Chapter 2
Technical Universities: A Historical Perspective

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2.1 Introduction

The aim of the chapter is to reflect upon the core missions of technical universities—education and research—in relation to various actors, including other HEIs, industry, and the state, and thereby to provide a historical background to the following chapters. This aim is also related to the terminology and definitions used. As this volume sheds light on, there are many ways to be a technical university and this is to a high degree context specific, related to national and regional specificities. This is of course also the case if we, as in this chapter, start tracing the historical development of technical universities. Even the term technical university quickly becomes an anomaly if we go back to the beginnings in the eighteenth century. Most technical universities started as teaching only technical institutes or polytechnic schools before they, rather late became research institutions. One common feature is the education of engineers. Whereas there is great variety in contemporary technical universities regarding breadth and scope, they all educate engineers. However, missions have broadened with the introduction of research and the disciplinary scope has changed over time as well, partly as response to external actors' demands, partly as the inevitable consequence of technological development. As we shall see, this has created a number of persistent and prevalent tensions and challenges for technical universities as organisations.

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2.2 The First Technical Institutes and the Industrialisation of Europe

The technical universities of today all have a shorter history than universities such as Oxford, Krakow, Copenhagen, and Uppsala which have medieval origins and a started out as organisations intertwined with the Church (de Ridder-Symoens 2003). Furthermore, in contrast to the Humboldtian research university, the emergence of technically oriented HEIs was closely related to—even intertwined with—the industrialisation of Western societies in the eighteenth and nineteenth centuries. In the words of Anna Guagnini: "The majority of the new schools were created outside the university system, in a variety of quite distinct institutional contexts, and they were admitted to the highest levels of the educational hierarchy only slowly" (Guagnini 2004, p. 595). As Swedish historian of technology Svante Lindqvist has argued, engineering schools in the industrialised nations of the Western world share the same basic characteristics and they have more in common with each other than with other HEIs (Lindqvist 1998).

The emergence of engineering and technological knowledge as subjects of advanced study occurred during the eighteenth century. An important precondition was that technological knowledge and engineering became a science of its own, not just a craft with its practices verbally and practically transmitted to following generations, but systematised, described, and printed in books made available to students. Technological knowledge could then be duplicated and taught, thus enabling lectures and theoretical studies on the subject (Lindqvist 1994). Among the earliest examples of such technological education systems were the Institute of Engineering Education in Prague, the German Bergsakademie in Clausthal (founded in 1775), and the French Ecole polytechnique (1794). There were indeed other early attempts to establish technological education across Europe, but the first 'mechanical institutes' were a product of the early nineteenth century. These institutes include, for instance, the Technische Universität in Vienna (1815), the University of Manchester Institute of Science and Technology (UMIST) in Manchester (1824), Rensselaer Polytechnic Institute in Troy (NY, 1824), and Danmarks Tekniske Hojskole in Lyngby (1829, now known as the DTU, the Technical University of Denmark). These provided elementary knowledge in physics, chemistry, mathematics and machine drawing (Fox and Guagnini 2004).

Technological education remained a business apart, separated from the existing universities but linked to evening and Sunday schools, thus enabling professionals to be educated in their spare time. The schools were typically located in early-industrialised cities and their main aim was to educate engineers for the emerging industrialised society (Hobsbawm 1989; Fox and Guagnini 2004). The schools also reflected local industry in terms of profile. In Sweden, for example, education in mining was provided in the mining town of Falun, shipping and textiles in the port city of Gothenburg, and machine engineering and chemical technology in the capital Stockholm (Runeby 1976). More generally, we can talk about three levels of technicians and engineers during the heydays of industrialisation. At the top, we find the engineers who were educated by the technical universities, designated for leading positions in public and private sector. The next level of engineers were educated at secondary schools or equivalent level and worked in medior positions in industry or in leading positions in small firms. At the lowest level, technicians received vocational training for operatives of various kinds (Ahlström 2004).

During the nineteenth century, an important step in early development was the establishment of polytechnic institutes, offering education for many different kinds of industrial work. In many European countries, nineteenth century polytechnic institutions later became national 'siblings'. Table 2.1 provides examples.

The experience of the Nordic countries could serve as an example. While technical universities founded in the nineteenth and early twentieth century (KTH in Stockholm, Chalmers in Gothenburg, NTH in Trondheim and DTU in Copenhagen) enjoyed considerable reputation by the mid-1900s, no second wave of establishment of technical universities took place (although there were a few exceptions, such as Lappeenranta University of Technology, established in 1969, TUT in Tampere established in 1965 and Luleå University of Technology, established in 1997). In the Nordic countries—as in many other European countries—a large part of twentieth century expansion of engineering education was channelled into comprehensive universities as faculties, or into university colleges with limited research resources. Thereby, the older technical universities found themselves positioned in a more diversified landscape.

Throughout the years, education and research activities of technical institutions have changed in reflection of industrial development. Such change has included adding new organisational units, sections, and educational programmes (Brandt and Nordal 2010). Complementing their original sections and departments, new units and sections such as electronics, ICT, computer science and biotechnology have been added along the way (Lindqvist 1994). However, critical voices have argued that European technical universities are subject to overly strong inertia (Lindqvist 1998). As Henrik Björck (2016) has shown, also in relation to curriculum design,

Table 2.1 Examples of European polytechnic universities

Country	Nineteenth century polytechnics	Twentieth century polytechnics
Germany	TU München	TU Dortmund
Italy	Politecnico di Torino; Politecnico di Milano	Politecnico di Bari
the Netherlands	TU Delft	Eindhoven University of Technology; University of Twente
Spain	TU Madrid	Polytechnic University of Catalonia; Polytechnic University of Valencia
Switzerland	ETH Zürich	EPF Lausanne
the Czech Republic	Czech Technical University in Prague	Technical University of Liberec

Note: The present name rather than historical names are used. Several of the universities founded in the twentieth century have predecessors or earlier history engineering education did not follow the Humboldtian ideas of free studies. Rather the contrary, engineering programmes were already highly structured and congested from the outset. Furthermore, a first phase of global convergence took place in engineering programmes in the 1870s when increasing credentialism replaced the earlier apprentice model. A "school culture" was implemented in the quest for a legitimate engineering education, in contrast with the former dominating "shop culture" (Seely 1993; Case 2017).

2.3 The Twentieth Century: Balancing Theoretical Knowledge and Scientification with Relevance and Application

During the inter-war period, a transition from being teaching only institutions to becoming modern, research-intensive universities was begun by technical universities. Part of this process was to relate to and adapt to the concepts of 'university', 'science' and 'scientific research'. This created significant tensions in the higher levels of the educational system, both epistemologically and financially: "In all European countries, resistance to change was a deeply entrenched feature of higher education, and there is no doubt that the 'utilitarian' character of the new curricula continued to fuel hostility towards technological education long after engineering schools were accepted as a recognized part of the university system." (Guagnini 2004, p 595).

These values were also institutionalised in the form of promotional criteria, technical doctoral education, and increased investment in research infrastructure (Björck 1992). However, the introduction of a technical doctoral degree was debated in many national contexts—in particular in European states with well-established comprehensive universities. In Germany, Austria, Switzerland, Denmark, and Norway a doctoral degree in engineering had been introduced during the first decades of the twentieth century, significantly later than for other subject areas of the higher education sector. In Sweden, it was not until 1927 that a technical doctoral degree was introduced, after consultation with the universities in Uppsala and Lund. It was not until 1932 this was introduced as a recognised task for KTH teachers, and sparse research was undertaken before the end of the Second World War. Financially, a designated budget was also developed during the 1940s and 1950s for research and the councils responsible for technical research (in Sweden *Tekniska forskningsrådet*). During the 1920s, scientific excellence became the most important assessment criterion for the appointment of professors, copying existing practices at traditional universities. The tension between engineering practice and being a scientist has since produced a number of conflicts in peer review processes.

The tension between theory and practice has been another prevalent issue in the history of technical universities. In the words of Jenni Case: "From a survey of the history, it is clear that programmes in engineering education have always been a site of struggle—for both legitimacy in the university and legitimacy in the eyes of employers" (Case 2017, p 978). This has affected both the design of engineering education curricula and approaches to research and innovation, as well as the organisation of technical universities (see also Björck 2004; Etzkowitz 1988; Edström 2017). This tension is one that is shared with other specialised universities, in areas such as medicine, business and agriculture (cf. Augier and March 2011; Huzzard et al. 2017).

Already during the nineteenth century, there were frequent discussions on the balance between practical skills and theoretical knowledge in the curriculum of engineering education. In the Swedish context, Berzelius' conflict with the Technological Institute (currently KTH) Director Gustaf Magnus Schwartz during the 1840s is a striking example. Berzelius, Professor of Chemistry at Uppsala University argued that engineering education should be more strongly theoretically grounded, whereas Director Schwartz believed it should be a practical, craft-oriented education. A decision from the Parliament (*Riksdagen*) decided in Berzelius' favour and Schwartz was forced to resign. This development towards a further scientification of the study of technology continued during the latter decades of the nineteenth century (Lindqvist 1994). The theory-practice dichotomy has since then grown into a more complex, multifaceted set of issues.

Another point of tension for engineering education is that between foundational and applied subjects. At some institutions, including some technical universities, this tension is dealt with and recognised by the organisational response of organising itself into separate faculties for science and an engineering. Contemporary engineering science comprises both theory and practice; it includes both a knowledge perspective and a product and process perspective (Hansson 2007).

By the end of the nineteenth century, engineering education had won broad acceptance and a status equivalent to other types of higher education. However, the balance between theory and practice remained a prevalent issue of concern, requiring various compromises (Harwood 2010). On the one hand, theoretically oriented engineering education enjoyed considerable status within society, in particular among university stakeholders (Torstendahl 1975). On the other hand, industry was facing structural transformations such as the introduction of large-scale process technology, electrification, and the expansion of waterpower. This development was argued to require engineers to be practically educated, in order to ensure that new graduates were in touch with economic and societal realities. Hence, industry demanded seats of learning to educate more 'employable' students. This phase in the history of universities also placed some pressure on the traditional areas of study and the provision of higher learning. As Sheldon Rothblatt has shown, the disruption of Cambridge's historic and special association with Church and State even threatened professors with alienation from industrial society (Rothblatt 1968). Further, in relation to public authorities, increased scientific and practical legitimacy for engineers was called for to challenge the dominance of law graduates as civil servants (Kaijser 1998).

With the foundation of the first polytechnic institutes of education being primarily motivated by the need to train people in skills central to further industrialisation, it was natural for these institutions to nurture a close relationship with industry. Over time, a variety of channels for direct knowledge exchange between (technically oriented) universities and industrial firms were developed. This development was championed by HEIs in the USA, which responded to economic downturn during the depression by increasing their efforts to collaborate with industrial firms based on their expertise in science and engineering.

By this time, the North-American HEI landscape was dominated by two forms of institutions. The first of these was the teaching-oriented college (many in the tradition of liberal arts education). These had roots in the college system established in colonial times, modelled on its British equivalent (Wittrock 1993). The second dominating organisational category in the USA during the interwar period was that of the research university. While the motivation for strengthened academic research came partly from calls for enhanced scientific efforts in 'practical' fields, such as agriculture and engineering, as well as in the sciences, these efforts were channelled into institutions with broader academic agendas than that of the typical contemporary European polytechnic school. It was these kinds of research institutions, with flagship names such as the Massachusetts Institute of Technology (MIT), Stanford University, and the California Institute of Technology (Caltech) that attracted the world's attention through their strong engagement with industrial development and their vision of undergraduate and postgraduate training being carried out in close association with technical research. Consequently, they established a partly new ideal for what it might mean to be a successful technical university. The establishment of the Indian Institute of Technology after World War II is one of the most obvious examples of direct isomorphic mimicry, but the influence of American role models has also provided significant influence throughout Europe.

The evolution of the polytechnic institution into a technical university was driven by a view of science and engineering (that is, technical) research as interrelated and interdependent activities. In the American context in particular, this view was combined with an academic culture embracing entrepreneurial activity. During the nineteenth century, institutions built on such a credo won widespread societal support by demonstrating their worth to industry and, through linkages initiated during World War Two, to the military (Etzkowitz 1988). In view of this, great expectations were laid with the technical universities as 'engines' of economic growth and renewal. In many European regions facing industrial decline, the foundation or strengthening of technical universities has been a crucial component of the attempts of governments to bolster new development. The foundation of the Technical University of Twente in 1961 presents a particularly clear example of how national and regional level strategies to facilitate a transition from failing industrial structures to a new regime of technology-based entrepreneurship were strongly anchored in ideas about what a technical university would be able to achieve in this domain.

2.4 Post War Focus on the Development of Research and Emerging Differentiation

In terms of science and education policy, the period after 1945 has been characterised by growing investments in technical research, high expectations, and strong support from state and industry in many countries. The perceived need for stronger research and for research education did not replace, but rather complemented the need for basic technical training. This led to a situation where in many countries the lower levels of postsecondary engineering education were provided by polytechnics or universities of applied sciences with little or no research, while an ‘elite’ of technical or comprehensive universities took on roles as champions of technical research. Such division of labour was achieved in some contexts through organisational restructuring, an early case of which was the ‘spinning out’ of the vocational school from Caltech in 1907. In other instances, institutions with long historical roots, for one reason or the other, did not follow the ‘typical’ trajectory of developing into (technical) universities, but remained strongly focused on applied research and practical training. Examples include the Polytechnic of Central London, which is today known as the University of Westminster. However, the majority of ‘second-tier’ institutions were founded anew in the context of strong expansion of higher education during the second half of the twentieth century.

Differentiation between institutions set a new stage for the already age-old conflict between the applied and the scientific aspects of engineering education and research. The concepts of academic drift and vocational drift have been commonly used by higher education researchers to describe perceived imbalances within technical universities (Harwood 2010), together with the structural issue regarding national higher education systems (Kyvik 2008). More recently, the trend towards emphasising measurable research output in terms of publications and citations has, it has been argued, changed publication strategies as well as the coupling between education, research, and practice, which constitute such important roles for engineering disciplines.

2.5 Twenty-First Century Technical Universities—In Search of a New Identity

The new century has been characterised by both continuity and change. The relations to industry remain strong and they have become more institutionalised and structured. It has become commonplace to initiate strategic partnerships with industrial partners, showing responsibility and long-term commitment to major societal challenges (Broström et al. 2019). This is also linked to increased focus on branding and corporate behaviour in line with some technical universities being described as entrepreneurial (Clark 1998).

The tension between theory and professional practice is ever present in contemporary technical universities. This has been described as a ‘swinging pendulum’, in other words, a balance to strike for both educators and managers (Seely 1993). With demands from higher education regulations and quality assurance agencies, links to research have been a sine qua non of higher education, also including engineering programmes (Magnell 2019). Not to be described as the opposite of research links, the CDIO (Conceive, Design, Implement, Operate) movement could be understood as a response to what is perceived as too much emphasis on theoretical knowledge in engineering education (Edström 2017).

The organisational identity of technical universities is now being challenged by major restructuring initiatives in the higher education sectors. Meanwhile, in some countries—notably including world-leading university nations such as the USA and the United Kingdom—the domination of the research university as an organisational template for what it means to be a successful higher education institution means that differentiated institutions have prevailed in many settings. However, recent trends are re-shaping the territory once again. Many countries have seen a push for universities and states to reconsider binary systems, blurring the boundaries between groups of HEIs where they have previously been reinforced by differential regulation. For instance, former polytechnics have challenged existing research universities in the UK, France, and Germany, while simultaneously universities have become more profession-oriented and geared towards collaboration, co-creation, and impact on society (Delahousse and Bomke 2015). It has also been commonplace for technically focused universities to widen the scope of their activities in the quest for increased attractiveness, status, and visibility (Christensen and Ernø-Kjølhede 2011), as well as cost-efficiency and expectations on interdisciplinary work, for example, in response to so-called grand challenges.

Numerous mergers between HEIs identified as ‘technical universities’ and other types of HEIs, motivated by highly related ideas of the importance of scale and scope, have also been launched (Curaj et al. 2015; Pinheiro et al. 2016). Eye-catching initiatives include the Aalto University in Finland (Aula and Tienari 2011) and the merger between the United Kingdom’s UMIST and the Victoria University of Manchester (Georghiou 2009). Several other mergers have been proposed but not (yet) realised (Benner and Geschwind 2016). The general tendency of these mergers has been to merge ‘technical universities’ with HEIs of other types; typically comprehensive universities or universities of applied science. Examples of mergers between technically oriented universities can also be found elsewhere, for example, in India where the separation in governance of technical universities and ‘regular’ universities serves to uphold institutional boundaries. Also interesting in this context are Irish attempts to incentivise vocationally oriented technical institutions to merge by offering opportunities to become technical universities within the context of a binary (or possibly trinary) higher education system (Harkin and Hazelkorn 2015).

Technical universities have also been active when it comes to new strategic initiatives, of which some can be traced to external stakeholders’ agendas and demands, while others could be explained as strategic action by increasingly profiled university managers. Also related to the historical legacy is the idea of the university as a problem-solver and responsible actor towards ‘grand challenges’ (Sørensen et al. 2019). They may also be related to an increasing awareness of image and branding. A number of examples could be mentioned, including linking university strategy to sustainability goals, launching global development hubs, and appointing a pro-vice chancellor for sustainability and gender equality respectively.

2.6 Conclusion

This brief historical overview based on earlier research, has discussed the history and evolution of technical universities in relation to other universities and to the societal development. The analysis shows that the chronology of technical universities is in many ways different from comprehensive universities; they are—as a category—considerably younger than the comprehensive university. Technical institutes of education and training were first established during the late eighteenth century, with further foundations throughout the nineteenth century, because of demands within industrialised western nations. This close historical relation to industry appears clearly, and is a reminder that what is nowadays commonly referred to as ‘technology transfer’ and ‘collaboration with industry’ was present from the beginning in the technical universities. The graduation of ever more engineers was the principal and foremost task for the early technical universities/institutes, and the rationale behind the expansion and new foundations of technical universities. The education of engineers has been crucial for the development of modern economies and the relations to industrialisation, societal development, and economic growth have also meant strong power relations, support, and high expectations from industrial actors, as well as the state. By and large, this societal status seems to accompany the history of technical universities into our time.

Our historical account has also revealed how several institutional boundaries defining what it might mean to be a technical university have shifted over time. One such boundary related to the disciplinary scope of universities. Technical universities have related their activities to the ‘pure’ disciplines of chemistry, physics, and mathematics at the comprehensive universities—an act of balance that has been relevant throughout their institutional history. Other scientific areas have also been introduced along the way, to complement science, technology, engineering and mathematics subjects. Their roles within technical universities have been continuously discussed throughout history, as have the advantages and disadvantages of integrating engineering education and research into the structure of a comprehensive university rather than as a more focused ‘technical university’. An important question for the future is whether the idea of the technical university will remain viable and attractive, or if more technical universities will be merged with other HEIs in the quest for excellence.

A second boundary concerns that towards institutions of vocational technical education, and towards engineering as ‘pure’ practice. Today, many technical universities are among the most research-intensive in the world. However, research was introduced later at technical universities and the need for a special technical doctoral degree was debated at the time of introduction. Technical universities' relation to research shows many similarities with that of medical schools and business schools, balancing practice-orientation with academic, theoretical knowledge. Similar to such institutions, technical universities co-exist with parallel systems of vocational engineering education and training—much like the kind of institutions from which many technical universities have developed.

The organisation of advanced academic education and elements of practical training within curricula and organisations remain contested, with notable differences across countries and settings. In many settings, an organisational boundary has been institutionalised in the form of binary systems, with the lower levels taught in polytechnics/universities of applied sciences/university colleges and the higher levels in universities, both technical and comprehensive. Such boundaries have been shifting over time, both in the form of top-down re-regulation and more bottom-up institutional change through diversification and mergers.

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