between the two cases are summarised in Tables 11.1 and 11.2. In the interviews, we not only asked for the opinion of our interviewees, but also what they remember that others at their institute expressed. We also gathered data from the interviews on how competence in this field has been built and how the programmes have been organised.

To complement the interview data, we studied contemporary documents expressing official arguments, for example, a governmental decision regarding CL, press releases, and debate articles. In some cases, the authors' familiarity with the programmes was used as a data source.

11.4 Results

The results are organised into four themes: motives for starting the programmes, perceived or experienced difficulties, how competence was acquired, and how the programmes were organised. Data from interviews and documents contribute to all four themes.

Table 11.1 Major motives expressed by interviewees for starting double degree programmes in engineering and education

KTH	Chalmers
(a) Worries and a sense of urgency regarding future recruitment of students to Engineering education	
a1. Lack of teachers in STEM-subjects in upper secondary school	
a2. Low quality in existing teacher education due to low application rates, which can be helped by the high application rates of engineering education	
a3. Questioned quality regarding examination and progression in existing teacher education	a4. The present situation is not satisfactory and something needs to be done: "[…] you [the established teacher education] don't recruit any teachers to be in chemistry, physics and hardly in mathematics. We can't just stand watching while the basis for our activities is falling apart"
(b) To influence the content of teacher education	
b1. Towards deeper knowledge in teaching subjects, especially in mathematics	b3. Towards more professional relevance
b2. Towards a more holistic view with better integration and progression between different parts of teacher education	
(c) To create competition	
c1. A desire to increase competition and mobility between the engineering and teaching professions, in both directions, in order to improve status and working conditions for teachers and make their knowledge appreciated in business	c2. Frustration regarding established education: "This [established] teacher education ought to have some competition."
(d) Personal interest and experience	
d1. Interest in education d2. Personal connections with politicians d3. Experience as headmaster for a technical upper secondary school	d4. Experience as parent to school children
(e) Contribute to meeting the needs of society	
e1. Educate teachers where the shortage is most challenging e2. "It was probably more of a societal interest. […] send signals to the system that we were prepared to take responsibility for this and do it in a manner that was characteristic for KTH"	
(f) Positive side effects for the technical university	
f1. Increasing the awareness at the technical university regarding teaching and learning in these school subjects and the connection to society	
f2. More emphasis on educational development, teaching and learning at the university	
f3. Synergies with other educations focusing on leadership	
(g) Existing examples	

(continued)

Table 11.1 (continued)

KTH	Chalmers
g1. Good experience of combining technology with other subjects in the programme "industrial engineering and management"	g2. Experience from the first years of having CL at KTH g3. Experience from similar education in the USA

11.4.1 Motives for Starting the Programmes

Many motives were similar at KTH and Chalmers when these programmes were considered. In order to illustrate similarities as well as differences, the results regarding motives and fears are presented in Tables 11.1 and 11.2. The tables contain two columns, one each for KTH and Chalmers. Motives that are expressed regarding both Chalmers and KTH are presented across both columns, but motives expressed regarding only one of the institutions (and relevant illustrative quotes) are presented in the appropriate column for the institution.

The picture provided by the interview data can be complemented with what is expressed in documents. In the governmental decision by the Ministry of Education, 2002-03-07, mission to Stockholm Institute of Education and KTH Royal Institute of Technology, it was expressed that the programme should commence as a means of searching for new ways to educate teachers specialising in technology and science to meet the demands of competence in these areas, primarily for upper secondary school teaching. One motive was expressed as being to stimulate pupils' interest in science and technology by renewing teacher education, as illustrated by the following quote (translated from Swedish): 'Education and teaching for prospective teachers in elementary school and upper secondary school should be renewed for an education that increases and stimulates students' interest in technology and natural sciences.'

In a joint press release by the Stockholm Institute of Education and KTH, "*Lärarhögskolan och KTH startar gemensam lärarutbildning*" (Lärarhögskolan 2002), the following motives were mentioned:

- Economic development of Sweden.
- Increase in status and better recruitment for teacher education.
- Renewal of school teaching in science and technology.
- Combining solid subject knowledge (provided by KTH) with knowledge about teaching processes and their prerequisites, provided by Stockholm Institute of Education.
- Development of research cooperation and cooperation for interaction with society.

Motives for starting LL at Chalmers were spelled out in three debate articles, one written some years before the programme started (Engström 2005), one written when the plans were taking form (Bengmark et al. 2009), and one written when the programme had been running for some years (Engström 2014).

Table 11.2 Concerns and difficulties expressed in the interviews

KTH	Chalmers
(a) Concerns regarding number of applicants and economy	
a1. At KTH as well as at Chalmers, there were concerns about anticipated low numbers of students, due to low application rates to teacher education. Small student groups imply difficult economic conditions. Both programmes have received economic support from the university	
(b) Concerns regarding weakening of the engineering concept	
b1. Colleagues at other departments at KTH informally expressed personal concerns regarding reduced contents in classical engineering subjects	b2. In recruitment contexts, students expressed concerns regarding the engineering concept. 'Several [students] expressed that this is interesting, but I am not sure I would like to jeopardise my classical engineering degree by including this as well'.
(c) Concerns regarding retention and demands on students	
c1. The demands for passing a course are perceived to be low in some cases c2. In some contexts, students have had difficulties passing courses	
(d) Concerns regarding teaching subjects	
d1. Technology is a comprehensive teaching subject in the upper secondary school. It is difficult to prepare students well in all aspects of it	
d2. Difficulties finding sufficient overlap between engineering and teacher education. The physics needed by a teacher should correspond to the curriculum for the upper secondary school, but most engineering educations need to specialise in one domain and have little interest for e.g. astrophysics.	d3. Most of the teaching subjects are studied in preceding bachelor programmes. All of them but one (electrical engineering) are recognised as acceptable (accredited) by LL. The teaching subjects included in the degree are determined by the courses studied during bachelor programme. In some cases, students must have done certain choices during the bachelor programme.
(e) Concerns regarding difficulties cooperating	
e1. Some people expressed fear that KTH and Stockholm Institute of Education would find it difficult to cooperate due to cultural differences, and this was perceived to be a source of distrust and conflict. This is also described by Geschwind and Scheffer (2007)	e2. During the initial stage cooperation with University of Gothenburg was considered. There was friction and conflicts between different actors engaged in the established teacher education
(f) Differences regarding epistemology	
f.1 Distrust between KTH and Stockholm Institute of Education due to epistemological differences regarding learning, but also regarding subject knowledge especially in mathematics. Some people expressed that engineering mathematics was perceived to be focused on integrals and calculations rather than on understanding. "Teachers should study some other kind of mathematics."	

Engström (2005) suggested that established, traditional teacher education would benefit from competition, as there are unsolved problems. These problems relate to weak connections between teaching subjects and educational courses, and conflicts and antagonism between different parties involved in the programme. The meeting between a problem-solving engineering culture and the more problematising and reflective culture of teacher education was also considered fruitful.

The discussion by Bengmark et al. (2009) focused on anticipated advantages of educating teachers at Chalmers. The CL-programme at KTH was mentioned as a successful example; however, the intention for Chalmers was not to copy this structure, but to create a programme composed of a three-year bachelor programme together with a two-year master's programme, following the Bologna model. Many advantages were identified, as follows:

- The bachelor programmes at Chalmers would offer a large basis for recruitment.
- The applicants would be good quality students, already used to demanding studies at a high pace.
- Engineering studies and school subjects have many similarities, for example, both include problem solving, sustainable development, economics, and ethics.
- Programmes at Chalmers include training in general skills, such as teamwork, communicative skills, and leadership.

A significant overlap between a Master of Science in engineering and in education was emphasised. Furthermore, increased mobility and competition between the engineering profession and the teacher profession, as well as educating good teachers, were cited as factors that would improve the attractiveness of the teaching profession.

Finally, Engström (2014) identified motives for starting teacher education at Chalmers in retrospective, but also went on to describe problems that had been encountered, which are detailed in the next section. The motives include:

- Chalmers is described as dependent on recruitment of students with good preknowledge, while the shortage of duly qualified teachers in the upper secondary school is described as a threat to Chalmers' existence.
- The engineering background that students receive at Chalmers will enable educated teachers to add relevance to society in the subjects of mathematics, physics, and chemistry.

11.4.2 Perceived and Experienced Difficulties

According to all interviewees at both KTH and Chalmers, people were generally positive about the idea of including teacher education. None of the interviewees recalled any strong objections against the inclusion of teacher education in the tasks of a technical university. On the contrary, management and other colleagues were perceived to be very supportive, as illustrated by the following quote (regarding the

situation at Chalmers): 'We received support from the management at Chalmers, and I feel that we have had it just the whole time, and from Chalmers as a whole and from everybody around Chalmers, that this is strategically enormously important'.

However, there were some concerns, or difficulties. Some difficulties were anticipated (either by those involved in delivering the programme or by others), whilst some issues emerged as the programmes commenced. Concerns and difficulties expressed in the interviews are presented in Table 11.2.

Engström (2014) also discussed a number of problems. Even though many bachelor students at Chalmers are qualified to apply for the LL programme at Chalmers, the number of applicants was lower than desired. Reasons were stated to be outside of what Chalmers can control, in the hands of the employers (municipalities and educational companies) and the two major Swedish trade unions for teachers. Engström argued that rivalry between the trade unions for teachers had resulted in a major loss of status for teachers, and that the trade union for engineers would be the best option for teachers who graduated from Chalmers, and a means to regain status for the teaching profession in general.

11.4.3 How Competence Was Acquired

As these programmes implied development in a new direction for the technical universities, it was necessary to build competence in this field. Here we consider how this issue was tackled.

At the time, when discussions regarding teacher education started at KTH, teacher education was frequently criticised in public contexts. Consequently, KTH drafted a proposal for alternative teacher education provision, which was rejected by the Swedish National Agency for Higher Education (at that time Högskoleverket). This led to further contact and resulted in a governmental decision, implying that KTH and Stockholm Institute of Education have been assigned to start a new programme in cooperation with each other. The mission was to create an alternative to existing teacher education, with an explicit aim to renew school teaching in science and technology.

Some funding was associated with the governmental decision, which was used over a period of years for specific projects, regarding goals for teacher education and studying the intended learning outcomes of the upper secondary school (for example). Efforts were made to start common research projects in educational science with the Stockholm Institute of Education. However, these were described as unsuccessful by one interviewee.

The design of the CL programme included both traditional and new elements regarding educational subjects. Some courses were based on traditional teacher education content. Other courses contained new features or new aspects of learning. One particular related issue was the development of a new final degree project, combining insights from both engineering and education, in collaboration with industry (Geschwind and Scheffer 2007).

Competence was needed from many fields to run the CL programme (from KTH as well as from the Stockholm Institute of Education). Teaching subjects included mathematics, physics, chemistry, and computer science. The programme had three programme directors appointed when it started, two from KTH (with backgrounds in mathematics and physics), and one from Stockholm Institute of Education. In order to ensure the necessary subject competence, staff from other departments of KTH were also involved. A steering committee was formed that included people from both institutions.

At Chalmers, the original plan was to design a programme in cooperation with another university, in either Borås (Engström 2005), Jönköping, or Gothenburg. However, due to political decisions, the application was to include only competence available at Chalmers. A group including two mathematicians, a chemist, and a person with background in administration was formed to start the programme. The National Centre for Mathematics Education is situated at Chalmers, and their competence was included in the design of the programme. To strengthen research, two PhD positions were instituted on the border between subjects and pedagogy/didactics. Teaching and learning in higher education and an annual conference on teaching and learning (KUL) were identified as related areas, with possibilities for synergy with the LL programme.

11.4.4 Organisation of the Programmes

The CL at KTH is an integrated 300 ECTS programme. Since the start, it has been run in cooperation with Stockholm Institute of Education, and later Stockholm University. In the initial phase (from its beginning in 2002 to 2004-12-31), the programme was organised directly under the central administration of KTH. In 2005, there was a general reorganisation, where KTH was divided into a number of schools. Thus, CL came to belong to the School of Engineering Sciences (2005-01-01 to 2013-06-30). Connecting the programme to industrial engineering and management was discussed as an alternative. In an effort to strengthen the support for the programme, the School of Education and Communication in Engineering Science was created at KTH, and the programme belonged to this school during the period 2013-07-01 to 2017-12-31. In 2018, a new reorganisation was undertaken, and the number of schools at KTH was reduced to five. The CL programme was thus moved to the School of Industrial Engineering and Management, from 2018-01-01.

A minor revision of the CL programme was implemented in August 2005 (Skolan för teknikvetenskap, Årsrapport 2005, p. 15). The first year of study was revised, strengthening the mathematics and the introduction to the engineering and teaching professions courses. The Stockholm Institute of Education was integrated into Stockholm University 2008-01-01. A major revision of the programme was implemented in 2011, based on a new application for the right to award degrees and a new higher education ordinance. In this revision, the first year of study was entirely

redesigned in order to improve retention, and KTH received the right to issue degrees in both engineering and in education.

The LL at Chalmers is a 120 ECTS master's programme, following the Bologna arrangement. Chalmers chose not to copy the design model chosen by KTH. By making this choice, the programme does not have the same responsibility for the bulk of courses in mathematics, physics, chemistry, and technology/engineering subjects. These subjects are mainly studied in the preceding bachelor programmes, and then students from the Bachelor of Chemistry, Chemical Engineering with Physics, and Biotechnology programmes become teachers in mathematics and chemistry. Students from the Bachelor of Engineering Physics programme become teachers in mathematics and physics. Students of other courses (such as applied mathematics, mechanical engineering, computer science, information technology, and civil engineering, except for those from electrical engineering), become teachers in mathematics and technology.

When LL was started it received active support from the president of Chalmers, by driving questions and conveying contacts. The programme received economic support for the development of courses and employment of two teachers for the upper secondary school. Within the organisation, it was placed under 'engineering mathematics', as the programme directors had backgrounds in mathematics. However, the communicational pathways were different from other master's programmes. The programme director of the LL mainly communicated with the vice president and deans of education (utbildningsområdesledare) directly and less so with the Programme Director of Engineering Mathematics, as other master's programme directors would.

11.5 Discussion and Conclusions

The data from interviews and contemporary documents allow for triangulation. We see no contradiction between them, even though more aspects are covered in the interviews. The interviews provide richer, more nuanced, and more focused data, whereas the documents contain original formulations unaffected by later events. Both authors have also been familiar with the context of the double degree programmes for many years.

Teacher education has been seen as key to finding a sustainable solution to the problem of weakened recruitment of engineering students. The concerns have been not only regarding numbers of graduated teachers, but there has also been anxiety regarding the quality of teacher education and a desire to attract better students to teacher education. With many teachers leaving the profession, there has been a further aim to improve the status of teachers and teacher education. The complex mix of rationales are structural, such as the those cited previously, and are related to prominent individuals in each institution who champion this initiative (cf Geschwind 2019). The arguments, more or less pronounced, include strong self-confidence as leading technical universities, and a critical stance towards teacher training

provided by other universities. At times, this self-confidence has been mirrored by strong confidence from the responsible Minister of Education.

The basis of both programmes in engineering is evident, as reflected by the names of the programmes. Regarding CL, the initial name of the programme expressed that it was a programme in engineering with a specialisation towards teaching, but this was changed to the more neutral current name, whereby engineering and teaching are equally weighted (even though engineering is mentioned first). Reasons for focusing on engineering could be that the programmes have been developed in engineering contexts at technical universities, but it could also reflect the fact that engineering education has a higher status than teacher education. Over many years, the suitability of the name CL has been discussed by students of the programme at KTH. Some students argue that the presence of "*lärare*" (teacher) in the name makes it more difficult for graduates to obtain engineering jobs, and that the name of the programme should describe what kind of engineers they are, much like names of other engineering programmes. Another indication of the importance of the engineering context is that in yearly evaluations CL students often express their wish to learn more about adult learning. Here, teacher education mainly focuses on child and adolescent learning, especially in courses given by departments mainly involved only in teacher education. In the reorganisation 2013 (when CL was moved to the School of Education and Communication in Engineering Sciences), many expressed concerns that this reorganisation would reduce the emphasis on the engineering aspects of the programme. These concerns were expressed by staff as well as students before and during the transition—although not afterwards.

The acquisition of competence is connected to the university's view of its identity. The first draft for CL at KTH, in which views on teacher education are expressed, indicates a very confident self-image. However, the educational competence of KTH was considered too low for starting a teacher education, by the government as well as by some key persons at KTH, and thus the programme was started in cooperation with the Stockholm Institute of Education, according to a governmental decision. The identity of KTH was based on solid subject knowledge, in both engineering and (especially) mathematics. The cooperation with the Stockholm Institute of Education revealed differences in culture and in epistemology. Although there was some friction and KTH began with a strong self-confidence (whereas Stockholm Institute of Education was used to being questioned), the self-image of KTH was affected by the cooperation and an awareness and appreciation of differences in culture arose. Arguably, the self-image at KTH today is more nuanced and humbler. Fifteen years' experience of educating teachers has provided insight in the nature of this challenge to more people. The self-image of the university is probably highly dependent on the views of rather a small number of individuals. The programme is still based on cooperation, even though today KTH has a department of learning in engineering science and has had the right to award degrees in education since 2011.

During the studied period, a desire also existed to reform engineering education. At KTH, the development of the CL programme coincided with the emergence of a reform movement of engineering education: 'conceive, design, implement, operate'

(CDIO) (See also Chap. 8 in this volume). The traditional engineering role was questioned, as expressed in the CDIO syllabus 2.0 (Crawley et al. 2011): 'In order to be able to handle real-world engineering situations, engineers should not only master technical challenges. They must also have e.g. personal, interpersonal skills and system building skills'. Both KTH and Chalmers are founder institutions for CDIO, and this desire to introduce interpersonal skills in engineering education in general may have facilitated the acceptance of the new engineering profile expressed in these programmes. The European Society for Engineering education (SEFI) also questions the traditional engineering role. In the SEFI position paper *Developing Graduate Engineering Skills*, (2015), they state 'Engineering is not just about applying technical principles', and 'Therefore, engineering education must broaden the engineer in addition to providing deeper specialized subjects (the "T-shaped Engineer"). Critical thinking and self-reflection are necessary ...'. The 'T-shaped engineer' provides a useful description of the ambition behind these programmes. The engineer shall have solid knowledge in one relevant area, but also needs a wide perspective and broad competence including many different skills, some of which are promoted by courses in education. Studies of alumni motives for choosing CL (Cronhjort 2017) and the careers of alumni (Cronhjort et al. 2017a, b) confirm that the wide span of subjects included in the programme attracted many of the students to CL and that the students benefit from these joint competences in their careers.

The organisational positions of the programmes reflect strong connections to mathematics. Both programmes have had at least one programme director with a background in mathematics. This corresponds with the ambition to promote subject knowledge. A connection to a department with high status supports the ambition to raise the status of teacher education. At KTH, the CL programme now belongs to the School of Industrial Engineering and Management. The long-term effects of this are still unknown, but one rationale behind the change was that the future development of the programme would be supported in a supposedly stronger academic environment.

In 2018, the Swedish Higher Education Authority (UKÄ) launched an evaluation of all mathematics teacher educational programmes in Sweden. The outcomes were published in 2020 (Universitetskanslersämbetet 2020). CL at KTH and LL at Chalmers were included in the evaluation, and both received the opinion "High quality". In addition, twenty conventional mathematics teacher educational programmes were included, and seven of these received "High quality" and 13 received "Questioned quality". This shows that the quality of mathematics teacher education has not been questioned only by technical universities. Presently, UKÄ questions the quality of about two thirds of the conventional programmes.

As already mentioned, our data illustrates that engineering education has had strong confidence, whereas teacher education has had weaker confidence. However, conclusions regarding self-sufficiency, based on the strong confidence associated with the engineering identity of the technical universities must be drawn with prudence, keeping in mind the very special and highly regulated conditions under which these programmes were developed. KTH wished to develop an alternative to existing teacher education provision, but was not allowed to do it on its own. In

2002, according to the governmental decision, KTH was forced to cooperate with Stockholm Institute of Education. This cooperation resulted in some struggle but proved fruitful and was still appreciated at CL more than 15 years later. On the other hand, when Chalmers in 2011 designed their LL programme, they wished to cooperate with other universities but were informed that this was not allowed. At that time, all universities had to make new applications for the right to award degrees based on a new higher education ordinance. Thus, Chalmers was forced to start its programme depending on in-house resources. Both these cases show that governmental regulations regarding teacher education interfere with the ambitions and plans of universities, and that actual developments cannot be interpreted as manifestations of the intentions of the universities themselves.

Engineering education, on the other hand, which benefits from greater confidence in the public eye and support from industry, is entrusted with a higher degree of freedom that has allowed these two cases of combined education to emerge. This illustrates that technical universities have potential to have impact that is important for society, even far outside of the classic domain of engineering.

Conflict of Interest Cronhjort was Programme Director of Master of Science in Engineering and in Education at KTH 2014–2019. Geschwind was Course Director for the final degree project 2013–2016.

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