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Technical Universities

Past, present and future

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Lars Geschwind, Anders Broström and Katarina Larsen

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Chapter 1
Organisational Identities, Boundaries, and Change Processes of Technical Universities

Katarina Larsen, Lars Geschwind, and Anders Broström

1.1 Technical Universities in Context

Historically, polytechnic schools rose to prominence in many national settings during the second half of the nineteenth century (Fox and Guagnini 2004). Over time, new areas of technology have been developed and incorporated into their repertoire, and waves of academisation have swept over the former polytechnics, transforming some of them into technical universities (Christensen and Ernø-Kjølhede 2011). Their proud traditions and brands tend to prevail. Several technical universities are included among the most prestigious academic institutions of their nations and the training of engineers and engineering research still enjoy a high level of prestige and national priority, for example in the context of innovation and industrial policy (cf. Clark 1998). Many institutions that might be referred to as technical universities are also held in high regard by industry, and embraced as focal points for regional renewal and development (Lehmann and Menter 2016).

Despite their often formidable success as higher education institutions (HEIs), higher education research has not concerned itself with the study of technically oriented universities as a (potential) organisational category. By no means do we argue that universities within this category of higher education institutions have been entirely absent in previous research. Technical universities feature in studies

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analysing university-industry interaction in engineering (Perkmann and Walsh 2009) and in historical studies of universities and individual technical universities (Fox and Guagnini 2004). Institutions with a technical profile also play prominent roles in studies discussing relations between scientific ideals and the engineering profession (see, for example, Björck 2016; van der Vleuten et al. 2017; Williams 2002), in studies on the history of engineering education (Jørgensen 2007), as well as in the broader literature on the sociology of higher education (Gumport 2007).

Whereas such previous studies have addressed technical universities in relation to the education of engineers and the provision of engineering education, the starting point for this volume is an interest in technical universities *as organisations*. Scholarly interest in what HEIs known as 'technical university', 'university of technology', 'institute of technology', or similar have in common today is warranted to better understand historical and contemporary ideals embedded in this type of organisation. Empirically, the volume limits its scope to Europe whilst drawing on experiences from various national contexts, but it also relates to other settings where necessary to understand the respective European settings that the volume engages with.

Since this volume is dedicated to the study of a specific acclaimed category of HEIs, we need to address the issue of specifying how we intend to define this category and its boundaries already at the outset. Is there such a thing as a distinguishable category of HEIs, which we may consider to constitute a field of technical universities? As further explored in specific empirical settings in the empirical chapters in this volume, demarcating such a group of organisations is not a trivial task. For example, to consider the technical university as being 'the place where they educate engineers' (cf Jørgensen 2007) would not seem to be precise enough for our purposes.

A first delineation is based on the traditional academic educational hierarchy. At the first—lowest—level of this hierarchy, we find vocational training for technicians; at the second level there is a more advanced type of engineering education, as typically provided in technical secondary schools and colleges (polytechnics); and at the highest level, we find the highly educated engineers. This latter type of academic education is expected to prepare students for working with technology development, and many such engineers are destined for a leading position in industry or administration. In this the volume focuses on institutions awarding advanced engineering degrees of the latter type, the technical universities and their equivalents (cf Ahlström 2004, p. 116). We are particularly interested in technical universities with both teaching and research as missions and less with teaching-only polytechnics. However, when the role of polytechnics and lower levels of engineering education is challenged and discussed at the higher education "landscape", such as, in this volume, in the binary sectors of Finland and Portugal, or in the unitary of Sweden, this sheds light also on technical universities.

Another dimension that we need to consider is the breadth and scope of the institution. A first suggestion here is that an attempt to delineate what it might mean to be a technical university should not be anchored in a strict disciplinary focus on the field of engineering sciences. The engineering sciences have a long-standing relationship with the domain of the natural sciences. Over time, the development of 'fundamental' knowledge about the world has occurred through a dialogue of interdependences between science advances and development in the sphere of 'practical' engineering knowledge, and with the development of technical artefacts and new technologies. At times, the scholars behind advances in engineering and those responsible for major scientific advances have been the very same individuals. Furthermore, in contemporary academia, it is not uncommon for significant projects to require expertise related to both engineering and the sciences—although nowadays this most often implies work in teams involving researchers with different specialisations. Nonetheless, faculties of both engineering and the sciences continue to acknowledge each other's relevance and embrace—or at least do not strongly resist—co-organisation into the same HEI.

Some HEIs that identify themselves as technical universities are single faculty institutions which have a disciplinary focus on engineering science and related natural sciences. The Nordic HEIs Chalmers University of Technology in Gothenburg and the Technical University of Denmark -DTU in Copenhagen are prominent European examples. Other HEIs that, in name and in identity, may be referred to as technical universities are broader, multi-faculty universities. Examples include NTNU—the Norwegian University of Science and Technology in Trondheim or indeed MIT in Boston, USA. HEIs such as these, which were originally more scientifically narrow institutions, have in many cases over time evolved into broader universities through mergers and diversification (see e.g. Chap. 4 in this volume).

In summary, this type of organisation forms a diverse category and has, in the European context, been characterised by idiosyncratic development paths. These paths can be traced to a historical evolution within the respective national setting, but are also clearly affected by international exchange of ideas and templates for institutions (see Chap. 2 in this volume).

Against this background, we adopt a pragmatic approach to the question what institutions are to be considered as technical universities. For the purpose of this volume we consider a HEI whose institutional identity is linked to technically oriented research and advanced education as a technical university.

1.2 Organisational Identity in Academia

Laden with values of autonomous scholarship, sceptical inquiry, and deep subject expertise, HEIs do not function as average organisations. To understand them from an organisational perspective, it is essential to tackle issues of identity. Organisational identity shapes strategic action (Brunsson and Sahlin-Andersson 2000; Krücken and Meier 2006; Whitley 2008) and response strategies (Oliver 1991) among universities, in relation to changing internal demands and power groups, and to the state and external stakeholders (cf. Augier and March 2011; Maassen 2000). Other examples of studies from knowledge-intense organisations, such as museums (DiMaggio 1991), emphasise how organisational change can be shaped by several—possibly competing—professional identities present within the same organisation. In seeking to study identity processes, extant literature suggests to start in the assumption that organisational identity is communicated through local narratives of HEIs (Kosmützky and Krücken 2015).

Previous studies have emphasised how the identity formation of HEIs is strongly dependent on cross-organisational comparison. The specific mechanisms and underlying logics through which identification with various entities can shape patterns of organisational behaviour have, however, been difficult to pin down. In the case of research on HEIs, research on organisational identity is made inherently difficult by the embeddedness of university activities within several layers of institutional and organisational complexity. With scientific fields and disciplines constituting such strong entities of identification and mediators of values, and with universities being embedded in nested organisational fields of international, national, and regional influence (Hüther and Krücken 2016), it is not clear what room (or need) there is for individual HEIs as organisations to develop strong identities and organisational cultures of their own. To a significant degree, identity in the world of academia is shaped in relation to categories of knowledge and of organisations.

A few studies have discussed what organisational categories that are relevant for historical and contemporary HEIs, and how the boundaries of these categories are being negotiated. For example, Gornitzka and Maassen (2017) recently focused on flagship universities. Another prominent example, which has some parallels to our own effort, is the analysis of Augier and March (2011). They show how business schools in the US underwent a transformation in the early part of the twentieth century, e.g. drawing on principles of 'education must be built on science' which at the time were already being championed in other types of HEIs—notably by institutions adhering to belong to the (potential) organisational category of 'research university'.

1.3 Organisational Identity and Organisational Categories

In our study of the 'technical university' as an organisational category, an important starting point is to consider how this category is related to other available categories that may be of relevance for a contemporary HEI. For example: how and why does being perceived as a technical universities differ from what it would entail to be characterised as a comprehensive university, or a research university (Musselin 2006; Maassen and Olsen 2007; Stensaker 2015)?

We conceive of a category of relevance for organisational identity formation to be associated with specific sets of attributes. Relevant attributes for the category technical university may, for example, be 'industry relevance', 'being entrepreneurial' and 'being scientific'. These attributes provide links to and positioning towards other identity category positions, against which a specific position is being assessed. Technical universities may share, for example, the attribute 'industry relevance' with institutions of applied engineering education, and the attribute 'being scientific' with the identity position 'research university'. At the same time, the position of 'technical university' may gain status as separate from both these related identity positions by being more strongly associated with industry relevance, than is the comprehensive university, and more strongly associated with 'being scientific' than is the technical institute.

An enquiry about this also prompts questions about how procedures, values, and organisational identity trickle down to and influence the behaviour of individuals in their roles as teachers, researchers and managers. In other words, how professional values are manifested in organisations related to engineering education ('as a teacher at a technical university, I should…') and decisions about research activities ('at technical universities we have a tradition of research in collaboration with industry in areas such as…'). These processes take place both directly (through strategic decisions, implementation of plans etc.) but also indirectly, mediated through the way in which organisational identity is grounded in (typically several) organisational identity categories.

In this context, we consider the orientation towards an organisational category as providing justification for, and being shaped by, different institutional logics in organisations (Ocasio et al. 2015). An organisation can harbour several logics as a counterforce to processes leading to isomorphism and similar looking institutions (DiMaggio and Powell 1983). Furthermore, a certain level of autonomy (achieved through, for example, excellence and/or industrial relevance criteria) can in turn safeguard practices and vocabularies used by the different units within an organisation such as the example of competence centres or centres of excellence hosted by university organisations that also have strong ties to industry (Larsen 2019). Chapters 2 and 8 in this volume describe how tensions between engineering as practice and engineering as scientific discipline characterise the development of HEIs referred to as technical universities. Identity work drawing on the position of technical university has from time to time sought to maintain and develop a balance between these two values. Thus, we may understand 'technical university' as an organisational category that harbours and enables an institutionalised compromise between potentially conflicting logics. Furthermore, the attributes and boundaries of an organisational category can be understood as being negotiated by the actors and interests that constitute an organisational field (Powell and DiMaggio 1991; Wooten and Hoffman 2017), which in themselves "are certainly the result of human activity but are not necessarily the products of conscious design" (Powell and DiMaggio 1991, p. 8). This brings us to also recognise that the technical universities, on the one hand, respond to external influences but, on the other hand are guided by internal processes of identity formation and reshaping of ideals, categories and boundaries. These boundaries are shaped in interaction between universities and knowledge intensive organisations including industry and are creating interfaces between ideals in academia and commercial logics and ideals (Murray 2010). At the same time, the organisational boundary between the external and internal can, in turn, become more permeable when organisations try to access critical knowledge and skills (Powell and Soppe 2015) through collaborative projects and exchange.

1.4 Localized and International Negotiations on Institutional Change

The idea (and ideal) of what it means to be a technical university is to a significant extent shaped by national contexts, as further explored in the chapters about Poland (Chap. 5) and Germany (Chap. 7) in this volume. That is, universities are grounded in national institutional frameworks (Fagerberg et al. 2009), which may differ in terms of historical contexts, and education and science policy reforms. However, the notion of 'technical university' as an organisational identity category is, in an important way, subject to internationally oriented mimetic processes. Such mimetic influence is exerted by globally visible role models or (as illustrated in Chap. 6 on OECD advice regarding technical universities) through ideas that travel through international institutional benchmarking (Pinheiro and Stensaker 2014). Hence, while technical universities have different roles, organisational structure, and traditions in different countries, they are also expected to share common roots, and to be subject to related external expectations and influences. With globalisation, they are also increasingly addressing the same audiences: internationally mobile students and faculty, and international bodies involved in policy development.

However, in the absence of strong templates representing a specific category (such as technical university), isomorphic development may dilute existing categories at the expense of others or alternatively, merger processes of higher education institutions can catalyse processes of voicing and redefining what the distinctive characteristics are. What will be the position of HEIs currently identified as technical universities within university systems in the decades to come? Will being a technical university appear as attractive to newly started or re-orienting HEIs? The central ambition behind this volume is to provide underpinning to a discussion of these issues by providing a comprehensive analysis of what organisational traits and ideals are associated with the term technical university in contemporary societies. This encompasses a discussion (based on empirical cases) concerned with how the organisational identities of technical universities are influenced by internal and external factors and activities carried out in collaboration with industrial actors and other HEIs relating to core activities, including engineering education, and research activities. Thereby, it seeks to provide a basis for a discussion on what it means to be a technical university in the twenty-first century and beyond.

1.5 Co-existing and Competing Ideals of Technical Universities

As further developed in other parts of this volume, the broad research university is by many seen as the leading ideal for HEIs. So how attractive is it for contemporary European HEIs to be oriented towards the more focused category 'technical university'? This question is theoretically linked to a more general set of questions about how organisations such as HEIs can adapt to (or resist) the influence of global templates defining a set of well-defined categories and associated organisational traits. Can diversity in terms of these traits that are developed locally prevail, despite standardisation efforts at an international or global level?

Some studies of universities apply sociological concepts, such as diversity, recognition, and local order to discuss ideal types applicable to comparative inquiry, concluding that 'standardization according to a global hierarchical institutional order may coexist with diversity' (Thoenig and Paradeise 2018, p. 197). This is an important observation since it suggests a need to study how organisations respond to multiple logics and institutional complexity (Greenwood et al. 2010) and how identity categories are communicated internally and externally by organisations (Ocasio et al. 2015). A theoretical point of departure in contemporary organisational studies is to acknowledge organisational narratives and discourses rooted in locally anchored values as being of key relevance to understanding identity formation, inertia, and actions of organisations (Gabriel 2004). In particular, studies of decision-making in situations dealing with dilemmas (when logics clash) and paradoxes are called for to understand sense-making processes more clearly in organisations (Weick 1995). This is relevant for the analysis of coupling between policy and daily practices of organisations and, as a concrete example, how organisational practices of engineering education can undergo processes of academic drift (Harwood 2010), while still remaining relevant to societal expectations and the demand for traditional skills associated with engineering education and technical universities. In the context of this volume, we are led to ask how different co-existing ideals regarding the organisational form of a HEI with a strong engineering tradition may play out in internal and external negotiations. In other words, an overarching question driving our research is what it means to be, or not to be, a technical university.

1.6 Are Technical Universities Essentially *Different*…?

Throughout this volume, organisational traits and ideals anchored in the identity and organisational category technical university are studied. At this point, the reader may ask why we suggest that understanding whether a HEI does or does not orient itself against a given category is an important question to consider. For example,

> what reasons would we have to expect engineering science and engineering education to be enacted in a different way if performed in the organisational context of a HEI with an organisational identity leaning towards the notion of 'technical university', compared to the corresponding activities being performed at a technical faculty embedded in a large, multi-faculty university?

Our general take on this question is that a 'technical university' can be expected to be permeated by culture derived from the context of engineering. For example, we note a tendency of single-faculty technical universities to set up organisational structures that are less clearly drawn along disciplinary boundaries, than what is the case in many traditional multi-faculty universities. It may also be expected that the actions and behaviour of university leadership figures and administrators will be shaped by norms and ideals related to organisational identity, and thereby to available categories.

In a 'classical' university setting, actors have to balance a multitude of disciplinary cultures and traditions. In an organisation where an engineering-dominated culture prevails, leaders may be expected to be more unrestrained e.g. in regard to prioritisation and in shaping relationships to external actors (Broström et al. 2019).

These arguments are congruent with how the identity and institutional history of other specialised HEIs (such as business schools and medical schools) have been analysed in previous scholarly work. Both types of HEIs, in what seems to be a relevant parallel to technical universities, have relatively strong and separable organisational identities rooted in practices, routines, and rituals. Specifically, Augier and March's (2011) work on the US-based business schools as a particular type of organisation emphasises the context of change and the roots of change.

We find the argument that organisational forms also matter for the performance and choice of direction in academic activities convincing enough to motivate the study of technical universities as an at least partially separable group. However, whether a specific HEI has more or less in common with one or the other HEI (for example, if technical university X has more or less in common with technical university Y or comprehensive university Z) is essentially an empirical question. Readers of this volume will find several discussions regarding sameness and difference across the different chapters. One example is the chapter by Vellamo et al. discussing organisational identity as a collective identity and distinctive characteristics (based on the organisation's collective "we" rather than individual identities within the organisation). That study focuses on technical identity in a merger process through analysis of characteristics that particularly set the organisation as different from other (similar) organisations (Albert and Whetten 1985). This highlights how organisational identity of technical universities can be articulated and narrated under processes of change. Rather than providing a definite answer to the question on what basis a HEI is to be included or excluded from the category of a 'true technical university', the empirical analysis focuses on identity formation processes but is nevertheless informed about ideas (and ideals) associated with technical universities.

1.7 The Volume's Approach

Our point of departure for this volume is a view of changing academic realities, through which an identity as a technical university is challenged and reconstituted. The idea of what is entailed in being a technical university evolves over time in response to changes in the structure and dimensioning of national higher education systems, to changes in the disciplinary basis of academic research, and to changes in the governance, organisation and funding of HEIs.

This volume should be seen as representing a mission to cover some of the ground for empirical analysis and provide some theoretical points of departure for a conceptual discussion about the past, present, and future of the technical university. Our ambition is to offer an empirically grounded analysis of cases in the European context to provide a foundation for discussion about future positioning and strategic development. Our main business, however, is with the present. To provide an analysis of what it means to be a technical university, and how influential ideals associated with that particular category affect the actions and reactions of university stakeholders, a number of empirical and conceptual studies are conducted. These studies are set in different national settings including Germany, Finland, Norway, Portugal, Poland, Sweden, and Switzerland.

Chapters 3, 4, 5, 6, 7, 8, 9, 10, and 11 which constitute the bulk of this volume, are independent studies selected and designed to allow insights into how the notion of the technical university is mobilised in times of change within HEIs. The individual chapter contributions display a wide array of theoretical perspectives, although they share the focus on the identity of technical universities. The chapters contribute in different ways to the broader discussion about how change and stability of existing organisational identity arise. Further, they discuss different ways that tension arises through internal reforms negotiating the boundaries of the organisation, but also through external pressures envisaged through reforms initiated from the outside. They discuss coercive change initiated through regulatory reforms, as well as processes of imitation or isomorphism to resemble other HEIs with which the technical university wishes to be associated, or share its similar core identity (DiMaggio and Powell 1983). Theoretical perspectives and methodology differ between chapters, reflecting their shifting foci.

Overall, the volume addresses two main lines of inquiry, both related to the organisational identity of technical universities: (a) formation of ideals and boundaries and (b) responses to change and how it relates to formation and re-negotiations of identity. The chapters in the volume are concerned with how technical universities respond to *external influences* but also are guided by *internal processes of identity formation and reshaping of ideals and boundaries*. This focus represents two research strategies to uncover key elements of organisational identity and the mobilisation and renegotiations of the boundaries and elements of organisational categories.

The first of these strategies is to analyse institutional responses to external pressure at HEIs defining themselves as technical universities. Studies following this approach are reported in Chaps. 3, 4, 5, and 6. These chapters offer in-depth studies of the reactions to external initiatives aimed at affecting how HEIs in general and technical universities in particular manage their teaching and research activities. In particular, the chapters explore how different national-level reforms and processes of institutional isomorphism play out at the organisational level.

The study reported in Chap. 3 considers the different traits and heterogeneity of technical universities and their consequences, drawing on a study of technical universities in Europe, including Denmark, Sweden and Switzerland. The analysis includes a discussion about scientific impact profiles and their alignment with government steering, funding, and internal organisation and leadership. Despite sharing some similar traits and (on the surface) appearing similar—in the sense of providing professional training of engineers in the range of areas that fall under the epistemic and organisational category of 'engineering'—the chapter concludes that they configure tasks and roles differently. Moreover, their scientific impact profiles should be considered in a wider national context, where technical universities serve different purposes and have a variety of collaborative alliances with industry partners and public sector organisations.

Chapter 4 is set in the technical university in Trondheim (NTNU), which has historically, and in terms of number of engineering students, played a prominent role in the Norwegian higher education system. Due to mergers, NTNU now covers most academic fields, including the humanities, social sciences, medicine, and law. However, as illustrated by the chapter, STEM disciplines (science, technology, engineering, and mathematics) continue to dominate. Thus, one the one hand, the study raises questions about strategic steering of a technical university in relation to national priorities in STEM disciplines, and on the other hand the autonomy of a technical university, which has a broad profile including disciplines of social sciences and humanities that go beyond traditional engineering disciplines.

The historical analysis of technical universities in Poland, presented in Chap. 5, provides an insight into traditional roles of technical universities in providing professional training in engineering, and the rise of technical universities as an educational institution with close ties to industry, and as a non-elite educational institution. Three phases are identified that link to industrial development in Poland in the late nineteenth century, followed by a phase after the Second World War to create new expertise and industrial centres in areas of engineering and agriculture. Following this expansion, the 1960–70s is linked to the expansion of higher education in Poland resulting in technical universities evolving from the already established engineering schools in Poland.

In many countries, formalisation of institutional categories plays an important role in creating and maintaining differences between HEIs. Chapter 6 draws on experiences from two national contexts, Portugal and Finland, to address questions regarding the mission of higher education systems in advancing binary ideals of distinct roles for technical universities and polytechnics. The distinct national contexts are contrasted with international scripts suggested by advice from international organisations such as the OECD for introducing change or suggesting continuity through a reinforcement of differentiated higher education systems in the two countries studied.

The second main line of enquiry of the volume, which is presented in Chaps. 7, 8, 9, 10, and 11, is to study identity formation at technical universities through the lens of how internal processes of the organisation drive changes of how the organisational boundaries are defined. These analyses are empirically rooted in studies of historical and contemporary discussions about changing the organisation of engineering research and education. Specifically, the chapters in this volume that examine mergers between higher education institutions, the introduction of new curricula deviating from the tradition of advanced studies in engineering, and the establishment of new organisational entities within technically oriented universities. Utilising the mobilisation of identity issues brought about by suggestions for change, the chapters study boundary work—or the lack thereof—by key actors. Such boundaries particularly concern the demarcation between academia and (industrial/technological) practice, and curricular strategies (for example, concerning the relationship between knowledge based clearly within the domain of engineering science and other knowledge bases). In doing so, the chapters provide insights into the construction of organisational identity and institutional boundaries at technical universities.

The analysis in Chap. 7 addresses the justification of technical universities in Germany by discussing the compromises of the civic-industrial order, focusing on the products of research and teaching as competitive public services. By scrutinising the situation in technical universities, the temporary stability of the civic-industrial order and the dynamic challenges of the market order can be analysed for the period 2000–2014. In a related enquiry about the relationship between academic and professional values in technical universities, Chap. 8 discusses an important developmental initiative in the area of engineering education: the 'conceive, design, implement, operate' (CDIO) framework. This analysis draws on the concept of integrated curriculum, which is based on experiences from the mechanical engineering programme at Chalmers University of Technology in Sweden. Further, it discusses implications at both curriculum and organisational levels of the technical university.

Chapter 9 analyses processes of identity formation during an ongoing merger process in Tampere, Finland. The historical backdrop to the Finnish case of technical universities is that the field of technical/industrial education was, in the late nineteenth century, nationally defined in terms of content, level, and qualification. Identity is understood as a collective social concept, where being part of a group is important for individual identity, and group identity is considered in relation to other groups (representing other identities). In the context of technical universities, the process of organisational mergers therefore poses questions about how an engineering identity (associated with a technical university) is preserved or evolves within a merger process resulting in a new university with a broader scope of disciplines represented.

The issue of change processes and identity is also addressed in Chap. 10, through an analysis of engineering academisation based on a study of an externally initiated process to reform engineering education in Sweden. Experiences from technical universities show that organisational identity was anchored in both the research and master's programmes and that this also affected the internal responses to change (or resistance to transformation). This resulted in a strategically designed initiative of a dual engineering education system within the leading technical universities that preserved or even strengthened the existing identity in the organisation of engineering programmes. Chapter 11 discusses the introduction of new curricula into technical universities. Specifically, the chapter studies how double degree programmes in engineering and teaching were set up at the two largest and oldest technical universities in Sweden.

The broader themes of the volume and insights from the different chapters are brought together in the concluding chapter, where the focus shifts from experiences of contemporary higher education institutions and systems to the world of ideas and conceptual understanding of technical universities. Thus, we seek to draw on our amassed insights from the past and present of technical universities to gaze into the (near) future. The volume concludes with an analysis of the content of the identity category 'technical university' and a discussion about contemporary categories and future prospective trajectories of technical universities.

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Chapter 2
Technical Universities: A Historical Perspective

Lars Geschwind and Anders Broström

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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Chapter 3
Are Some Technical Universities Better Than Others?

Mats Benner

3.1 Introduction: Are Technical Universities Birds of a Feather?

On a surface level, technical universities appear similar throughout the world: they provide professional training of engineers in the range of areas that fall under the epistemic and organisational category of ‘engineering’, sometimes aligned with adjacent areas, such as medicine, biology or the humanities. They conduct research to underpin that educational remit – and their development is closely aligned with those of its industrial and societal partners. Technical universities are education-focused but with a research function to underpin that mission, and they are strongly aligned with social forces in their evolution.

The impression is validated by an examination of the educational offerings of technical universities. They tend to have a similar core of programmes and areas irrespective of their location and history, and although they have gradually expended into other areas, the composition remains stable: mathematics, chemistry and physics, civil engineering, etc. form the foundation, and added to this, we find computer science (incepted in the 1980s), biotechnology and biosciences that emerged in the 1990s. More recently we have seen inroads into the cognitive sciences with the rise of Artificial Intelligence and other domains at the interstices of the technical and the humanistic. Most technical universities have also widened their remit and incorporated both education and research in the social sciences, with inroads also in the humanities, education and adjacent areas.

Technical universities as an organisational category have not been studied extensively, unlike their professional counterparts in the areas of business and medicine

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(cf. Huzzard et al. 2017). This is somewhat of a conundrum: while specialised schools and universities in the areas of business and medicine certainly embody frictions between vocationalism and research professionalisation, and between public and private interests, that call for analytical attention, similar contradictions and tensions shape the technical universities. This notwithstanding, quite a few studies have been done of specific characteristics of technical universities, mostly with a historical bent: first and foremost as extensions of industrial interests within academic programmes (Edgerton and Horrocks 1994), later on as vehicles of national mobilization in the cold war period (Lowen 1997), or as intersections between government and corporate interests (Björck 2008), or as widely deployable infrastructures in the modernisation of local economies (Etzkowitz 2002). The most recent wave in higher education studies – of which the present anthology is a profiled example – locate technical universities at the intersection of different societal forces, which triggers organizational responses, albeit in a specific form based on the societal and cognitive specificities of technical universities.

What these studies have in common is a reading of technical universities as adaptable and embedded in society: their academic core is stable but also open to influences from areas outside that core, and that they respond to impetuses from sources and interests located outside the confines of academia. This combination of a core and an expansive periphery (both in epistemological and organisational terms) was epitomised in Clark's well-known study of "entrepreneurial universities". The very template of (and exemplars of) entrepreneurial universities was shaped by largely engineering-based higher education institutions (Clark 1998). Such entrepreneurial universities, Clark argued, were marked by "non-traditional" academic traits, such as a strong steering core, a culture of entrepreneurial achievements and a commitment to financial expansion, also in forms outside the traditional avenues of academic fundraising. The combination of strong steering and network-based enlargements was therefore epitomised in technical universities, especially those of a more recent inception (such as Twente, Warwick, Joensuu and Strathclyde in Clark's study), but also in older ones like Chalmers University of Technology, which – in Clark's reading – had been able to reinvent itself (and "steer itself" to use Clark's definition of an entrepreneurial university) despite its venerable age. Clark's analysis, which was clearly focused at the level of organisational structures and adaptations, indirectly also covered epistemic aspects of the entrepreneurial universities and their development. He inferred that the entrepreneurial trait also involves the capacity to explore and exploit interdisciplinary studies and areas that engage with issues deemed important by societal and industrial interests (Gibbons et al. 1994).

Does this mean, then, that technical universities form a specific university "species", marked by their articulated societal embeddedness and leadership forms that emulate those of their environments, and their capacity and ingrained orientation towards "new forms of knowledge production"? Or are there several subspecies of the technical university template, several different ways of interpreting and acting upon that template? These issues form the starting-point of this chapter: are technical universities with seemingly similar conditions and expectations different? And why? To simplify the issue and to find a suitable way to highlight but also address organisational similarities and differences, the paper uses a simple empirical and analytical starting-point: the scientific impact of three technical universities. One of the universities, EPFL in Lausanne, Switzerland, counts among the most prominent universities in the world when it comes to scientific impact, and has the highest scientific impact among European technical universities, as measured in the share of its publications that is in the top 1% category. In fact, only two universities globally, Massachusetts Institute of Technology (MIT) and California Institute of Technology (Caltech), score higher than EPFL in this category. DTU is among the leading European universities in scientific impact, and ranks as number four among technical universities in Europe on this measure (after EPFL, ETH in Zurich and Delft University of Technology in the Netherlands). KTH, finally, is at a global average.

3.2 Explaining University Differences: A Brief Overview

There are different potential ways to highlight and analyse differences between different types of universities. Many contemporary studies of universities as organisations pinpoint how institutional mechanisms turn global and generic reform templates into emulations with little resonance with historical legacies and local practices (Musselin and Teixeira 2014). This juxtaposition of novelty and inertia creates organisational practices and leadership models that incorporate different institutional logics in parallel, with often ironic and unexpected outcomes. While this approach to the analysis of university governance is in many aspects laudable and intellectually clarifying, especially to decipher the often unexpected and ironic outcomes of policy reforms, a remaining analytical gap awaits to be filled, namely how we can account for variations between universities with roughly similar institutional conditions (in the sense that they are publicly funded and regulated). Why are publicly funded universities in similar political and governance settings doing this differently and with different outcomes?

For this topic, we may instead turn to another aspect of institutional theory, namely the strand which searches into divergence patterns and the continuous interplay between institutional conditions and performance (Hall and Soskice 2001). From such a perspective, similar tasks are embedded in different contexts, which leads to a variation in procedures and measures of goal attainment. Unlike the institutional studies conducted at the level of organisations, this strand is undeterred to make comparisons and judgements of the (variegated) outcomes of different institutional settings. Hence, the underlying assumption of this analytical strand is that there is a strong "institutional effect" – organisations should primarily be viewed and assessed as outcome of strong institutional determinants (e.g. Lane and Bachmann 1997). Some of the differences that are highlighted in our analysis may be relatively easily distinguishable, for instance, between private, well-endowed and small-sized universities on the one hand, and public, state-funded and large universities on the other hand – the former will most likely be predominantly focused on reputation and selectivity whereas the latter will have accountability and access as their main characteristics (Bienenstock et al. 2014). A comparison between physics at Stanford University and Lund University (op cit.) revealed dramatic differences in scientific impact between the two, which may not be overly helpful in understanding how specific universities function in relation to goal attainment; it may, however, clarify how variations in institutional conditions produce very different organisational practices also within similar fields (history and physics, which were the cases chosen for Bienenstock et al.'s (2014) study).

In the present case we are comparing universities with similar preconditions and embedded in similar institutional systems (that is, cases that have been chosen because of their similarity, Porta 2008): publicly funded, broad in access due to public regulations, and with research-intensive counterparts in industry – and located in non-English speaking countries, which should diminish risks of skewed impact patterns (cf. Gingras and Khelfaoui 2018). To further elaborate the analytical template and to account for the differences in scientific impact, these general institutional conditions will be further refined, by investigating the following dimensions:

- Type of interaction with government, including funding profile and governance arrangements.
- Internal governance, including resource allocation and power and authority structures.
- Types of interaction with industrial and societal partners.
- Models of recruitment and promotion.

3.2.1 The Topic

In this chapter, I compare governance, organisation, leadership, and funding at three technical universities in Europe: the Royal Institute of Technology in Stockholm, Sweden (KTH), the Technical University of Denmark in Lyngby, Denmark (DTU), and École polytechnique fédérale in Lausanne, Switzerland (EPFL). The aim is to clarify why the technical university template, as outlined above, takes such different forms when it comes to scientific impact for universities with seemingly similar conditions. Is the template really as consistent as we have assumed, or are some institutional factors at play which influence approaches when it comes to scientific publishing? And is there a link between publication patterns and the other missions that the technical universities have? Underlying this issue is an assumption that there is a relation between modes of research practice, scientific publication patterns and scientific impact as measured by shares in high-impact (10%) publications. The validity of such measures for the analysis of individual institutions has been questioned (van Raan 2005) – such figures arguably do not take into account the considerable variations that shape and constitute higher education institutions, and risk affording a reified understanding of differences. On the other hand, such measures may be of more use if comparing universities with similar conditions when it comes to their mission, profile, funding, and governance models. Using bibliometrics as a yardstick also enables a comparison, which has been fairly uncommon in studies of higher education institutions which instead tend to focus on specific factors or on individual case studies, thereby missing the opportunity to actually relate institutional factors to outcomes.

3.2.2 Methods

The article is based on a combination of sources. Interviews were conducted in 2012–2013 for DTU and EPFL, and continuously over the period 2011 to 2018 in the case of KTH (20 interviews altogether). Interviews were done primarily at the level of institutional leadership (presidents and deans) but also with individual faculty to match and map statements from formal leadership with those of teachers and researchers. In addition, secondary material has been collected in the form of strategy documents, financial reports, staff directories and minutes from leadership bodies, both to corroborate and validate interview data and to complement and update information that had provided earlier, as well as material that showcases the universities' activities and their networks, financial underpinnings, employment and promotion strategies, and other types of relevant information. Like Clark's study (1998), this study relies heavily on information provided through elite interviews; however, the discursive and potentially hyperbolic effect of depending primarily on leadership interviews has been mitigated through document studies and complementary interviews with faculty and staff. The bibliometrics is used for descriptive purposes and is derived from the publicly available Leiden Ranking database (www.leidenranking.com).

3.2.3 Operationalisation

In this chapter, I use a simple baseline for the performance of technical universities – their scientific impact as measured by their bibliometrical profile – and compare that to their organisational structure, forms of leadership and articulation with society.

3.2.4 A Benchmark

The three universities are roughly similar in size, and publish around 1000–1500 papers per year. Their respective publication patterns are also similar:

In the most recent Leiden ranking of the scientific impact of universities (covering 2012–2015), EPFL is among the most visible of universities worldwide, with a citation level of 86% above world average for top 10% publications. DTU stands at 36% above world average. KTH, finally, is one (1) percent above world average. The pattern holds also if we extend the period under study: for 2006 to 2009, EPFL is at 73% above world average, DTU at 37% above world average, and KTH at 2%.

The three technical universities have a roughly similar scientific profile: in engineering and physics, their annual output is similar (around 800 publications annually). EPFL stands out with its significant presence in biomedicine and life sciences, about three times the size of DTU and KTH in these areas (with some 400 publications annually for EPFL). DTU and KTH have somewhat larger shares of activities in the social sciences than EPFL – even though the shares are small in comparison with those of other areas. EPFL and KTH are significantly larger than DTU in computer science and mathematics. Hence, the three technical universities have a core of engineering sciences and physics, which they combine with other areas in somewhat different proportions.

When it comes to the scientific impact of the respective areas of specialisation, the patterns are quite distinct. In engineering and physics, KTH is at the global average whereas DTU is 36% above the world average and EPFL 87% above it. In biomedicine, EPFL is over 100% above the world average for the top 10% category, while KTH, with almost 100 publications annually, is more than 40% under the world average, while DTU is 25% above it within this category. DTU is particularly strongly represented in highly cited papers within the life sciences, at around 70% above world average.

If anything can be said on the basis of the bibliometrical survey, it is that the EPFL has successfully diversified its activities into the life sciences and biomedicine. Even though those areas are still smaller in size than those of the core engineering school fields of engineering and physics, EPFL comes across as a hybrid technical university with a large and growing share of life sciences.

3.3 The National Role of the Universities

The three technical universities under study here are all "flagship" technical universities, and among the largest in their respective countries. EPFL is part of the Swiss federal structure of technical universities and belongs, together with its sister university in Zürich, ETH, to that structure. Even though the relationship between EPFL and the Swiss government can be considered as demanding, where the President is held accountable not only to the overarching ETH Council but also the Swiss Federal Council, the relationship is marked primarily by trust – "one line in the budget suffices to define the budget of the university" (Interview: EPFL leadership; cf. Kleiber 1999). The same type of relation has historically been translated into internal governance of the technical universities in Switzerland, with the ETH Board setting only rather general goals; the latitude at lower levels is therefore considerable. As Griessen and Braun (2008) have noted, there are frictions and incompatibilities in the Swiss science and technology policy system, including a divide between the federal and the state levels, and between basic and applied research, but the ETH system occupies still a privileged zone in policy-making with limited fluctuations both financially and expectation-wise. If anything, the EPFL has been well-served by the commitment of the federal level to propel the competition between the two federal universities, and to elevate the relative position of the EPFL vis-á-vis the other technical university, ETH in Zürich, which has traditionally been far superior in rankings and international visibility.

If the Swiss system is very much based on trust and long-term commitment from the government, Danish university governance is an almost ideal-typical adoption of New Public Management, with performance indicators formalised in contracts which survey and measure the activities of its universities (Foss Hansen 2016). DTU, as all Danish universities, operates under the auspices of the Ministry of Higher Education and Science, and has its relationship with the government formalised in a multi-annual development contract. The contract covers a combination of points raised by the government and of the university itself. DTU's contract includes a combination of employability concerns and scientific measures, such as the number of indexed publications and relative citation impact with comparisons made to other "top" technical universities in Europe, such as EPFL and KTH. The contract operates in parallel with and as a non-monetary supplement to the model of funding allocation, which is based on a combination of the number of students, the scientific impact, number of PhDs produced and the size of the external funding. The Danish government has also formalised and streamlined the mechanisms of university governance considerably in the last decades, and has pushed universities in the direction of appointed leadership styles, with considerable managerial discretion, and expectations that the formalised leadership should set internal goals and performance indicators along the lines of the relationship between the government and the higher education institutions.

The Swedish governance system is the most complex of the three as it combines elements of a trust-based (historically founded) allocation of resources for research with performance-based indicators that shape a tenth of resource allocation. This mix of trust and performance is combined with a sizeable part allocated through contracts and agreements with the state. Swedish universities, especially those which are research-intensive, rely considerably on external funding of research, which in the case of KTH consists of more than 60% of the total resource basis for research – which can be compared with 20% for EPFL and 35% for DTU. External resources come in a very large plurality, ranging from European Research Council grants to commissioned studies from local authorities. The main funders are the Swedish Research Council, the European Union, the Wallenberg Foundation and the Swedish innovation agency, Vinnova. For education, Swedish universities rely on an allocation model based on a combination of admissions and degrees taken, with no guaranteed and unconditional funding. University governance reflects the complexity of the funding of universities in Sweden, with a mixture of bottom-up and top-down mechanisms, and with a general vague foundation of leadership tasks and roles (SOU 2015:92).

As to the educational profiles of the three universities, they are similar: KTH has nearly 13,000 students enrolled in 24 different educational programmes at the bachelor's and master's levels and nearly 2000 PhD students. DTU has around 11,000 students at bachelor's and master's levels in some 50 different programmes and 1300 PhD students. EPFL, finally, has around 8000 students and bachelor's and master's levels in 37 different programmes and around 2000 PhD students.

For funding, DTU has a total turnover of 5 billion DKK, and a research turnover of 3.6 billion DKK (440 million Euros), of which 53% (1.9 billion DKK or 240 million Euro) comes directly from the government. EPFL has a total turnover of almost 1 billion Swiss francs (860 million Euros) of which two thirds are for research – and of that, almost 70% comes directly from the government. KTH has an annual turnover of 5 billion SEK (500 million Euro). Of its research turnover of 2.5 billion SEK (250 million Euros), 44% comes directly from the government and the remaining 56 through third party support.

As to the structure and composition of the academic staff, KTH employs 300 full professors, DTU 240 full professors; EPFL on its side has only 350 faculty altogether, of which half (170) are full professors. EPFL, while small in size when it comes to its faculty, has a significant pool (over 1000) employed as staff scientists and post-docs, in addition to the sizable number of PhD candidates.

Another important aspect of the respective universities is their faculty composition in terms of nationalities. One straightforward reason why this is important is that has been a stated preference for DTU and EPFL to internationalise their faculty; another is the theoretical observation of an interplay between the composition of a university's faculty and its managerial models (internationalisation driving a more generic and vertically integrated leadership style; Bartell 2003).

It is difficult to ascertain the number of foreign recruits to the different universities, at least for KTH (Swedish law does not permit records of ethnic backgrounds of students or staff). Sweden and Switzerland are among the most internationalised countries when it comes to the composition of the scientific workforce, and for Switzerland it is clear that internationalisation is a characterising feature of recruitments at both the level of professors (about two thirds of the faculty is non-Swiss) and among PhD candidates and post-docs. KTH, in contrast, has the main share of its international scientists employed only at the level of PhD candidates and post-docs, but significantly fewer at the level of professors and other tenured positions. A rough estimate, provided by a member of KTH management, is that about 10% of KTH faculty is non-Swedish. DTU, finally, is again somewhere in-between: a senior member of the leadership team at DTU estimated that one third of DTU faculty is non-Danish, and DTU is also strongly oriented to international recruitments among senior members of the faculty. To sum up, then, 10% of faculty at KTH is internationally recruited, 33% are non-Danish at DTU and EPFL's is overwhelmingly international at 66% of total faculty. We assume that these differences in recruitment pattern will affect the governance and leadership of the higher education institutions.

The funding and employment patterns therefore differ significantly. KTH has a large pool of full professors, largest of all three despite the fact that is significantly smaller in economic terms, at least as concerns its research component. Part of the explanation resides in the larger educational remit of KTH, but another and more important in the construction and constitution of the professorial position. KTH professorships are predominantly promoted professors, where internal candidates at KTH have had their qualifications tested.

EPFL and DTU also have, however, far more restrictively, the possibility of promotion. EPFL professorships are fully endowed, and come with significant additional resources: assistant professors receive generous starting-packages enabling them to form research groups on the basis of university funding, which can then be complemented by external sources. KTH, on the other hand, has no, or at best highly limited, starting packages for junior professors while senior professors receive no supplementary funding and in most cases also are expected to raise parts of their own salaries from external sources. Funding of PhD candidates and post-docs is also largely tied to external funding sources. DTU is similar to KTH in that professors have only limited extra resources attached to their positions. However, the departments are in disposal of more support staff as well as internal funding of PhD candidates.

3.3.1 Governance: Similar Issues, Different Models

Governance issues have already been touched upon briefly, as part of the contractual relationship between the state and the universities in their respective settings. We argued that governance at the level of universities in its turn is shaped by the relations that governments set up with their respective universities. In the Danish case, we depicted a New Public management-inspired model which is institutionalized through a the combination of a rather straightforward model of resource allocation intertwined with a contractual relation where the state articulates a set of specified goals, conjointly with universities which in their turn present some goals of their own. In more elaborated terms, DTU, EPFL and KTH represent three different approaches to the governance of universities and their alignment with societal missions. DTU, which started out as a strictly domestic and residual institution in a society and economy dominated by the primary sector, has been gradually transformed into a spearhead of a national developmental model taking form in the 1990s and onwards. In this model, expressed and embodied in the ideal of a "globalized, knowledge-based economy", universities were singled out as a critical resource in the redeployment of Danish society (Benner 2003). The successive university law reforms in the 1990s and 2000s transformed the governance of Danish universities and empowered the previously mostly ceremonial roles as rector, deans and head of department. DTU was the exemplar institution in this development, with a leadership and governance model that caused enormous controversies at the time, but it also fostered a much streamlined academic organisation, with clear-cut ambitions when it came to the recruitment and promotion of staff, the modernisation of DTU's facilities, an upgrading and modernisation of DTU's educational offerings, and enhanced interactions with external partners (Interviews: DTU board member, DTU leadership, DTU faculty). More specifically, that model includes a clear-cut division of labour between different management levels: the board sets general targets and strategic directions in tandem with the rector. The president operates together with a leadership group (executive team), and the president together with this group exercises a strong influence on decisions to hire senior staff and department heads. Departments, in turn, have a considerable leeway within the confines of this governance model when it comes to hiring decisions, strategic orientation, networking and alliances. A few events which have received large attention have showcased the centralisation of power around the president, for instance when individual professors have been forced to leave or when department heads have been dismissed. DTU is therefore shaped by a tension between centralisation and decentralisation, which has caused some visible strains but which seems also to have empowered an academic culture which is geared towards international visibility and networking. From the board's and the management's perspective (as well as the government's), this reorientation of DTU has paid off, and a (purportedly) myopic institution has been transformed into a global elite institution. In its most recent strategy, DTU also sets the goal to be an elite university, counted among the five best technical universities in Europe (DTU strategy 2014–2019; http://www.dtu.dk/english/About/ORGANIZATION/Strategy).

EPFL is founded and governed to serve as a global, elite institution, and its funding and overall directions afforded by the government are unambiguously oriented in that direction. EPFL leadership in turn has been very dedicated to streamlining the relationship with lower levels of authority and relegating tasks and authority accordingly. Deans are recruited internationally, as are – to some extent – heads of the EPFL institutes. Decisions to hire and promote are taken at the dean's levels, after considerable inputs from the departments and final vetting from the President. In this respect, EPFL has emulated a governance style similar to that of leading US universities, where the President sets the strategic directions, is in charge of relations with the patrons, does large-scale fundraising and is responsible for the hiring of faculty leaders, where the faculty leadership is tasked with the role of hiring faculty and aligning its organisation with specific conditions pertaining to the respective faculties, and where departments function as the primary site of activities with the role of the department leadership to ascertain a high level of internationally competitive research and teaching. This model marks a break with the highly decentralised way its sister university in Zürich (ETH) is governed, where the departments are the main site of power and resource allocation, without the intermediary level of faculties and schools (Interview: ETH professor). It also marks a break with the traditional way EPFL was governed, where even departments were weakly structured internally and where individual professors determined the direction of their activities and those of their professorial domains (Interview: EPFL leadership). EPFL has not been without controversies and clashes, and the highly visible and directive leadership has resulted in both considerable gains in international visibility and in internal strains; the most recent and visible example are the controversies surrounding the flagship project "Blue Brain Project" (cf. Frégnac and Laurent 2014).

KTH, finally, is a mixture of expectations and leadership roles. The university president's role is not entirely clearly defined, more than that it should serve as the ultimately responsible. The heads of school (equivalent to deans) have a clear-cut and continuous relationship with the president and university management. However, the schools are quite large and diverse, and the relationship between the school management and administrative levels below show a bewildering variety. Given KTH's broad-based and complex funding base, and the many different funding sources – each with its specific set of expectations and obligations – leadership and authority thus appears variegated and shaped by the tasks and funding available at the different divisions and departments at KTH (cf. Geschwind and Broström 2015). This does not mean that the formal leadership does not aim to make an imprint. The main expression of this has been a series of reorganisations, done mostly, critical observers note, to ensure that the university leadership exercises some power in the organisation (Interview: KTH professor). Decision-making when it comes to recruitment and promotions are nominally controlled by formal levels of authority but in many (but not all) cases tied to funding opportunities. As an example, KTH has hired a large number of professors in areas richly endowed with funding but with only small number of students: "we have five professors in the area of (X) and some 12 students at the advanced level in the same area – this does not make sense" (KTH head of school). Hence, the KTH governance model is eclectic and complex, with multiple power and authority sites and fuzzy demarcations between the different levels. While this may again be interpreted as a flexible and pragmatic stance in a national governance landscape which is more variegated than the Danish and Swiss counterparts, it risks leading into goal conflicts and also unproductive impasses when different interests try to enforce its influence: the relationship between what is decided at the level of the President, the heads of school, departments, and individual research groups seems not entirely clear to any of the actors. This shows also in the model of recruiting and promotion, which is largely tied to the supply of external funding rather than to internal considerations. Unlike DTU and EPFL, KTH does not seem to use its internal forums for systematic consultations of hiring needs, potential candidates inside or outside of Sweden, or complementarities between areas that new recruits could fill. This is, instead, largely seen as the remit of individual research groups and areas, dependent on their success with funding agencies.

3.3.2 Industrial Relations

A technical university has traditionally been defined by its industrial connections, with its educational profile shaped by the expectation of the industrial environment, and the research function serving as a supportive infrastructure for the educational role – and consulting and informal networks as the primary form for knowledge exchange between academia and industry.

Arguably, the current model of university governance makes the forms of industrial relations for technical universities more variegated and even more central, but in slightly different ways than in earlier periods (Geuna and Rossi 2015). Industry serves as a significant source of direct funding of research, but also as a partner in research activities, shown also in corporate support of research and education facilities, shared infrastructures and the like. All three universities under study here have extensive industrial contacts and networks, but they serve somewhat different purposes. DTU operates in a largely network-based form, and is embedded in a knowledge-intensive industry with tradition as working as supporters of academic research and academic environments. Several of these companies have afforded resources for laboratory facilities, recruitments, exchange programmes, and the like. DTU has been able to capitalise on its industrial partners, which through forms of ownership and control are largely tied to Denmark and which therefore have cultivated strong linkages with academic partners – and which therefore have welcomed the reforms of academic governance in Denmark with a more elaborated leadership structure, which they view as more conducive to industrial partnerships (Interview: Board member DTU). For DTU, this taken the form of a series of partnerships with Danish firms and the conjoined investments in new facilities in the biosciences and biotechnology.

Switzerland and EPFL have adopted an aggressive policy to obtain endowments and support from adjacent actors and organisations, witnessed in spectacular endowments for buildings but also for research centres. This reflects in part the environment of EPFL, with several large multinational firms sited in Switzerland for a variety of reasons, but also the model adopted in the governance of EPFL, namely an emulation of US private universities and their network-formation around donors and corporate beneficiaries (cf. Mathies and Slaughter 2013).

KTH, finally, has a more mixed model of interacting with its industrial partners, formalised into a series of designated "partnerships" which stipulate a number of interdependent commitments on behalf of the partners, but relatively little in terms of actual contributions for research centres, buildings or similar. What KTH has been able to capitalise on is its historical ties to the dominant ownership centre of Swedish industry, the Wallenberg family, which through one of its research foundations (Knut and Alice Wallenberg Foundation) has been very supportive of three of KTH's pillars: research in forestry (tied to the interests of the Wallenberg family in StoraEnso), in biotechnology and genomics (tied to the family's engagement in AstraZeneca) and in information technology and artificial intelligence, related to its large share of ownership in the telecommunications firm Ericsson. Hence, KTH relies even more strongly than DTU on bilateral relations with a very limited set of partners, and is very far from the aggressive and multipolar industrial relations strategy of EPFL. The fact that KTH's partners are also part of a more complex ownership structure than DTU's partners may also – from a long term perspective – hamper KTH's possibilities to extract value from its partnerships.

3.4 Discussion

Overall, power, leadership and governance (at both the level of the political alignment and intra-university decision making) appear probable as explanations of the differences in scientific impact among the three universities. The leadership models vary between the universities – largely based in different national models for university governance. DTU is shaped by the Danish model of a high degree of centralised control to top leadership, with a tandem-like relationship between the rector level and departments when it comes to goal setting and accountability. The same applies to the relationship between the government and DTU, which is moulded by contracts between the two, specifying the goals of DTU's activities in rather elaborate detail. The contract also incorporates yardsticks – including the EPFL and KTH – when it comes to the number of indexed publications and the citation impact of DTU publications. A particularly important factor behind DTU's development seems to have been the reforms of its leadership and organisational templates, which have moved from a highly decentralised and variegated model to a streamlined ideal. EPFL is even more elaborately organised, with a clear-cut differentiation of goals and means available at the level of the President, deans and heads of departments. EPFL's model and status derives from its special relationship with the federal government: the university is lavishly funded and the relationship with the Swiss Federal Council is mediated through the ETH Council; the expectations on the ETH universities are broad and in practice focused on visibility and prestige, and the accountability of the EPFL vis-á-vis the government is therefore demanding but unambiguous. The push that EPFL experienced in the late 1990s illustrates the importance of direct governmental intervention to reinvigorate the university, and the political commitment, despite political changes elsewhere, to globally leading universities. KTH is the most complex of the three when it comes to the distribution of power and authority within the organisation: the relationship between president, dean, heads of school and department heads is not entirely clear and the responsibility for resource allocation and recruitment is divided between the different levels, with a significant input also from an advisory function. And in addition, recruitment is to a significant degree contingent upon the obtainment of external funding, which is far less common for the other two technical universities. The relationship with government is also more variegated than those of its counterparts, without the contractual foundation of the DTU and the EPFL but instead a mixture of inputs. However, the most striking difference between KTH on the one hand and DTU and EPFL on the other is the composition and structure of its financial underpinnings for research: not only does KTH receive less in total appropriations for research, it receives the main share of that funding in the form of external (third stream) funding, tied to individual projects and research groups. Despite a vociferous critique of the composition of research funding in Sweden and its (alleged) consequences on research quality and the alignment between education and research (Bienenstock et al. 2014), there are no signs of a political reorientation. The government remains committed to external funding as an important measure to direct the Swedish universities' activities, and great stress is placed on the design and implementation of governmental research programmes and initiatives.

Industrial relations are similar between the three: all have significant direct funding from industry, at around 10% of total turnover for research. They have all secured significant private endowments for infrastructural investments, and for new facilities at significant levels for all three. The industrial partnerships are particularly broad-based for KTH, showcasing the university's strong ties with Swedish industry in its breadth ranging from forestry, biosciences over to ICT and transportation; DTU and EPFL have a somewhat narrower industrial ecosystem, which can be explained by the composition of their economies with heavy dominance of bio-related industries. Arguably, the mandate and role of KTH are more complex due to the variegated expectations of its different constituencies and eco-systems.

When it comes to the final aspect of the governance model that we have used as our analytical template, namely recruitment and promotion, we find a striking relationship between governance and funding on the one hand, and faculty promotion on the other hand. DTU, and even more strongly EPFL, identify themselves as international universities with global recruitments in particular on a senior level: EPFL recruits around two thirds of its senior staff internationally and DTU is also actively engaged in international recruitments. The number of faculty positions is also very different between the three universities: EPFL, despite being the most generously endowed of the three universities has by far the smallest number of professorial positions (but a very large number of support staff and staff scientist positions), while KTH has a significantly higher number of professorial faculty but fewer intermediary and supportive positions. DTU is in-between, but has seen a hike in the number of professorial positions more recently, where the influx of external funding has been translated into the creation of temporary professorships. The construction of professorial positions is also radically different in the three cases, with a fully supported model at EPFL with adjacent resources secured by the university including starting packages for junior professors, with DTU having a more eclectic model of supporting its faculty, while KTH relies primarily on external funding for the provision of supplementary resources for its personnel. KTH's economy is also based on the assumption that many (if not all) of its professors raise parts of their salaries through third-party funding. Even though there is not explicit policy in this direction, there seems to be considerable pressure to use parts of funding, also from prestigious sources (such as the Wallenberg foundation), to fund own salaries.

To sum up, how technical universities are governed and funded impacts on their scientific impact profile. DTU, EPFL and KTH, while sharing many characteristics, function and are organised in quite distinctly different forms. EPFL can be interpreted as an emulation of elite universities in the US, with a small, competitively selected international elite as its faculty, richly endowed in resources provided by the university and with external funding as an add-on and as a sign of the competitive standing of its faculty. KTH on its side has a largely in-house trained and recruited faculty, which relies heavily on external sources for the provision of resources and infrastructures for their research, and for the recruitment of additional staff. KTH is a national institution, even though it too increasingly hires staff internationally, albeit primarily at the level of PHD candidates and post-docs. DTU is a blend of the two, less global and elitist than EPFL, but more selective and resourceful in relation to its recruitments than KTH, and with a much clearer and stronger steering core. They certainly share many characteristics as technical universities operating at the interstices of professional education, academic research and societal collaboration, but the way they do it and their way to enact the technical university template varies to the extent that their similarities are overshadowed by the differences.

Is one or the other of the universities better than the other? EPFL clearly comes out as the leading scientific institution of the three, based on generous endowments, streamlined governance and a recruitment policy deeply entrenched in the international labour market for elite scientists (and with salaries to match). While this strategy has certainly paid off and elevated EPFL to the status of a globally leading institution, it has come at a considerable strain, dramatically exemplified with the governance crisis of the neuroscience flagship initiative. KTH is the exemplar "civic university" (Goddard et al. 2016) or "new flagship university" (Douglass 2015) which serves many different constituencies, with only limited ambitions to compete consistently at the globally leading level. While this balancing act can be seen as successful in its own right, squaring legitimation with international visibility, it does not come without strains and contradictions, not least concerning the fuzzy expectations on university leadership, which has led to a series of stop-go policies at the level of the university president. DTU has evolved in a process described both as highly successful and traumatic, as the beacon of the Danish government's ambition to transform its universities from insularity to global recognition. Controversies have circled around the exercise of presidential power but also a series of rather radical redeployments of resources and faculty at the level of departments. DTU's transformation has been largely exercised from above and the main challenge for DTU is if this momentum can be reproduced over time.

A critical reading of our analysis might infer that the issue is far less complex than we have made it into and that the three universities, despite their superficially similar starting points (public universities in non-English speaking contexts), actually operate in three separated institutional settings with adjacent funding models: the Swiss which views its elite universities as global institutions which should be governed and funded accordingly; the Danish which strongly emphasises the international visibility of its universities, and which operates with a streamlined governance model with performance targets as guiding principles; and the Swedish setting, finally, which is more meagre in its funding also of research within elite universities and which views its universities as containers comprising quite distinct missions and goals which the universities are expected to somehow square and align. This, in turn, is translated into funding levels, which vary considerable between the three, with EPFL operating at the level of well-endowed private universities in the United States of America as their benchmark, DTU which is well above a European average when it comes to funding levels and which serves to protect its research mission from an overload of goals and tasks beyond those of a bare minimum for public universities. KTH, finally, is a complex mélange of activities and funded accordingly.

While these are reasonable caveats, pointing at the relationship between inputs and outputs as a strong explanatory factor behind the differences in scientific impact, it disregards how different funding models are embedded in institutional settings. DTU is governed with a set of goals as the starting point, and organised along those lines. EPFL similarly has effected a governance model, which is relatively streamlined and it is assessed accordingly by its patron. KTH, as a contrast, operates with several different logics in parallel, which gives it, and its patrons, a higher degree of latitude but which also translates into a more complex and opaque set of expectations. This in turn has created an internal governance model, which is less stable and more prone to variations and turbulence over time. This is not entirely tied to funding but rather a more or less deliberate choice, to view the university less as a coherent organisation and more as a collection of different tasks with little alignment. When power and authority are superimposed on this, for instance, when an incoming President aims to take control over the direction of the university through reorganisations that may not serve the goals of long-term renewal or quality-enhancement but rather comes across as mere politicking.

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Chapter 4
The Position of Technical Universities Within Changing Frameworks of Institutional Organisation and Steering: The Case of the Norwegian University of Science and Technology

Agnete Vabø and Liv Langfeldt

4.1 Introduction

In Norway, the Norwegian University of Science and Technology (NTNU) is regarded as the preeminent technological university. Originally, it was an independent and apparently distinguished elite institution – the Norwegian Institute of Technology (NTH) – with few students and high admission requirements. This institution's primary task was to educate engineers (*sivilingeniør*), a profession historically the most important – and still important – supplier of Norwegian industry and industry leaders.

Within the framework of the massification of higher education, the institution's status and autonomy have been challenged by changing state governance and social conditions. The period from 1980 onwards has also been characterised by high demand for subjects other than the technological.

Today's NTNU is the product of several mergers and cooperation with other institutions, most recently with three state colleges, which means that NTNU appears as a hybrid of the traditional university of technology offering professional education, a university offering humanities and social sciences, a vocational college with lower-level professional education, and multiple research-intensive environments. Nevertheless, NTNU has managed to sustain its image as Norway's leading technological university. As part of its mandate NTNU also plays a key role in innovation, led by a pro-rector for innovation.

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This chapter establishes a sociological-historical perspective and concepts to highlight dimensions that are important for NTNU to reproduce its status under changing governance regimes – for example, in the form of closure mechanisms and close links to specific groups in the social class structure. NTNU is understood as part of an academic field (Bourdieu 1988) with unequal strengths and distribution of power between subjects and actors – which has an impact on how state governance and other external issues are interpreted and translated into the NTNU organisation.

In the Norwegian context, the role of the state as the owner and overall governor of this almost hegemonic position of NTNU and similar institutions is extremely important. Systematic governmental efforts on technology over time exemplify how the state's role as a protector provides scope for NTNU to develop a distinctive field logic and organisational identity, which contribute to the legitimisation of internal strategies and resource allocations where technological subjects are prioritised higher than at the other Norwegian universities.

However, we are not going to resort to a one-dimensional structuralist/institutional approach in our analysis of NTNUs development, but rather seek a more balanced actor/structure approach. Through empirical examples we illustrate how the characteristics of institutional leadership – their social identity – affect the content and outcomes of institutional strategy processes, for example, in the merger process towards the "new NTNU". It is argued that NTNU's choice of management model, principal and external chair of the university board symbolises dominant positions in the field as well as legitimises institutional strategies both internally and in relation to the significant external relationships.

The article is largely based on previous empirical studies of NTNU in connection with an analysis of national STEM initiatives (Langfeldt et al. 2014) and the follow-up research of the NTNU merger (Vabø et al. 2016).

4.2 Historical and Social Dimensions of the NTNU

As we learn in this volume, most Nordic countries have distinctive research-intensive universities with an emphasis on technology, such as the KTH Royal Institute of Technology in Sweden and NTNU in Norway. Finland and Denmark have also placed great emphasis on creating powerful environments through the merger of several institutions, such as the Aalto University of Finland with its emphasis on technology, natural sciences, architecture/design and economics/management.

The Norwegian University of Science and Technology (NTNU), established in 1996, originated from NTH – the Norwegian Institute of Technology, itself established in 1910. It is a 'new' university resulting from a merger between the Norwegian Institute of Technology (NTH), the Norwegian College of General Sciences (AVH), the Science Museum, and the Medical School in Trondheim. Together these units made up what was previously called the University of Trondheim (UNIT). UNIT, however, was more of an umbrella construction than an academically integrated university. Among other things, both NTH and AVH had their own rector before the merger (Stensaker 2004).

NTNU's oldest academic discipline – mineral resources engineering – can trace its roots to the foundation of the Royal Norwegian Geological Seminary opened in Kongsberg in 1757. The Norwegian Storting (Parliament) passed a resolution supporting the establishment of the Norwegian Institute of Technology in Trondheim and the decision was finalised on 31 May 1900.

Trondhjem Technical Vocational School (TTL) opened its doors as Norway's first technical college in 1870. Until it closed in 1916, TTL was widely seen as the country's leading institution for technical education. The vocational school was also the forerunner to Trondheim's two biggest educational institutions, the Sør-Trøndelag University College (HiST) and NTNU.

Hence, as the result of successive mergers, NTNU now covers not only most fields of science, but the humanities, social science, medicine, law and so on. Nonetheless, NTNU maintains its status as the premier technical university in Norway. Today, NTNU – measured by the number of students, employees and several other indicators – is Norway's largest university, with more subjects beyond the technological. In comparison with the other comprehensive universities, such as the University of Oslo, Bergen and Tromsø, at NTNU the disciplines of science, technology, engineering and mathematics – the STEM disciplines – remain dominant, and represent a much larger share of the total budget, students and staff. As revealed in Table 4.1, the R&D expenditure within science and technology in general and technology in particular is much higher at NTNU in comparison with the other comprehensive universities.

Technological subjects are primarily organised under the Faculty of Engineering and the Faculty of Information Technology and Electronic Engineering respectively. There are separate faculties of Humanities, Education, Economics and Management, Medicine and Health Science, and Natural Science. In addition to campuses and departments in Trondheim, Norway's third largest city, NTNU also has departments in the cities of Gjøvik and Ålesund, where the merged state colleges were located. The departments in Gjøvik and Ålesund are organised under the respective faculties.

NTNU is characterised by its preeminent engineering education and research excellence especially in the technological disciplines. Why this status is so strong despite there being more subjects and institutions included under the NTNU umbrella can be understood in the light of some of the historical and sociological dimensions of NTNU's position in society and in the academic field.

Table 4.1 Current R&D expenditure within natural sciences, engineering and technology at NTNU and the comprehensive universities in Bergen, Oslo and Tromsø 2017. Mill. NOK. (NIFU: FoU statistikk)

Institution	NAT	TECH	Total
Norwegian University of Science and Technology	426	1663	2089
University of Oslo	1128	262	1390
University of Bergen	901		901
The Arctic University of Norway	458	152	610

Norwegian higher education is shaped within the context of a young nation, with its oldest university established in the capital Oslo in 1811. Norway is a small country (approx. five million inhabitants) with (since the 1970s) an oil-producing economy. Norway has had good conditions to achieve its welfare state policy objectives in a social democratic regime placing great emphasis on higher education as a strategy to reduce social inequality (Ahola et al. 2014). The expansion of higher education in the 1960s and 1970s was marked by the social democratic era, where both social and geographical equality of education was normative for central policies concerning the number of students, the number of institutions as well as their geographical location, and a high level of institutional standardisation.

A strong focus on equal rights to higher education is illustrated both by the absence of tuition fees and through the limited emphasis on developing elite institutions (Bottomore 1993). NTH's role as an elite institution, rather than indicating a conscious awareness of the elite, is as we argue as much a result of Norwegian pragmatism – a strong scepticism towards investing in expertise – which resulted in weak growth in higher education, not meeting the actual demands (Forland 1996). This explains why Norwegian students, especially from the 1950s to beyond the 1990s, typically went abroad to study for engineering, medicine and other professional education. In many ways, this is a paradox also considering the then burgeoning national oil economy.

For several decades, NTH had a national monopoly in educating engineers. It admitted few students, hence operating with high admission criteria. NTH was able to maintain it status by such restrictive mechanisms (Murphy 1988) as rigorous criteria of admission in general, and particular emphasis on the qualifications of applicants within mathematics and physics. Civil engineers – especially from NTNU, are still highly appreciated in the Norwegian workplace, and NTNU recruits high-achieving students from upper secondary school.

Furthermore, there are distinct patterns of recruitment characterised by a high proportion from the middle class – as well as a significant degree of self-reproduction, statistically speaking: a high incidence of sons and daughters of engineers (Høstaker 1997). This is, we argue, a robust indicator of the ability of NTNU to maintain its status – as the social background of students can serve as empirical evidence of social and intellectual patterns of valuation of types of higher education in society.

The position of NTNU has also been supported through its close ties and cooperation with the largest Norwegian (and largest Scandinavian) technical industrial research institute – SINTEF, which was established by NTH in 1950 (its original full name was 'Selskapet for industriell og teknisk forskning ved Norges tekniske høgskole') and located in Trondheim (Borlaug et al. 2015). While SINTEF now also has close collaboration with the University of Oslo and offices at multiple locations in Norway and abroad, it remains a very significant part of NTNU's institutional environment. SINTEF represents vital scientific capital as a research collaboration partner, and as a recruitment and cultivation centre in a fluid exchange of students and academic staff.

4.3 Organisational Identity

The concept of organisational identity refers to the symbolic, mythological and cognitive sides of an organisation. Furthermore, an organisational identity is an important framework from which an organisational reality can be constructed (Stensaker 2004).

NTNU's organisational identity is first and foremost reflected in its name, and a result of the particular mandate given to it by the Ministry of Education and Research. There are further examples of how this identity is symbolised, as in this quote taken from the NTNU institutional strategy1998–2010: 'Through leading academic environments, NTNU will secure and renew the nation's technological competence. NTNU has a technical-natural science profile and main responsibility for education and research in technology in Norway. 2010–2020: Our technical and scientific main profile gives us a special assignment to develop the technological foundation for future society.'

This does not mean that we fall into a one-dimensional understanding of organisational identity. As within most comprehensive universities, the academic discipline is usually the most important point of identification for academic staff (Henkel 2000). It may be difficult, not least at comprehensive universities, to clarify distinctive aspects of identity at the institutional level. As was also apparent within the framework of the most recent merger process at NTNU, investigations of possible new internal organisational structures were characterised by tensions between the professional education milieus and the members of disciplinary based departments and faculties (Vabø et al. 2016).[1]

NTNU's identity and national status over time are maintained partly through such symbolic characteristics and through recruitment patterns among students and academic staff. Inevitably such characteristics will affect the self-understanding among the academic staff – in particular those who are members of technological disciplines and fields.

As we shall return to below, this organisational identity is both directly and indirectly reinforced by externally-induced policies such as national policy priorities of the STEM disciplines as well as management policies that allow additional priorities of technological subjects through internal strategies.

4.4 The State as a Protector

While elite institutions, as we know them from most western countries, are relatively autonomous, NTNU is subject to state ownership and governance. Public policies and financial priorities for higher education and research, and the relevance

[1] https://www.ntnu.no/documents/1262755726/1264426837/Arbeidsgruppe+for+disiplinfag.pdf/7272262a-9760-4868-8f96-3e3ab505942d

of different parts of the academic field – in this case the technological disciplines and engineering – are therefore significant empirical aspects of governance and strategy that can explain NTNU's ability to reproduce its status as a technological university.

Norway has a well-established consensus for prioritising research and education in the areas of natural sciences, technology, engineering, and mathematics. Special policy priority at the national level – from the state and a range of stakeholders, such as the National Federation of Enterprises (NHO), has been given to the technical disciplines. These policies should be understood in relation to the idea, or myth, of technical disciplines as being of greater general importance for society than other academic disciplines.

One type of measure is the establishment of national centres for the enhancement of mathematics education (2002), and a centre working to increase recruitment to the sciences (1998) – typically located at the NTNU campus. Another type of measure is the inclusion of STEM research as a steering indicator in the Ministry's governance of universities and university colleges. The rationale for strengthening these subjects is partly based on identified weaknesses, such as gradual decrease since the 1970s in the national level of knowledge in mathematics among students. This is also revealed as low performance among Norwegian students in international tests in mathematics and science, insufficient recruitment to graduate studies in science and technology as well as a relative decrease in the share of R&D expenditure devoted to science and technology. It is widely recognised that research and education in science and technology is crucial for the ability to address societal challenges. The first national STEM action plan was issued in 2002. Since then, policy expectations of strengthening STEM subjects have been expressed in various contexts and included in a number of policy processes.

Policy expectations to strengthen the STEM subjects have generally taken the form of "soft" policy directions rather than top-down instructions on internal budget allocations. One exception is the Ministry's allocation of strategic institutional funding, where funding of new students and PhDs in STEM disciplines, as well as for scientific equipment, has been systematically prioritised over recent years (Langfeldt et al. 2014).

Nevertheless, also in line with international trends, recruiting the most able students to the elite technological subjects and disciplines has not always been the easiest task, as these study programmes face competition from other popular areas of study, such as business administration, aesthetic subjects, or biology and medicine.

Also for other reasons, including demographics, there have been limitations to the realisation of national policies for enhancement of STEM disciplines. There are well-known trends, such as a decreasing number of students with the necessary admission qualifications, e.g. an adequate basic level in mathematics. According to the admission criteria of NTNU there are simply not enough able students in the potential pool of recruitment. Hence, despite its high general admission criteria, and despite its popularity in general, today NTNU has to offer special preparatory courses etc. in mathematics. Furthermore, there are in general difficulties in attracting female students as they might prefer other types of STEM subjects rather than civil-engineering oriented study tracks. There is also competition from other fields, not least from the aesthetic turn in the 1980s, where humanities began to recruit more students, also in such subjects as media and film. Nevertheless, as we turn to below, national policies for the enhancement of STEM disciplines (and particularly the technological subjects) have provided a legitimate frame for institutional strategies favouring these academic subjects.

4.5 On Constructing an Organisational Field

As a result of increasing global competition and international cooperation, the development of NTNU as an institution is no longer perceived as part of a nation-building project. It is to a greater extent characterised by international standardisation, for example, in degree structure and more pronounced competition along selected indicators important for scientific and other forms of reputation.

Nevertheless, as in other Nordic welfare state countries, contrasted with many European countries, which have more privatisation of technical universities, Norway's public universities are to a large extent protected by the state. The state is the main source of finance. Due to these funding criteria and other market regulating mechanisms, such as number of students, this makes institutions such as NTNU less sensitive to cyclical shifts in the market than most probably would have been the case in technical universities that are players and compete between many technical universities in the private sector economy (e.g. Portugal, Poland). The strong state integration is an important backdrop for NTNU's ability to reproduce and strengthen its status over time.

NTNU has its formal governance structure as enshrined in law, and other principles of organisation in Norwegian higher education. But, we shall not neglect that internal decision-making processes, as they seem to be rational, will be characterised by power relations in the academic field nationally and locally (Flyvbjerg 2012).

As government agencies, Norwegian universities and colleges are primarily subject to the allocations and budget guidelines emanating from the Ministry of Education and Research. At the same time, the government aims to govern at an overall level, leaving much of the professional management to the institutions themselves. This has been based on concerns of academic and institutional autonomy and the sector's heterogeneity. The funding system for universities and colleges currently consists of long-term and strategic allocations and performance-based funding, where the – rather minor – performance-based part depends on the results achieved in education and research respectively. Mechanisms in the system have been relatively similar over several years. From 2012, the Ministry introduced a more general incentive structure (Ministry of Education, Prop. 1 S (2011–2012)). A key point of these changes has been that the institutions' goals and strategies should be followed up on the basis of the entire budget framework allocated to them. Basically, therefore, the institutions have the flexibility to make their own budget priorities. They can follow the ministry's emphasis on STEM subjects in a variety of ways, through direct and more indirect instruments, such as granting fellowships/postdoctoral studentships, support for application work in STEM subjects, support for projects that have received (attractive) external funding such as ERC grants, support for infrastructure, equipment, construction, support for measures to stimulate cooperation with other external research communities as well as development and strengthening of teaching in STEM subjects. These are examples of priorities that may be important institutional measures to strengthen research in the STEM subjects, and to make STEM subjects attractive for students and employees.

4.6 Top of Form

The budget process is usually characterised by many different and partly contradictory targets involving a more or less permanent competition between subjects to win forward with their legitimate needs. Our question, however, in this case concerns NTNU's ability to prioritise one thing over another, and the meaning that national guidelines may have for such priorities.

The question of how incentives work depends here on the degree to which the institutions have the room and the will for such cross-subsidy between fields. NTNU has had more differentiated (internal) rates for its various study programmes and subjects. This can be illustrated by NTNU's own assessment, which states that "*When it comes to division between faculties, NTNU has a distribution model that gives technology communities good results compared to the humanities and social science environments.*"(Langfeldt et al. 2014: 77). The distribution models have many different elements, and the most important differences between the NTNU model and the Ministry model are NTNU's finer calculation of rates for different types of education. This means that it is not the individual department which has to absorb extra costs for most field and laboratory class teaching. Here it is worth noting that NTNU is one of the universities which has had the greatest growth in permanent scientific staff in STEM subjects, indicating the will and ability to allocate funding for STEM subjects (Langfeldt et al. 2014: 51).

This case is yet another example of how organisational fields are constructed as part of the interest of certain professions, disciplines, fields of science etc., as well as to how organisational identity characterises institutional strategies – and their outcome.

Against DiMaggio's (1991) perspective we might also understand why in the oldest comprehensive universities, the universities of Oslo and Bergen (UiO and UiB), the strength between various fields of science is more balanced than at NTNU. It is more difficult for these universities to justify internally that some subjects, in this case STEM subjects, are more important than others, especially in periods where other subjects experience more growth in student numbers than the STEM subjects, as has been the case periodically. By contrast, the management of institutions with a heavy emphasis on STEM can facilitate the legitimacy of changes in favour of these subjects.

As we will turn to below, NTNU is also characterised by a management model with appointed leadership, which gives more legitimacy to implement the strategies that benefit the STEM subjects. In comparison, the UiO is more fragmented and has less ability to implement strategic choices. The implementation of strategically prioritised focus areas through redistribution of funds internally – i.e. taking from one subject area and giving to another – necessarily attracts resistance and protest, not just internally, but also externally, from the groups of stakeholders that are attached to the subject in the form of candidates, contractors and users.

Such institutional dynamics are no less interesting considering the ongoing debate in the Nordic region about the need for increased institutional autonomy from government management as part of increasing the institutions' strategic management capacity (Hedmo and Jernberg 2017). Formally, a number of governance reforms have taken place towards more institutional autonomy in the last two decades in all the Nordic countries. Academic and administrative leaders have gained a clearer and stronger position. The increasing use of *appointed* leaders, with effective decision-making and strategic priorities, is believed to counterbalance a potential struggle of interests between different disciplines and interest groups. Accordingly, the boards at all levels have fewer members. Academic staff have fewer representatives, and there has been greater emphasis on external representatives. By this, the institution is supposed to bring in other competence through board members than the institution itself possesses, be it professional competence, networking, supply of ideas and legitimacy, or the interests of the various external stakeholder groups. Considerations of openness and democratic transparency are also an argument for the use of such boards in the public sector. The current comprehensive Universities and Colleges Act provides clear guidelines for the organisation and composition of boards at the institutional level, but it is open to significant institutional autonomy when it comes to questions about the use of elected or appointed leadership at the various levels, or the extent to which one should use boards or advisory groups at faculty and departmental level.

According to research from Norwegian higher education, however, the choice of governance model has little significance for strategic decision making at institutional level within the framework of strong state ownership (Frølich et al. 2018). However, we argue that we should not resort to rigid institutionalism – nor to a one-dimensional structural approach. Irrespective of choice of governance model, we argue that institutional policies are decisive for maintaining status as the number one technical university and should be understood in light of the background and social identities of leading actors in decision making processes: the head of the board, the collegial bodies, as well as the academic staff members of the technical disciplines.

NTNU's rector (in the period this chapter is focused on: 2013–2019) is a professor of medicine, Gunnar Bovim. His professional and academic background represents a departure from previous practice at NTH, where the principals have typically represented the classical domains – and important building blocks – of engineering education. In one period during the 1960s, the NTH rector was a statistician; and in a two-year period in the 1970s, the rector was a social economist. Since NTNU's creation in 1996, the three rectors preceding Bovim had backgrounds in mathematics (E. Spjøtvoll), and physics (E. Hiis Hauge and T. Digernes) (NTNU 2018).

While the choice of a medical scientist as principal represents a departure from earlier traditions, it is still typical of trends in the Western world, where rectors at research-intensive universities often represent medicine or natural science or technological subjects/professions (Goodall 2006). We have the impression, although no systematic empirical evidence, that strong alliances between academic milieus and leadership within technology and life sciences are typical of the ongoing development of Europe's major universities taking place within the framework of structural reforms and extensive mergers.

The strong position of NTNU as the leading technical university also manifests itself in the use of an appointed external leader of the university board. The current (2019) leader of the board, Svein Brandzegg, is not only the top executive manager in one of the most significant industrial companies in Norway (*Norsk Hydro*), he is also educated as a civil engineer and holds a PhD in chemistry from NTNU. The local institutional leadership we understand as part of enlarged policy communities (Sabatier 1991) involved in identifying issues and alternative solutions. As chairman, Brandzegg is also important in legitimising key policies, towards the dominant professional coalitions and external stakeholders. Brandzegg symbolises in this respect not only the masculinised technological scientific order – he is also at the same time the industry's representative in Academia.

In the following analysis of the latest NTNU mergers, we will argue that these local institutional positions and power relations, in conjunction with national political conditions, were decisive for the shaping of the merger as a strategy to strengthening NTNU's position as a technical university.

4.7 Mergers as a Catalyst for Boundary Negotiations

As argued in Chap. 1 in this volume, the idea of a technical university typically evolves in response to changes in structure and dimensioning of national higher education systems – or changes in governance of higher education.

In the case of Norway, the NTH monopoly was gradually reduced during the 1980s when some universities and state colleges were given the right to grant engineering degrees (Forland 1996).

In the early 1990s, the status and autonomy of NTH were changed due to policies aimed at changing the steering conditions of the higher education sector. The rapid growth of higher education in the 1960s, '70s and '80s, combined with the upgrading of vocational schools to institutions of higher education, led to a substantially increased number of higher education institutions. A national committee appointed by the government to propose future policies suggested that extensive mergers and other efforts to concentrate resources were needed in a sector characterised by fragmentation and poor utilisation of resources, both economic and academic (NOU 1988:28).

At this time, the NTH represented a highly autonomous unit within the University of Trondheim, UNIT, which in addition consisted of the AVH, a museum and a section for medicine. NTH was governed by its own academic collegium, which implied that professors in technology represented the majority of the academic senate of NTH. The suggestion to develop this into an integrated university (NTNU) threatened the independent status of NTH (Brandt and Nordal 2010).

The launch of such initiatives by the then Minister of Education, Research and Church Affairs in the Labour party government, sociology professor Gudmund Hernes, caused debates in the national press and central political decision making bodies, such as in the Storting.

The idea of NTNU was criticised for not living up to the standards of a classical comprehensive university, in that the technological subjects represented the majority. It was argued that technical specialisation would exist at the expense of academic pluralism. Given many contextual factors, such as the general growth in higher education, competition from other study segments and the fact that NTH no longer had the national monopoly in educating civil engineers, it was, however, not easy to argue for maintaining the institutional autonomy of NTH (Brandt and Nordal 2010).

Since the 1980s, the overall structure of the Norwegian higher education has gradually switched from a binary system to an integrated system where one easily can combine studies from the state colleges with university-based courses and degrees. In recent years several state colleges have been upgraded to university status, and as a result of mergers many former colleges have been incorporated into universities (Elken and Frølich 2017). These and other developments are part of the backdrop that the then government and Minister of Higher Education and Research referred to in their White Paper released in January 2017. It proposed a series of reforms that could be interpreted as an expression of finding a new formula for clearer differentiation between mass and elite studies in Norwegian higher education, aiming for more distinct quality differences between study programmes, for instance, through the establishment of research-oriented programmes, and an academic positional hierarchy marked by a clearer division between research and a teaching-oriented career track (Vabø 2017).

Turning to the more recent stage in NTNU's institutional history, we find another kind of merger process. In January 2016, NTNU merged with the three University Colleges of Gjøvik, Ålesund and Sør-Trøndelag, with the result that NTNU is currently Norway's largest university.

The institutions' decision to merge took place against the background of key political ambitions to reorganise the structure of the Norwegian higher education system, with an aim to increase the quality and efficiency of education and research. Achieving higher quality of education and research has also been a key ambition for the four institutions in this particular merger process.

In 2015, the parliament suggested that 14 institutions merge into five, of which the new NTNU is one. Central authorities suggested that the existing structure was not adequate to improve quality in higher education and research, but that mergers would provide a better basis for improving both academic and administrative capacity. The existing institutional structure in Norwegian higher education, it was argued, was characterised by challenges as a result of the existence of many small academic communities, geographically dispersed and fragmented. It was argued that the academic communities were characterised by too-low quality in their core activities – research and education. Some institutions attracted few students and researchers published too little. These institutions are regarded to be ineffective and they attract too little external funding. Too many small institutions are considered to be unsuitable also in terms of future development, in terms of demographic development, social knowledge needs and an increasing degree of international competition in higher education and research.

Prior to the mergers, it was expected by the Ministry that the institutions would be proactive in terms of with whom they should cooperate. Here the NTNU top management was in the early stages and was able to get into agreements of intent with state colleges that particularly emphasised areas that could supplement NTNU's technological subjects: Gjøvik with its ICT research, and Ålesund with its maritime technological research. In line with DiMaggio's (1991) point about how organisational fields are constructed as part of the interests of professions and field of practice, this NTNU case is yet another example of how organisational identity characterises institutional strategies – and their outcome.

The official arguments in the merger process and the decision-making and budget allocation processes internally at NTNU, in which NTNU planned the merger process with other institutions, were definitely in line with the central authorities' objectives of the Structural Reform. Thus, following Flyvbjerg (2012), behind the apparently rational narratives alternative explanations and perspectives can be identified. The Structural Reform also represented a window of opportunity: a policy stream (Kingdon 1984) which helped the policy entrepreneurs of NTNU's top leadership to colonise and control parts of an academic field that were relevant for NTNU as a technological university. The state colleges in Gjøvik and Ålesund were interesting both as outstanding research environments in ICT and in relation to practical maritime technology. Alternatively, NTNU could end up with a less strong base in the new institutional landscape that is under development in higher education nationally and internationally.

The last three decades have been characterised by further developments of great importance for the organisation of higher education. Students taking more higher education, more systematic political commitment to research and innovation, and increased global competition for the most talented researchers, are among the trends that have helped to justify recent comprehensive structural reforms. As mentioned above, NTNU is currently in a post-merger phase in the process of integrating three state colleges in its organisational structures.

This recent merger caused a reaction among the academic staff in the technical disciplines at NTNU and their union, the Norwegian Society of Graduate Technical and Scientific Professionals (Tekna), as they feared the merger would diminish their status – "market brand" – and working conditions in favour of academic staff at the former colleges (Vabø et al. 2016).

Like most other merger processes, the process towards "the new NTNU" has partly been met with much resistance, not least among the academic staff at the old NTNU. Subject to limited representativeness (N 447), Tekna's survey among its union members at the four educational establishments showed that 65% were in whole or in part against the merger, especially at NTNU (Vabø et al. 2016, p. 25).

As elaborated in Chap. 2 of this volume, in common with many universities, lower-level engineering is taught in polytechnics or universities of applied sciences/university colleges, with the higher levels in the technical and/or comprehensive universities (or both). This model is based on the idea of a division of labour in tertiary systems of higher education. However, by merging state colleges and universities this idea has become challenged. The resistance to the merger in the established technology environments of the old NTNU is, from that perspective, as expected.

4.8 Conclusions

NTH, the original renowned technical higher education institution in Norway, long had a national monopoly in educating civil engineers. The fact that NTH also operated with limited student numbers, high admission requirements, and student recruitment patterns with distinct traces of self-reproduction, indicates that this institution's position clearly reflected classical perspectives on professional and elite institutions.

In comparison with its Nordic neighbours, Norway has invested less in technological research. Nevertheless, state ownership in higher education may be important in maintaining NTNU and its technology teams' high degree of social and scientific standing – both as a protector against adverse cyclical fluctuations in the student market, and through specific national initiatives and financial and other measures to strengthen these subjects.

High rankings in a social and intellectual hierarchy have also highlighted the internal dynamics in such a way that study places in technological subjects are valued higher than other subjects in the internal resource allocation formula. Here NTNU distinguishes itself from other Norwegian comprehensive universities which, for reasons of internal legitimacy and balance, do not make use of this budgetary scope. In line with DiMaggio (1991), among others, we understand the resource allocation dynamics at NTNU as institutionalised practices that help maintain boundaries – boundaries between the technological and other subjects.

Gradual loss of monopoly over civil engineering education, and the expectations of central authorities to collaborate with other higher education institutions, have over time contributed to this technological institution – not unlike developments in some other countries –gaining a more hybrid character. Status as the foremost technological university, rather than as a comprehensive university, has nevertheless been an important part of the organisational identity of NTNU – even if it is still challenged.

For NTH, and subsequently for NTNU, mergers have been characterised by boundary negotiations, such as regarding the reorganisation of subjects and disciplines, position structure and career dynamics for scientific staff coming from different subjects and institutions. The institutional transformation processes that followed in the wake of the former NTH's mergers with other institutions clearly reflect such organisational theoretical concepts as organisational identity and boundary negotiation.

However, the analyses in this chapter also argue that the merger processes can be understood as a policy stream, where local leadership includes an alliance between the principal – a professor of medicine – and the chairman, one of Norway's best known business leaders, who holds a PhD from NTNU. Together they have taken the opportunity to colonise key technological research environments and practice fields in the former college sector.

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Chapter 5
Understanding the Development of Technical Universities in Poland

Dominik Antonowicz

5.1 Introduction

This chapter aims to examine the past, discuss the present and speculate about the future of technical universities in Poland. Technical universities perform an important, though often undervalued, role in Polish higher education (HE) and undoubtedly remain an under-researched segment of the system. Therefore, this chapter presents technical universities as higher education institutions (HEIs) with special organisational features related to their strong organisational identity, which has a profound impact on how they address and strike a balance between numerous and often conflicting expectations. It explores the historical foundation of Polish technical universities, looking to the past to answer questions about their organisational attributes and behaviour as strategic actors (Vuori 2016) during turbulent times of political and economic transformation. Furthermore, it elaborates on the dynamically growing challenges that might affect the trajectory of their development in the coming decades.

Technical universities were first established to provide professional training, and as such, they were distinctively different from comprehensive universities in terms of organisational profile, governance model and social esteem. During the communist period (1945–1989), technical universities increased in number and societal and economic significance, and they developed rather steadily. The fall of the Iron Curtain marked the beginning of a period of turmoil and deep structural change in HE that embraced technical universities. There is rich literature on the transformation of Polish HE covering a wide range of topics, including the evolution of HE policy (Antonowicz 2015b), the rise of private-sector HE (Duczmal and Jongbloed 2007), structural changes (Kwiek 2012a), university governance (Dobbins and Knill 2009), research evaluation systems (Kulczycki and Rozkosz 2017), quality

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assurance (Brdulak 2016) and changes regarding the academic profession (Kwiek 2003). Although a great amount of literature has addressed the institutional transformation of HEIs (Białecki and Dąbrowa-Szefler 2009; Pinheiro and Antonowicz 2015; Kwiek 2012b; Antonowicz 2015b), little is known about technical universities specifically, although there are 23 technical universities in Poland educating around 320.000 students (21% of the student population in Poland). The reason for this might be that they are less politically sensitive and less exposed than other HEIs. The only attempt to explore this topic was performed by Maria Kostyszak, Jan Wadowski and Marcin Zaród (2015), who present the major common features of engineering education in Slavic countries.

There are several reasons why technical universities deserve greater research attention, including the fact that they stand out in the Polish HE environment as they are distinguished from comprehensive universities in terms of their profile, organisational culture and prestige. Despite this, technical universities have never been the crown of the Polish system of HE; this position was available only to well-established comprehensive universities in Cracow and Warsaw. Nevertheless, similar to many other European countries, technical universities have always played a highly important role and – as Chap. 2 in this volume acknowledges – possessed distinctive attributes, such as a focus on providing professional training in engineering and industry relevance.

Overall, the chapter has two major objectives. First, it aims to identify the sources of the distinctiveness of technical universities among Polish HEIs based on their historical legacy and patterns of behaviour as strategic actors (Vuori 2016) during a turbulent period of political and economic transformation. Second, bearing in mind the first objective, it aims to discuss the future of the development of technical universities in Poland. The analysis draws upon both quantitative and qualitative secondary data. The most important source is the statistical information published regularly by the Central Statistical Office (GUS) in a series of reports entitled 'Szkoły Wyższe i ich Finance' (Higher Education Institutions and their Finances) (e.g. GUS 2016). The second most important sources are policy papers and discussions about the re-structuring of HE in Poland. The third are official statements published by the Conference of Rectors of Technical Universities (KRPUT[1]).

5.2 The Rise of Technical Universities

The rise of Polish technical universities needs to be considered independently of the development of the modern university. The concept of institutional autonomy was deeply embedded in the Humboldtian university model (Dobbins and Knill 2009), and the modern nation-state was supposed to protect universities from the

[1] Note that the website of KRPUT (http://www.krput.edu.pl/) is outdated (the last updates was made on 27–29 October 2016), which indicates that this organisation is not very active.

interference of external stakeholders (in particular, corporate actors). This detachment from the external environment brought technical institutions of various post-secondary status closer to industry, leading them to become non-elite educational institutions. The establishment of this type of HEI was a direct consequence of industrial development and growing demand for highly trained specialists in engineering. Polish universities, by definition, did not provide professional education, except perhaps for law programmes, although these still required additional professional legal training and a final bar exam. In this way, technical universities were established as complementary and certainly not competitive institutions.

The country needed engineers to facilitate economic growth and fuel industrial development, but the process of establishing technical universities required a great amount of resources and time. From a broad perspective, technical universities were established in Poland in three major phases. The first phase dates from the late nineteenth century to the early twentieth century, and it is closely associated with the intensive industrial development that took place in Polish-speaking territories (until 1918, Poland did not formally exist as an independent state). The first institutions were established in Lviv (1877), Gdańsk (1904), Wroclaw (1910), Warsaw (1915), Cracow (1919) and Poznań (1919). Technical universities were expected to supply new industries in these locations (e.g. mining companies, shipyards) with a highly skilled workforce to stimulate further growth of the economy. In the first part of the twentieth century, technical universities remained deeply in the shadow of universities and performed not only a complementary but also a supportive role to post-secondary education. This was a form of programmatic diversification (Mayo 2009) without a single element of competition, and the state played a prevailing role in fostering not only horizontal but also vertical diversification of HE. A landmark event that perfectly reflects the asymmetry of prestige between universities and technical universities was the all-national Gatherings of Polish Sciences that took place in 1920 and 1927. During these gatherings, academics discussed issues of high importance to academia in Poland. However, there were hardly any representatives from technical universities, and those that did attend did not play any role in the gatherings.

The second phase of the development of technical universities took place shortly after the end of World War II. Poland was not only destroyed by military conflict but also massively depopulated by its aggressors. The elite, best-educated citizens in Poland were targeted and executed as a part of policies of extermination implemented simultaneously by Soviet Russia and Nazi Germany. This created a huge (almost generational) gap in human capital. Shortly after WWII, Poland attempted to compensate for this loss by educating the new generation. Unlike traditional comprehensive universities, technical universities were able to provide professional education and expertise in the fields of engineering and agriculture. A number of technical universities were established, including those in Łódź (1945), Gliwice (1945), Szczecin (1946) and Częstochowa (1949), to support the growth of new industrial centres. Simultaneously, the central authorities established a network of regional Schools of Engineering, which were locally focused teaching institutions that initially relied on academic staff from the main technical universities. Once they achieved a certain human capacity, they immediately transformed into independent HEIs.

In addition, in the post-war period, communist authorities favoured ideologically new (i.e. non-university) types of HEIs. They believed that less hermetic, less elitist and autonomous organisations would be able to provide more practical, down-to-earth education. Traditional comprehensive universities were depicted as ideologically hostile remainders of bourgeoisie society that served their own interests (Szczepański 1963). Strong critiques of liberal universities were published by leftist academics such as Józef Chałasiński (see Piskała and Zysiak 2013), and the Communist Party made numerous political threats to these universities, demanding more openness, diversity in the student body and subordination (Connelly 2000; Zysiak 2016). The concept of technical universities perfectly fit the ideological purpose of providing an alternative organisational model to the Humboldtian ideas about universities and served as a good example of responsiveness to the needs of the new (socialist) economy and society.

The third phase of the development of technical universities occurred from the late 1960s to the 1970s, and it is linked to the expansion of HE that occurred in response to the first generation born after the end of WWII and industrialisation of the country. This phase included the creation of institutions in relatively small cities, such as Kielce (1965), Rzeszów (1963), Zielona Góra (1965), Koszalin (1968), Białystok (1974) and Lubin (1977), marking the industrial development in regions that previously had been rural and lacked HE. Most of these institutions evolved from the previously mentioned local Schools of Engineering. In several cases, depending on their profiles, these later transformed into agricultural universities (e.g. in Bydgoszcz), while others transformed into technical universities, such as the Opole University of Technology (1996).

In addition to the three major phases, private HEIs with a technical profile were established after the 1990s to complete the already diverse institutional landscape of HE in Poland. Private HEIs were founded as primarily entrepreneurial organisations with more flexibility in curricula development and much greater concern about students' needs than public HEIs. Private technical universities have neither become large nor very important among technical universities, but their establishment undoubtedly refreshed engineering education.

In short, technical universities were established in opposition to the idea of the (liberal) university, which embodied autonomy and academic self-governance, non-practicality and elitism. Using Peter Maassen and Johan Olsen's (2007) framework, public authorities approached universities as institutions with distinct sets of values and social norms embedded in tradition, whereas technical universities, as newly established entities, have always been seen through instrumental lenses. This difference has had a massive impact on the trajectory of the development of technical universities, and it must be analysed in political, social, economic and geographical contexts.

5.3 Blurring Boundaries

'Technical university' has become an increasingly complex and dynamic category of HEI. Although such universities used to have a strong organisational identity, this has been recently challenged by the increasing expansion and privatisation of HE. In the early 20th century, as mentioned in Chapter in this volume, a clear line was drawn between technical universities and other types of HEIs, particularly comprehensive universities. Historically, technical universities focused on engineering education and were typically located in early industrial cities aiming to educate engineers to support the emerging industrial society of Poland. Only later did they develop a research capacity to provide knowledge and expertise in the field of technology. For decades, they enjoyed an almost monopolistic position in the field of technical education and did not want to develop into more comprehensive HEIs. However, this changed in the early 1990s due to political, economic and social transformations that enabled rapid expansion of HE (Pinheiro and Antonowicz 2015). The consequence of this process was a restructuring of the entire organisational field of HE that undermined existing boundaries; technical universities developed social sciences and humanities programmes, and comprehensive universities and other types of HEIs developed engineering programmes. The previously sharp, unquestionable distinction between different types of HEI became increasingly questionable. In addition, the newly established and dynamically expanding private HEIs, some of which offered engineering programmes, enriched diversity in an already complex organisational field.

Technical universities, as a separate category of HEIs, are scarcely recognised in the literature. In numerous analyses conducted on Polish higher education, only two major taxonomies of HEIs have been developed, which refer to the institutional setup (public and private) (e.g. Antonowicz et al. 2017) and, to a lesser extent, the institutions' profile (academic and vocational) (Kwiek 2012a). It should be noted that, on the policy level, technical universities organised themselves via the Conference of Rectors of Polish Universities of Technology (KRPUT), a formal representative body of technical universities. This body does not include any private technical universities or agricultural universities, but it does include two maritime universities.

The most accurate way to define technical universities is the categorisation used by the National Statistics Office (GUS). According to this, there are 23 technical universities in Poland that are considered HEIs, among which 18 are public and 5 private, and 22 are academic, while one is vocational. For the sake of this analysis, I will use this categorisation. The list of technical universities and their profiles is presented in Table 5.1.

There are three major characteristics of technical universities in Poland. First, technical universities are extremely diverse with respect to organisational size; private HEIs usually have less than 1.000 students, while Politechnika Warszawska has 33.000 students. In total, 301.000 students attend technical universities in Poland,

Table 5.1 List of technical universities in Poland

	Name	Status	Profile
1	Polsko-Japońska Akademia Technik Komputerowych W Warszawie	Private	Academic
2	Wyższa Szkoła Ekologii I Zarządzania W Warszawie	Private	Academic
3	Wyższa Szkoła Informatyki I Umiejętności W Łodzi	Private	Academic
4	Politechnika Białostocka	Public	Academic
5	Politechnika Częstochowska	Public	Academic
6	Zachodniopomorski Uniwersytet Technologiczny W Szczecinie	Public	Academic
7	Politechnika Gdańska	Public	Academic
8	Politechnika Śląska W Gliwicach	Public	Academic
9	Politechnika Świętokrzyska W Kielcach	Public	Academic
10	Politechnika Koszalińska	Public	Academic
11	Akademia Górniczo-Hutnicza im. Stanisława Staszica W Krakowie	Public	Academic
12	Politechnika Krakowska im. Tadeusza Kościuszki	Public	Academic
13	Politechnika Lubelska	Public	Academic
14	Politechnika Łódzka	Public	Academic
15	Politechnika Opolska	Public	Academic
16	Politechnika Poznańska	Public	Academic
17	Uniwersytet Technologiczno-Humanistyczny Im. Kazimierza Pułaskiego W Radomiu	Public	Academic
18	Politechnika Rzeszowska Im. Ignacego Łukasiewicza	Public	Academic
19	Politechnika Warszawska	Public	Academic
20	Politechnika Wrocławska	Public	Academic
21	Akademia Techniczno-Humanistyczna W Bielsku-Białej	Public	Academic
22	Wyższa Szkoła Informatyki Stosowanej I Zarządzania W Warszawie	Private	Academic
23	Wyższa Szkoła Techniczna W Katowicach	Private	Vocational

which is 21.4% of the entire student population in the country, making these universities the second largest group of HEIs after comprehensive universities.

Second, technical universities stand out from other Polish HEIs due to their considerable proportion of full-time students. On average, 76.7% of their students are enrolled full-time, which is higher than the average across the HE sector (65.3%) (GUS 2016). Third, despite the great diversity in the size of technical universities, most are relatively large public HEIs with an academic research profile. These universities serve approximately 98% of the students at technical universities, and the view of Polish technical universities as public organisations with an academic profile is fully legitimised. Nevertheless, the fact that several HEIs have a technical profile and the uncertainty regarding whether private HEIs and marine and agricultural universities fall into the same category as technical universities create fuzzy boundaries within the organisational field of HE. In addition, the incoherence between membership in rectors' conference for technical universities and the categories developed by GUS indicates identity problems among technical universities.

Despite historically entrenched differences between technical universities and other HEIs, the line between them is disputable. This is partly due to HE expansion, the marketization of HE and, perhaps most profoundly, uniform policy measures implemented by the government. Paradoxically, while the traditional institutional identity of technical universities remains distinctive and strong, the boundaries between the profiles of HEIs and the organisational characteristics of different types of HEIs are becoming fuzzy.

5.4 Technical Universities in Turbulent Times

Since the early 1990s, the Polish HE sector has experienced substantial changes. Its path of development is often pictured as tumultuous, chaotic and driven by rapid expansion (Antonowicz et al. 2017; Kwiek 2010). Between 1990 and 2005, the number of students skyrocketed from 380,000 to almost two million, although by 2017 the number dropped to 1,405,000 (GUS 2016). HEIs have experienced many demographic shifts that changed them in a significant ways. The expansion of HE was largely fuelled by the growth in private-sector HEIs, but the growth of public HEIs (including technical universities) also contributed to the significant increase in the student population, mostly due to the introduction of fee-based part-time programmes (Duczmal and Jongbloed 2007). The massive demand for credentials turned many HEIs into ‘diploma mills’ (CHEA & UNESCO 2009) and made fee-based programmes their key source of revenue (Antonowicz et al. 2017).

Technical universities did not fully participate in this expansion because it was difficult for them to increase the number of students in engineering programmes due to the limited capacity of classrooms with sophisticated technical infrastructure. Moreover, demanding entry criteria, especially regarding advanced math, dissuaded many students from engineering programmes. Instead, technical universities grew by developed a wide range of full degree programmes in the humanities and social sciences, as these did not require any investment in sophisticated infrastructure. They were taught in literally any spaces that were available, including unexpected locations such as kindergartens or elementary school buildings as well as rented auditory rooms (on weekends only) in big industrial factories. The first wave of Polish transformation of HE can therefore be adequately summarised as the more the better (Pinheiro and Antonowicz 2015).

It is important to note that most analyses emphasise the demographic boom that caused HE to expand, but they tend to overlook another important human factor (Antonowicz 2015a). In the 1990s, a large number of people in Poland had not participated in HE before entering the labour market. Their professional career development was severely restrained, as higher positions in public administration and large public companies were often formally restricted to those with HE degrees (Antonowicz et al. 2011). Those individuals were interested primarily in obtaining credentials to re-launch themselves on the rocky path of professional development. It is essential to distinguish ‘degree hunters’ from the broader student population due to their special expectations and purely instrumental (i.e. bureaucratic) approach to higher learning. It is not an exaggeration to claim that many of those students were keen on obtaining degrees but had little (or even no) interest in the quality of education. They were adults, most often employed full-time, that were interested in obtaining education part-time due to their professional commitments. Beyond any doubt, so-called 'degree hunters' were among the key drivers of the expansion of HE, and many private-sector HEIs wanted to meet their demands (e.g. Antonowicz and Borowicz 2006; Antonowicz and Gorlewski 2011). However, engineering programmes (a central part of technical universities) could not gain much popularity among 'degree hunters', and thus the student population, because these were seen as demanding programmes with respect to knowledge and skills.

The radical increase in student enrolment was caused by equally dramatic austerity measures imposed on HE in the early years of the political and economic transformation in Poland. With funding formulas based on the number of students and legal opportunities to charge tuition fees in part-time programmes, public HEIs had no option but to cater to the growing demands mentioned above. However, not every HEI had an equal chance to meet these demands and maintain its financial status. Among those unprivileged HEIs were technical universities, which had a limited capacity to provide more education due to logistical reasons (i.e. lack of infrastructure). Thus, if they stuck to their core mission, they risked serious financial problems. They had no choice but to launch several popular programmes that were outside the realm of engineering but consistent with their solid academic brand as technical universities. Therefore, their educational offerings expanded to include several highly in-demand (at the time) programmes, mostly those concerning economics, marketing and management, which could be run without much organisational hassle. However, technical universities did not follow the most popular path, rapid development of part-time education, which was the prevailing form of educational activity at the time. At the peak of the expansion (2005–2006), 48.7% of all students in HE were registered for part-time programmes. The highest proportion (75%) attended economic universities, followed by pedagogical universities (74%), comprehensive universities (56%), agriculture universities (31%) and medical universities (25%).

These numbers exemplify the variety of ways in which HEIs responded to the growing demand for higher learning as well as the consequences of the catastrophic drop in public funding. The fact that part-time education was only 32.7% of technical universities' educational offerings at its peak demonstrates these universities' conservative approach to the expansion of HE. Nevertheless, the number of students at technical universities increased from 75,700 in 1990 to 340,200 in 2015. This increase was mostly seen in full-time programmes, which, in principle, maintained quality standards, unlike many part-time ones (see Antonowicz et al. 2017). Thus, technical universities remained loyal to their core activity—full-time engineering programmes—but they also had to seek opportunities to compensate for the dramatic decrease in public funding. Instead of a panicked response, they took a more sensible position while part-time programmes. Contrary to many public universities and most private ones, technical universities never transformed into 'degree mills' or compromised their educational quality standards. As mentioned above and referring to the question posted in Chaps. 1, 2 and 3 of this volume about the notion of a technical university, it is not always easy to draw a line between different types of HEIs. However, when dealing with dilemmas such as HE expansion or the balance of research and a teaching mission, the attributes of technical universities are distinct (Porac et al. 1995) in the broader organisational field of HE. Technical universities are particularly loyal to their organisational ethos, which affected their long-term strategies as well as their everyday choices and, undoubtedly, later helped them to mitigate the effects of the 'demographic tsunami' (Antonowicz and Gorlewski 2011).

In summary, technical universities responded conservatively to the spontaneous and dynamic changes in the external environment that were triggered by the fall of the Iron Curtain. Unlike many other types of HEIs, they were never the prime destination for 'degree hunters' and never transformed into 'diploma mills' like economic and pedagogical universities. This illustrates their strong identity and reluctance to be driven only by the quick financial gains produced by uncontrolled expansion of part-time education.

5.5 Reaching a Teaching–Research Balance in Technical Universities

As elaborated earlier, technical universities were established to provide advanced professional education, and research was largely left to (comprehensive) universities. However, due to the rapid changes in the structure of economy and political pressure to forge the triple helix of the university, industry and government (Etzkowitz and Leydesdorff 1995), technical universities could have become frontrunners in knowledge production. Unfortunately, they were badly affected by the aforementioned catastrophic decline in public research funding and the growing demand for higher learning (and degrees). Most HEIs' ability to commit resources to research weakened, a development that Marek Kwiek (2012a) rightly conceptualised as de-institutionalisation of universities' research mission. Undoubtedly, the expansion of HE affected the composition of HE in Poland, blurring the line between its various segments. Extreme times called for extreme measures, and even some of the less prestigious technical universities located outside large metropolitan regions transformed into more comprehensive HEIs. In their educational portfolio, one could find programmes such as 'administration', 'economics', 'sociology', 'physical education', communication', 'journalism' and even 'German philology', which can hardly be associated with technical education. Even more established and prestigious technical universities found it hard to resist the rapidly growing demand for HE and offered some popular programmes. This of course helped them to keep the books balanced as public funding was severely cut, but such a change could not be implemented without any side effects. Nevertheless, technical universities did surprisingly well compared to other institutions. Even during the heydays of the 'educational drive', technical universities maintained a fairly well-balanced structure of

Table 5.2 Structure of operating activity revenue in HEIs in 2005 by type of activity

2005	Teaching activity	Research activity	Separate economic activity	Sale of materials and goods	Other types of operating activity revenue
Universities	86.8	9.2	0.1	0.1	3.3
Technical universities	75.9	19.6	0.6	0.1	2.8
Agriculture universities	73.8	10.5	4	0.3	10.8
Economic universities	94	4.4	0	0.2	1.3
Pedagogical universities	96	2.3	0	0	1.3
Medical universities	80.5	12.8	1.5	0.9	4.1
Physical academies	92.8	2	0	0	4.6
Fine arts academies	97.3	1.1	0	0	1.6

revenue. In 2005, GUS (2006) showed that revenue from research in technical universities comprised 19.6% of their total revenue, which was considerably higher than in other types of HEIs, such as comprehensive universities (9.2%), economic universities (4.4%) and pedagogical universities (2.3%) (see Table 5.2).

Technical universities never lost their research focus, but it would not be entirely true to say that the expansion did not have any impact on them. With newly hired staff over-occupied with their teaching workloads and without a tradition of conducting research outside STEM, technical universities found it hard to undertake serious research projects in the social sciences and humanities.

The results of recent institutional research evaluation exercises in 2013 and 2017 illustrate the asymmetry in the quality of research conducted in ‘old’ and ‘new’ departments. The latter primarily addressed the growing demand for higher learning (and increased financial revenues) but many failed to produce quality research outcomes. Initially, the consequences were not tangible, as the whole HE sector was driven by rapid expansion and teaching performance was prioritised over other missions. In fact, the massification was strengthened by radical cuts in research funding that led to the de-institutionalisation of research in some scientific fields (Kwiek 2012a). In addition, technical universities had to re-organise their priorities based on the available resources and gravitate towards a teaching orientation. However, it needs to be underlined that technical universities did not lose their engagement in research; even a quick look at the structure of their operating activities demonstrates how important it remains (see Table 5.3).

Considering that a balance between teaching and research is one of the most challenging issues faced by the Polish HE sector, technical universities seem to cope with it well. Many observers may find this to be a surprise, but contrary to popular belief, technical universities do not prioritise maximising their teaching

Table 5.3 Structure of operating activity revenues in HEIs in 2015 by type of activity

2015	Teaching activity	Research activity	Separate economic activities	Sale of materials and goods	Other operating activity revenues
Universities	77.4	15.1	0	0	7
Technical universities	70.2	21.2	0.4	0	7.7
Agriculture universities	71.1	14.4	4.8	0.1	9.8
Economic universities	93.2	5.2	0	0	1.3
Pedagogical universities	89.5	4.6	2.7	0	2.8
Medical universities	80.5	11.9	0.2	0.2	7
Physical academies	88.6	5.4	0	0.1	5.1
Fine arts academies	92.7	3.6	0	0	3.7

volume. They are also the least dependent on revenue from education (meaning that they are less vulnerable to demographic upheavals), and they were least affected by the recent demographic decline. In short, technical universities stand out from the rest of the HE sector for their (a) organisational and financial stability and (b) well-balanced teaching-research missions.

5.6 Stability as a Key Driver of Organisational Development

Technical universities enjoy a solid and stable position in the HE system, and unlike pedagogical and economic universities, they do not have to be particularly concerned about the lack of clarity and sustainability in HE policy. After two decades of expansion, the government suddenly shifted its political priority from teaching to research, catching many HEIs in a trap. This did not affect technical universities. However, although this organisational stability is valuable, it also reduces the need for innovation and renewal. Indeed, with a solid foundation, stable funding and good internal reputation, technical universities have become reluctant to challenge well-imbedded and institutionalised patterns of performance, as evidenced by the low number of international students and poor activity in short-term professional post-graduate programmes.

The number of international students at technical universities is well below the national average. In contrast, before 1989, technical universities hosted a considerable number of international students. For the sake of this analysis, let us look back 50 years to obtain a good point of reference. In the 1966–1967 academic year, among the 1679 international students studying in Poland, 753 attended technical

Table 5.4 International students in relation to total number of students in different types of HEIs

2015/2016	Total	International students	% of international students
Total	**1405.133**	**57.119**	**4.1**
Universities	422.211	12.655	3.0
Technical universities	301.412	6.280	2.1
Agriculture universities	70.792	1.347	1.9
Economic universities	179.794	13.204	7.3
Pedagogical universities	46.122	516	1.1
Medical universities	60.606	6.329	10.4
Physical academies	24.727	309	1.2
Fine arts academies	16.938	871	5.1

universities (MSW 1967). Together with medical universities, technical universities used to be the most internationally oriented HEIs, even though the programmes they offered to international students were mainly (if not only) in Polish. In addition, they attracted students from developing socialist countries in Africa and Asia through the government-supported programmes. However, the political upheaval broke ideological links and ended many funding programmes and the major source of international students for technical universities dried out. The educational market was changed as international HE was transformed *from aid to trade* (Knight 2008; Tilak 2011).

Technical universities failed to adequately respond to those changes, and unlike medical universities, they seemed to miss the window of opportunity to globalise (see Table 5.4). Medical universities still attract a considerable number of students from various countries overseas, but technical universities failed to adjust their educational offerings to the changing environment. Perhaps a part of the problem stemmed from the engineering profession; many countries require national-level certification, which does not fit well in transnational education.

Undoubtedly, the substantial economic crises in the 1980s contributed to the technological backwardness of the Polish economy and jeopardised the reputation of technological universities. Without political support, universities with good brands but a limited capacity to provide full degree programmes in English have little chance to compete in the global market. However, due to the growing demand among Polish students for fee-based programmes, technical universities easily found an alternative source of revenue. Among technical universities, only the Polish–Japanese Academy of Information Technology (8.33%) and, due to its location on the Polish–Ukrainian border, the Lublin University of Technology (6.21%) reported a level of internationalisation above the national average.

Not only did their problems with internationalisation indicate that technical universities faced difficulties in responding to the changing environment but also their engagement in another modern trend, lifelong learning (Field 2006), leaves much

Table 5.5 Number of postgraduate students in relation to the number of students registered for full degree programmes

2015–2016	Total	Postgraduate students	% Postgraduate students
Total	**1405.133**	**127.517**	**9.1**
Universities	422.211	24.536	5.8
Technical universities	301.412	11.040	3.7
Agriculture universities	70.792	4.120	5.8
Economic universities	179.794	31.489	17.5
Pedagogical universities	46.122	6.152	13.3
Medical universities	60.606	1.669	2.8
Physical academies	24.727	677	2.7
Fine arts academies	16.938	761	4.5

to be desired. Contrary to popular belief, technical universities are not eager to provide life-long learning programmes, which are a cornerstone of smart economic development (e.g. Livingstone and Guile 2012). This is demonstrated by the relation between the number of postgraduate students registered for short-term programmes and total number of students registered for full degree programmes (see Table 5.5).

Poland stands out as the country with one of the lowest rates of participation in life-long learning, although one would expect professional universities to develop rich educational offerings for those who aspire to upgrade or update their skills and knowledge. Among all types of HEIs, technical universities seem to be the least committed to developing short-term professional programmes, and external dynamics did not force them to do so. This is rather unexpected since knowledge and skills in STEM become outdated quickly. In addition, among all types of HEI, technical universities are most commonly expected to act as leaders and role models by providing new knowledge and updated skills through a variety of short-cycle programmes for adult students Although the education provided by HEIs has evolved into extremely heterogeneous forms covering a wide range of different modes and programmes, technical universities acknowledge their loyalty to traditional modes of professional education, which remains a pivotal part of their organisational identity. In contrast, private HEIs have been developed more as entrepreneurial organisations, and their organisational identity involves seeking opportunities to maximise revenue.

Over the years, technical universities have proved that stability is one of the strategic drivers of organisational development. Regardless of external dynamics, technical universities tend to stick to their core mission, avoiding interruptions by opportunities for quick financial gains. Neither international students (which are often seen as 'cash cows') nor the students enrolled in short-term postgraduate programmes seem to undermine their entrenched organisational patterns.

5.7 Future Challenges for Technical Universities

This chapter shows that technical universities are undoubtedly the most stable group of HEIs in Poland thanks to their well-embedded institutional identity. Thus far, they have responded conservatively but reasonably to the often radical, spontaneous and chaotic changes in the external HE environment. Faced with the long absence of governmental steering in HE policy, technical universities, as strategic actors, followed their entrenched mission and chose a 'secure' path of development in very unstable times.

However, a strong identity and path dependency could be a double-edged sword and might become problematic if technical universities need a firm response to address challenges and take advantage of emerging opportunities. In light of welfare state crises (Kwiek 2014), rapid increases in globalisation (Drori et al. 2006) and the rise of the knowledge economy (Peters 2007), it may be necessary to deeply reflect upon the traditional role of technical universities. However, change is neither a quick process nor a simple task because, as shown in organisational studies, reforms need problems (Brunsson and Olsen 1993: 34–42). Paradoxically, technical universities are the least problematic actors in the HE system due to their reluctance to change. They enjoy a comfortable position because they (a) are the least affected by the demographic decline, (b) produce graduates with the highest income in the labour market, (c) have good relations with industry, (d) have almost no competitors in the private sector and, last but not least, (e) provide high-quality education to students.

How can this list of compliments possibly be seen as negative? Despite their great potential, technical universities may find few reasons to challenge their existing situation and take serious measures to transform into world-class universities; they seem to be reasonably satisfied with their current situation. This ultimately becomes a challenge in terms of public policy, which puts a strong emphasis on institutional excellence (Antonowicz et al. 2017), measured by universities' position in global rankings. From this point of view, technical universities could follow the emerging global model (EGM) defined by Kathrin Mohrman (Mohrman et al. 2008) to develop a more adventurous agenda and become research-intensive universities. EGM stands out for the following reasons: universities' mission transcends the boundaries of the nation-state, they educate students with a global perspective and they advance the frontiers of knowledge worldwide.

This would require far-reaching, transformative changes at technical universities, which, based on the current governance regime, bottom-up decision-making process and strong collegiality in these universities, might be extremely difficult to pursue. In addition, the relatively good financial and reputational situation of technical universities does not support implementation of more adventurous changes. Well-entrenched risk-averse cultures are typical in the HE sector as a whole, and only those HEIs under financial or reputational pressure manage to implement structural reforms.

To determine whether technical universities are able to transform into research-intensive universities, we must discuss an even more fundamental question: Who is supposed to define the role of technical universities? It is difficult to provide a straightforward answer regarding the future of technical universities in Poland because it depends very much on the upcoming reforming agenda widely known as Ustawa 2.0. HE policy assigns increasingly diverse functions to different types of HEIs, which may be a motivation for change. However, the policy evolves toward vertical rather than horizontal (i.e. different profiles) diversity. It produces homogeneous pressure that may lead to the gradual disappearance of the distinctness of technical universities and uniformity among the three categories of HEIs.

Summing up, this study underlines the major policy concern related to technical universities. It remains unclear whether the government expects technical universities to participate in the global ranking race and focus on research activities or to remain unique HEIs. Due to the growing popularity of global university rankings and their influence on HE policy (e.g. Hazelkorn 2015), may Polish technical universities lose their unique identity and evolve into comprehensive universities? This is a real option, but it is also possible for technical universities to follow their own path and adapt to, rather than adopt, external expectations.

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Chapter 6
Formalised Boundaries Between Polytechnics and Technical Universities: Experiences from Portugal and Finland

Teresa Carvalho and Sara Diogo

6.1 Introduction

The structure of higher education systems has been under discussion since the turn of the millennium, especially regarding the future of binary or dual systems; i.e., systems constituted by two different types of higher education institutions.

Higher education institutions of a non-university type – dedicated to technical and professional training and applied research – are known under a range of labels. Well known examples include the German Fachhochschulen, the Hogescholen sector in the Netherlands, the Institutes of Technology in Ireland, the Polytechnic Institutions in Portugal and in Finland (Machado et al. 2008). This panoply of conventions is bewildering and raise confusion when adding the term technical universities into the discussion (Kyvik 2009). Nevertheless, there are differences in the terminology regarding professional higher education institutions worth exploring. Using the Weberian methodological tool of an ideal-type, one can define the traditional image or conception of polytechnics as referring to institutions that offer short-cycle professional and vocational programmes oriented to local and/or regional development and without a research mandate (Lepori and Kyvik 2010; Machado et al. 2008). These characteristics distinguished them from comprehensive universities that offered long-term programmes and developed scientific research, and from institutions such as KTH (Royal Institute of Technology in Stockholm), TUM (Technical University in Munich), MIT (Massachusetts Institute of Technology), EPFL (École Polytechnique Fédérale de Lausanne), TU Delft (Delft University of Technology) and TUT (Tampere University of Technology), which are considered to be technical universities because their focus is more on engineering education and they are more research intensive than polytechnics. In this context, one can also observe differences among technical universities, but

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despite such variety, both types of higher education institutions – research-oriented technical universities and more technical-vocational institutions – had a complementary role within binary systems. However, what it means to be a technical university, a polytechnic or an UAS nowadays may differ substantially from historical conceptions of a technical university as seen in the first chapters of this book.

HEIS belonging to non-university sectors have in common that they were created to answer to the needs of human capital within an industrialised society. During the twentieth century, non-university institutions emerged in response to perceived failings of ivory tower comprehensive universities to respond to the competence needs of modern economies. In this context, they were expected to be more socially oriented offering professionally training and undertaking more applied research. The non-university sector is, in this sense, closer to the socially dominant notion of 'technical universities' as an organisational category. Like technical universities, non-university institutions are also more oriented to technological knowledge. As explained in Chap. 2, many technical universities had polytechnics as predecessors in its history.

The process through which non-university institutions may be transformed into 'technical universities' nowadays has been less researched. This chapter aims to shed light in this domain by using the case studies of Portugal and Finland. As such, this chapter focuses on the way the non-university sector has been evolving in Portugal and Finland, exploring its relationship with the university sector as well as its gradual positioning within the higher education field.

A prior challenge was the acknowledgment that the boundaries between comprehensive universities and other types of higher education institutions, such as polytechnics, Universities of Applied Sciences (UAS), and technical universities are difficult to define and highly dependent on national contexts. In fact, in binary systems technical universities are subject to both horizontal comparison – with comprehensive universities – and vertical comparison – with more professional institutions. However, the intensity of these comparisons varies as exemplified by the case studies presented here.

The way the continuation of binary systems has been questioned is mostly associated with the expansion and subsequent massification of the sector, the influence of the knowledge society, academic drift and professional drift, along with the increase in institutions' diversity and even pedagogical restructuring (e.g., the Bologna process). The pertinence of maintaining a binary or dual system, including institutions with different missions, has been raising national and institutional debates, with the OECD being called on to advice countries in this domain.

Portugal and Finland are two European, OECD member countries, with different historical, geographical, economic and cultural characteristics. In 2015, Finland occupied the 23rd position in the United Nations Human Development Report while Portugal ranked 41st (UNDP 2015). Both countries have a binary higher education system that in its initial phase consisted of polytechnics and universities, which has been submitted to similar environmental pressures, leading them to ask for OECD political advice.

The reason why we focus on the OECD with respect to issues related to the continuity or discontinuity of the Portuguese and Finnish higher education binary systems and their operationalisation, and more specifically to the evolution and the current existence of polytechnics in these countries, stems from the political importance this organisation held and still holds for these governments in terms of legitimising their political action. Martens and Wolf (2009, p. 81) explain this relationship by stating that governments look at international organisations to pursue policy goals and also "because it was in their strategic interest to use the intergovernmental policy arena to manipulate the existing distribution of formal institutional competencies in their domestic political systems". Consequently governments gain leverage and legitimacy for their actions (Saarinen 2008; Kallo 2009; Kauko and Diogo 2012; Martens and Wolf 2009). This chapter assumes that the way higher education institutions are transformed, evolve and are socially conceptualised not only depends on national regulations, but also on the influence of supranational institutions.

Assuming that the OECD has a role as an epistemic community (Haas 1992), being able to frame the dominant notions of what higher education institutions and systems should be, it is relevant to understand which main underlying notions or concepts on the non-university sector frame OECD advices.

6.2 Challenges to Dual Systems – What Distinguishes Professionally Oriented Higher Education Institutions?

The topic of diversity has been widely discussed in the higher education literature (Birnbaum 1973; Trow 1995; Meek et al. 1996; Morphew and Huisman 2002; Wit 2007; Van Vught 2008; Huisman and van Vught 2009; Teichler 2014), assuming particular importance within the Bologna scope, since the "logic" of Bologna aspires to create "centrally organised diversity" (Marginson and Wende 2007, p. 48). Nevertheless, the implementation of such ideals created confusion and resistance in some higher education systems, such as the binary ones, which used to award more varied and longer degree programmes in the university component of the system.

The main concerns with this reform were related with the compatibility of the traditional degree structure – in which longer study cycles used to fall into the scope of comprehensive universities, and shorter ones, technical professionally oriented higher education degrees, were the domain of polytechnics, colleges or UAS – with the new two-tier cycle structure which stipulated that both academic and professionally oriented higher education institutions offer the bachelor and master programmes with the same length and applying the same nomenclature. In parallel, convergence and competition among European higher education institutions are emphasised by the European Commission. For example, discourses on the knowledge society have been used to promote European convergence on the grounds that economic competitiveness will be fuelled by research and development. Knowledge-society narratives (Santiago et al. 2008) legitimate the need to orient higher education institutions to society, research to innovation and teaching to employability. Thus, in the last three decades, and against this background, the binary divide has become increasingly blurred (Witte et al. 2008; Lepori and Kyvik 2010), giving room to several concerns, expectations and demands. These change dynamics transcend national boundaries, partly due to mimetic influence from internationally visible role models, and partly to similarities in the historical roots of polytechnic education and research across many western countries (Lepori and Kyvik 2010).

To a great extent, UASs and polytechnics changed in reference to comprehensive universities, and even to research-oriented universities. In their work on the research mission of higher education institutions outside the comprehensive university, Kyvik and Lepori (2010) referred to Burgess (1972) to describe the tendency of non-university higher education institutions to orient their activities in ways that bring them closer to the university template; namely, the development of research, designating this phenomenon as academic drift. The authors consider that this is, in fact, a special case of academic drift, which can be even labelled as research drift (Kyvik and Lepori 2010). On this, Harwood (2010) explains that the practice underlying academic drift – not only in higher education – is the process through which knowledge "(…) gradually loses close ties to practice while becoming more tightly integrated with one or other body of scientific knowledge". This explains why the same phenomenon in the United States is labelled "mission creep" (Badley 1998). In Norway, for example, university colleges had increasingly emphasised research as an important faculty task in addition to teaching (Kyvik and Skodvin 2003)[1]. Furthermore, it is also possible that the development of research in non-university higher education institutions is a result of the need these institutions felt to improve professional education and professional practice in occupations for which universities do not train people (Kyvik and Skodvin 2003) – similarly to the need of strengthening polytechnics' roles as regional knowledge providers (Heggen et al. 2010; Jongbloed 2010). Simultaneously, the introduction of master's degrees in polytechnics/UAS (due to the Bologna degree restructuration) implied that the curricula of these programmes required staff with research experience mainly, as this was required by national accreditation agencies (Lepori and Kyvik 2010). In parallel, professional institutions also become more prone to behave like universities since teachers in professional higher education institutions mainly graduated in universities and therefore carried to this subsystem the university culture they acquired in the past, imposing an academic drift based on normative isomorphism (Cardoso et al. 2011; Diogo et al. 2015; Kyvik and Lepori 2010; March and Olsen 1983).

These changes in research and teaching led to increasing convergence in higher education systems with the traditional boundaries between basic and applied research gradually disappearing (Horta et al. 2008; Santiago et al. 2008). In parallel, the inverse process of professional drift also emerged in the university subsystem.

[1] At the present, there are hardly any of these institutions left in Norway anymore – most of these have either been upgraded to university status or merged with a university.

This phenomenon is very much fuelled by the discourses on the knowledge society and the national innovation systems (Lundvall 2007), encouraging a stronger relation between universities and society. In this context, the production of knowledge is more associated with "applied" research, and teaching is also assumed to be more oriented to employability, also leading to professional drift in universities (Machado et al. 2008).

A visible sign of professional drift in the university subsystem is the way it has been shaping training programmes in order to comply with market needs and to increase graduates' employability (Harwood 2010; Morphew and Huisman 2002). Another relevant sign of this is the emergence and development of different forms of producing knowledge, other than basic or applied science.

It is, however, relevant to highlight that binary systems include institutions with different reputations (Scott 1995); usually universities tend to have a high symbolic status within the system (Badley 1998). As pointed out by Amaral and Magalhães (2005, p. 126): "diversification via a binary system is tainted by a political suspicion: the elitism implicit within the university subsystem". Adopting the sociological institutionalism perspective, it is possible to sustain that the search for stability, legitimacy and social prestige partly explains the academic drift in professional institutions (Oliver 1991; Cardoso et al. 2011; Magalhães 2004).

Within this context, stakeholders with divergent interests (namely non-university institutions and comprehensive university leaders) start pressuring national governments to promote changes in the system in different directions. Faced with these pressures, national governments started looking for external support in international organisations (such as the OECD) to advice on the best way to reform the structure of higher education systems.

Even if the OECD has no legally binding mandates in terms of educational policy of each member-state (Martens and Wolf 2009), it has the symbolic power to envisage polytechnics and UAS and recommend their role in binary systems. In this sense, the OECD can be interpreted as having a relevant role in the reconfiguration of national non-university institutions.

6.3 The Portuguese and Finish Higher Education Professional Subsystems

In Portugal, the professional higher education sector was formally established in 1973 through the Reform Act passed by the National Assembly (DL 402/73), under the 'Veiga Simão Reform', but due to the 1974 revolution, the process of expansion and development of the sector was disrupted. It was only in 1977 that the DL 427-B/77 (14th October) instituted the polytechnic higher education subsystem as aiming to train expert technicians and professionals of education at an intermediate level of higher education. From 1977 to 1981 there was a clarification of the strategic guiding principles defining the objectives of the polytechnic subsystem, namely bringing it closer to the economic and social needs of the country (Amaral et al. 2002). The OECD reports and recommendations, as well as their focus on the 'human capital' theory, helped to guide the strategic planning of Portuguese higher education (ibidem). The link with economic and regional development was reinforced through the agreement on specific objectives concerning the institutional mission of public polytechnics, which was meant to be different from "the more conceptual and theoretical characteristics" of universities (Magalhães 2004, p. 303). As such, Portuguese polytechnics, which have their origins in the former vocational education Institutes of Industry and Commerce, were expected to develop non-traditional research areas, quite differently from many of their European counterparts, which were not supposed to engage in research (Lepori and Kyvik 2010). In fact, since their creation, even if in moderate terms, polytechnics in Portugal were expected to perform "guided research" for the needs of national industry and closely align their education with the needs of the national labour market.

The development of the vocational subsystem was also strongly motivated by another attractive, political objective; namely to increase the chances of Portugal becoming a European Union member. The priorities were altered to match the performance of other European countries, to act strategically in terms of quantity, quality and access procedures (Amaral et al. 2002). The 1980s and 1990s were the "golden years" for polytechnics in Portugal. Public polytechnics have concentrated their enrolments in Engineering, Management and Business Administration (within the area of Social Sciences), Education/Teacher Training, Health and Social Protection and Agriculture, which corresponded roughly to the recommendations of the World Bank (Amaral and Magalhães 2007 p. 70). The literature also confirms that public higher education institutions, universities first and then polytechnics, tend to be the first choice of the majority of Portuguese students (Pedrosa et al. 2017).

Despite the existence of distinct types of higher education institutions in Portugal, universities continue to offer a higher number of vacancies and there is a higher number of enrolments in this subsystem. Even if there are differences in the total number of enrolled students each year, on average students enrolled in the polytechnic subsystem in Portugal represent around 40% of the total number of enrolled students in higher education (DGEEC 2017). Thus, within the public sector, consolidating the polytechnic subsystem took far longer than it did for the university subsystem (Almeida and Vieira 2011).

Although almost two decades later than Portugal, it was the belief in investing in human capital as the ultimate and indisputable spearhead of national progress that provided the Finnish higher education system with legitimacy and willingness to advance educational visions, proposing new concepts of youth and higher vocational education, and to expand higher and adult education (Rinne 2004, p. 98). Curiously, by the early 1990s, Finland was one of the few countries in the European Union with a uniform higher education system, consisting of universities only. Thus, the first polytechnics in Finland emerged with the wishes of the Finnish government to transform the country into a knowledge society. In order for this to happen, it was necessary to raise the knowledge and skill levels of the population by doubling higher education enrolments (Välimaa and Neuvonen-Rauhala 2008). As it was visible that universities could not expand their offerings without endangering the quality of education and research, there was the need to find an attractive alternative at the higher education level and to improve students' chances of finding a higher education study place. Also during the expansion period of the Finnish higher education system, the provision of equal educational opportunities became one of the most important objectives pursued by governments (Välimaa 2004). Similar to Portugal, pressures emerging from an increasingly massified system allowed for the diversification of Finnish higher education and subsequent creation of a non-university sector. Simultaneously, the development of modern technology and its rapid introduction into Finnish working life demanded the need for better-qualified people in the labour market. Indeed, this also contributed to the emergence of pressures for status competition of higher education degrees among professions and institutions as well as from labour market allocation and recruiting needs (Rinne 2004, p. 98).

Another important factor contributing to the establishment of the Finnish non-university sector was the Europeanisation journey. Especially after 1995, when Finland joined the European Union, and later on with the implementation of the Bologna process and subsequent convergence movements of European higher education systems, there were political pressures from the European Union for a renewed role, status and function of higher education in society.

One of the expectations with the Bologna reforms in the Finnish polytechnics was to provide their students an opportunity to deepen their professional competencies as well as to create opportunities for polytechnics to develop their activities as labour market-oriented higher education institutions. Another objective was to differentiate between polytechnic and university Master's degrees and to promote internationalisation in Finnish polytechnics. Nevertheless, the comparability of degrees and their prestige and status in relation to university degrees was found to be somewhat poor (FINHEEC 2012). Moreover, as in Portugal, the fact that both types of higher education institutions confer both bachelor and master degrees with the same degree titles does not help to differentiate both subsystems.

The establishment of the non-university sector was thus part of an extensive reform of post-secondary education, which consisted in merging around 215 existing technical and business colleges, and other secondary level institutions to form 32 polytechnics (Välimaa and Neuvonen-Rauhala 2008), also abbreviated to AMKs (ammattikorkeakoulut in Finnish). Similar to Portugal, the main supporters of the foundation of AMKs were the representatives of provinces and provincial institutions who saw the status of their upper secondary education institutions upgraded. On the side of universities, there were some mixed feelings about the new sector of higher education, as universities feared that it would shrink the higher education budget (Välimaa and Neuvonen-Rauhala 2008, p. 80).

In the beginning of the new millennium, Finnish polytechnic institutions began to be assumed and legally designated (Law 932/2014) as Universities of Applied Sciences (UAS). At present, most UAS are regional institutions with students being encouraged to make use of multidisciplinarity, namely by establishing their own business and combining enterprise education in many forms (Hölttä and Malkki

2000). Student selection in polytechnics is mostly based on secondary school achievement, work experience and in many cases, entrance examinations.

Finland has currently 14 universities and 24 universities of applied sciences (OKM 2016), while Portugal has 38 universities (14 public universities and 24 private); and 65 polytechnics (20 public polytechnics and 45 private) (Pedrosa et al. 2017, p. 65). The largest fields of study in Finnish UAS are engineering and transport, administration and commerce, social services and health care, information technology, and telecommunications (Official Statistics of Finland, OFS 2018). Finnish UAS account for a large share of national student enrolments, although still lower than universities (OFS 2016).

In the last two decades, the pertinence of maintaining a binary or dual system of higher education institutions has been questioned due to the increasingly blurred mission of both types of institutions, as mentioned before.

To a great extent, the discussion on the blurring of the institutional mission of HEIs, and the operationalisation of the binary divide in both countries provided Portuguese and Finnish governments with legitimacy to enforce change recommended in international forums. The OECD was then called on to advise countries in this domain, being relevant to analyse if and how the non-university institutions can evolve to become closer to the category of 'technical university'.

6.4 Methods and Data

Bearing in mind the binary organisation of both higher education systems, their development and the diversity among HEIs, a system level perspective is applied to understand how institutions have been re-conceptualising their role/mission in the present knowledge society.

Therefore, the next section discusses these views through the lenses of the OECD and through the voices of Finnish and Portuguese practitioners.

Analyses of OECD reports for Portugal and Finland were complemented with the discourses of 26 key actors interviewed at the national and institutional levels during the years 2011 and 2012. At the national level, 12 key actors (policy makers and former higher education ministers) were interviewed: six in Portugal and six in Finland. At the institutional level, the focus was on the institutional interviews carried out in the professional subsystem, having interviewed seven people with different roles (top-management actors and academics with management duties) in one Portuguese polytechnic and in one Finnish UAS. Both OECD reports and interviews were submitted to content analysis (Bardin 2010). Based on the theoretical framework and in the empirical data, three main dimensions of analysis were identified; namely: maintaining the binary structure; operationalizing the divide and new roles for higher professional education institutions. A summary of this content analysis can be found in the Appendix (Table 6.1).

6.5 Challenges of Dual Systems: A Single Binary Higher Education Model?

Diversity of institutional types is usually presented as a positive characteristic of higher education systems (Morphew and Huisman 2002) since it allows for teaching a large number of students without increasing the costs of education, while simultaneously offering distinct training to students more suitable to perform specific jobs (Guri-Rosenblit et al. 2007). This diversity also introduces more complexity and hierarchisation in the systems. Since comprehensive universities have been considered as the prototype of the 'University', the way other institutions may be reconfigured is expected to be by reference to it. This is especially true for Portugal where the existence of comprehensive universities since the XIII century give them a strong legitimation in the system.

OECD reports on the Portuguese and Finnish higher education systems diagnosed the existent systems, proposed a specific model for both and provided recommendations for the operationalisation of each country's higher education system. The following section compares these recommendations that are synthesised in Table 6.1.

Both panels agreed on the importance of maintaining a diversified binary higher education system in the two countries, visible in expressions such as: "The binary system should be maintained and strengthened" (OECD 2007, p. 55) and "Instead of blurring the boundaries between universities and polytechnics the vocational side of the tertiary system should be strengthened" (OECD 2009, p. 36). This common recommendation prescribed to the structure of both Portuguese and Finnish higher education systems suggests that the OECD recommended the continuity of the binary system in both countries. However, when analysing the way the OECD suggests countries to operationalise the divide, different models emerge, translating to different ideal types of higher professional education in each country.

While in Portugal the tendency was to recommend a diverse system, for Finland the OECD suggested a stronger role in the UAS research mission. Nevertheless, the team who assessed the Portuguese higher education system was more straightforward than the Finnish review team. In fact, the report on the Finnish higher education system is subtler, providing some leeway and room for other forms of differentiation than "simple duality". Actually, and especially regarding Portuguese higher education, the OECD offered a substantial amount of suggestions to differentiate both subsystems, which mostly related to: the type and nature of the degrees each type of higher education institution could award; governance structures; internal cultures and management practices; research vs. teaching functions; funding mechanisms; staff qualifications; etc. In sum, all the aspects covered in the OECD reports advice measures to differentiate universities and polytechnics. To a great extent, the operationalisation of the divide between polytechnics and universities in Portugal is presented in a way that reinforces the polytechnics' position in society and, in this sense, also reinforces its less prestigious position in the system. In this sense, the OECD reinforces the traditional position of polytechnics enabling its evolution to ‘technical universities’. Actually, polytechnics and technical universities are classified as distinct institutions. The first are expected to be devoted to vocational training and restrict the research they develop to ‘applied research’ while the second is sustained in the idea of developing technological knowledge and produce advance technological knowledge. The traditional ideal type of a polytechnic is clearly reinforced in this report both in relation to teaching and to research. In the case of Portugal the OECD turns to the perspective that polytechnics have a fundamental role in improving the qualifications of the population to support economic competitiveness. “They [polytechnics] need to return to their core mission of developing employable graduates with practical know-how, underpinned by analytical and problem-solving abilities” (OECD 2007, p. 78). Nevertheless, with respect to Finland, research specific roles are defined as aligned with the new codes of knowledge production: “the polytechnic role in the research space should not encroach on the university role but should be complementary to it, by focusing rather on technology transfer and development” (OECD 2007, p. 12). In this context, the recommendations are more aligned with the possibility of non-university institutions evolving into technical universities.

At this stage, it is important to highlight that these different OECD visions may reflect not only the different governments’ wishes, but also the different national realities. By the time the OECD revisions were conducted, Portugal was in a deep financial crisis. Maintaining different study options for a diversified student population, while following the “European Bologna model” went in line with the needs and challenges the country faced, while simultaneously avoiding increased expenses with the intensification of research in polytechnics if a unitary system was recommended.

Suggestions for Portugal are presented in the spirit of protecting the diversity of the system by limiting the capacity of universities to engage in professional drift (OECD 2007, p. 49), and the polytechnic tendency to be involved in academic drift (OECD 2007, p. 12).

Recommendations for specific legislation, clearly dividing the two subsystems, were also advised by the OECD:

> It is recommended that the government should introduce comprehensive university and polytechnic legislation in which (…) the different roles of universities and polytechnics are specified. (…) (2007 p. 55).

As a result of these recommendations, the Portuguese government passed legislation (DL 74/2006 and Law 62/2007) reassuring the binary divide of the system, even if some of the polytechnics’ aspirations were taken into account. Examples of accepted polytechnics’ ambitions were the development of master’s programmes (forcibly professional in polytechnics and scientific and integrated masters in universities); an increase of staff holding PhDs; or even the creation of consortia and not mergers. Interviewees perceive this difference as a positive step towards the increase of the prestige of professional higher education institutions, considering that the legislation (Law 62/2007) demanded higher qualifications for polytechnics’ staff and allowed for the creation of consortia and partnerships, which is likely to have an impact on the participation in national and international networks, as mentioned by one interviewee:

> It [Law 62/2007] helped to consolidate the image of polytechnics, once it helps to dilute their old problem of low quality perceptions (PMM).

This statement shows that institutional actors working in Portuguese polytechnics faced the stigma of lower prestige of these institutions, making them keener to defend a unitary system.

The differences between the two subsystems were also strengthened by the type of qualifications each one could offer, since the capacity to offer PhD programmes was conceded only to universities (Decree-Law 43/2014).

The suggestions to operationalise the system divide in Finland are presented in an opposite perspective to the Portuguese one. The main recommendations to institutionalise the binary framework are based on the institutionalisation of new roles for higher professional education institutions in Finland.

On this topic, Finnish UAS interviewees (contrary to their Portuguese counterparts) did not welcome the Bologna reforms; namely the reduction of the bachelors' length:

> Especially in the case of the School of Technology and their engineering programmes: they simply don't understand how you can guarantee the competences of the engineers in three years (…). The feeling I got, because in Finland we have quite strong associations of engineers and they have been consulted quite heavily, is that in order to guarantee the skills and the beliefs/attitudes to act as an engineer, you cannot do it in three years! (FPL).

The OECD also acknowledges the pertinence of having differentiation in Finland, but based on compliance; i.e. a unitary system which is more aligned with the conceptualisation of traditional universities. Bearing this in mind, it can be said that the OECD recommendations support more a potential transformation of non-university institutions into technical universities. The defence of the maintenance of a binary system is based on the assumption that UAS can be improved. This progress may be aligned with their conceptualisation as technical universities.

> The dual structure of the Finnish tertiary system should be upheld and the profile of the two sectors should be developed further according to the principle "different but equal" (OECD 2009, p. 35).

While in Portugal, higher professional education institutions were recommended to focus mainly on professionally oriented teaching and were forbidden to award doctorate degrees, in Finland, they were incited to diversify their teaching target and offer PhD programmes.

> (…) the possibility that polytechnics could be accredited to offer doctorates, as well as postgraduate professional doctorates, in areas of acknowledged expertise, under appropriate conditions of quality assurance, and attached to an appropriate graduate school (OECD 2009, p. 51).

Simultaneously, higher professional education institutions were also stimulated to diversify their research mission and to include a new research paradigm (OECD 2009, p. 92). The recommendations related to research activities can, on the one hand, be assumed as examples of academic drift in the higher professional education subsystem. However, on the other hand, this specialisation of Finnish UAS towards applied research, different from traditional universities, maintains the binary divide, respecting each type of organisational field mission.

> Polytechnics should develop a research strategy, (…) which would be likely to include, inter alia: inclusion of research in under- and postgraduate programmes and research training strategy; research contract generation priorities; essential items of internal research organisation and infrastructure; research collaboration priorities; (…) (OECD 2009, p. 52).

The dual recommendations for Portugal and Finland resulted in different national solutions for a binary structure, also resulting in different ideal types of professionally oriented institutions. In Finland, although the new legislation on this matter only came in 2014 (Law 932/2014, Universities of Applied Sciences Act), polytechnic institutions began to be assumed as, and to call themselves, Universities of Applied Sciences (UAS) during the implementation of the Bologna process.

The new designation seems to be institutionalised in the Finnish higher education system since not only the ministry assumes it, but also the institutional actors defend its adequacy. In fact, institutional actors working in this subsystem (in 2011) adamantly refused to be called "polytechnics": "The term UAS describes better what we do now than the term polytechnics" (FS).

In Portugal, since the DL 74/2006 until the present day, none of the polytechnics was upgraded to universities, their nomenclature is still the same, they are still called polytechnics and not UAS, and only now discussions are beginning to assess the possibilities to confer PhDs. According to the latest national legislation, Portuguese polytechnic institutes are "(…) high-level institutions dedicated to the creation, transmission and dissemination of culture and professionally-orientated knowledge through study, teaching, guided research and experimental development" (Law 62/2007 §7, 1°).

Different national realties, cultural factors and political traditions can explain this difference of position and acceptance. It is widely acknowledged that even though Finnish UAS are younger higher education institutions than their Portuguese counterparts, they do have a higher status and a more consolidated image than Portuguese polytechnics, also due to "high-quality, well-trained teachers, with strong academic qualifications and master's degrees" (Sahlberg 2011, p. 9). In fact, as it is perceptible in the Finnish OECD (2009, p. 114) report, this image of quality is "discernible to frequent visitors". Despite both OECD teams agreeing to maintain the binary divide, the paths to carry out this aim were distinct for the two countries, resulting in defining distinct non-university higher education institutions with two different ideal types in the two countries. While in Portugal the ideal type is more aligned with polytechnics' historical mission, in Finland their aims and objectives are more similar to those characterising comprehensive or even technical universities.

Different hypotheses can be formulated to explain these different recommendations. One is related with the economic realities of the two countries. Since Finland has a more stable economic situation, it could be assumed that the country has more resources to distribute more evenly within the system. Finland is one of the leading countries in Europe in terms of education and technological advancement, making the country closer to become a truly knowledge society. Furthermore, the higher levels of qualification of the population indicate that the need for diverse institutions to improve student enrolment is less relevant. An opposite situation is acknowledged by Portuguese actors who see polytechnic institutions as providers of higher qualifications with lower costs.

> (…) the effort one needs to do (…) will be smaller if the professional qualification programmes will be implemented on the polytechnic sector (Ps).

On the other hand, as mentioned previously, one cannot neglect the hypothesis that the OECD experts are also influenced by national governments in their proposals. It is possible that the different suggestions result from distinct national pressures of each country to organise their higher education systems.

The analysis of OECD reports allows for the conclusion that, for the specific case of the systems' structures, and, more specifically, for the hypothesis of non-university institutions turn into technical universities in the near future, one cannot talk about convergence policies nor about isomorphic behaviour between different national governments based on international organisations' similar recommendations. Although the OECD states that the polytechnic mission has to develop and offer teaching and research activities more oriented to the economic and social tissue, the scope of their action is quite different for the two national contexts, which reinforces the idea that boundaries between universities and polytechnics are hard to define. Even in the Portuguese case, where the polytechnic is historically more consolidated, the general perception of Portuguese interviewees about the binary divide and role of polytechnics in the country still seems to be "unproductive". Most of them mentioned that despite all legislative efforts made to differentiate both subsystems, in practice, it is still difficult to know:

> where the polytechnic ends and the university starts. With or without Bologna, the system will continue to be binary and it will continue to not make sense. I mean, polytechnics will progress towards becoming universities and universities will be closer to the labour markets and offering more vocational programmes that would be 'polytechnics' property' (PMM).

Not very different from the Portuguese scenario, Finnish interviewees believe that both recent pieces of legislation – the New Universities Act and the Universities of Applied Sciences Act "allow for increasingly more academic research, turning universities closer to UAS, through the third mission." (FPTM).

It is also interesting that regardless of nationality, interviewees belonging to the university subsystem still feel a kind of discomfort with the idea of being compared with more professionally-oriented institutions. They still position themselves – and their work – in a higher position (with a higher status) than those working in UAS.

> In Finland there still exists this dual system, research universities and UAS, and there is tension, you can call it competition, but is also competition for respect, for the status. I don't know if we compete from the students' point of view, because both systems have quite a lot of applicants… I think it is more about the status and the staff (FPTM).

Taking the fact that the OECD recommends to improve the status of UAS, it can be said that the possibility to upgrade non-university institutions to technical universities depends on national contexts – with countries with more universal higher education systems and more economically developed having a higher probability of moving in this direction.

Quite different is the discourse of system actors belonging to the organisational field of UAS and polytechnics, as they position the institutions and their role as equal to comprehensive universities: the same quality, the same level of hierarchy and demands. In Portugal, this was particularly evidenced from system level actors, which reflects the lack of compliance when compared to Finnish interviewees:

> The polytechnic won with Bologna because it gained the possibility of conferring masters degrees. (…) Therefore, polytechnics have been re-qualified because the profile of an institution is also defined by the top of degrees it can confer and now, with Bologna, they can create and assign 2nd cycle programmes, though not yet 3rd cycle programmes (Ps).

Nevertheless, and in line with what institutional actors feel about the maintenance of the binary system, "it doesn't seem to me that polytechnics used this [the possibility of conferring 2nd cycles] in Portugal to be really different in their mission. I don't see great evolution" (Ps).

In some cases, and especially in Finnish UAS, interviewees were quite critical about traditional universities, mentioning that UAS are innovative and in line with the demands of the present knowledge society.

> There are people who think that we are threat for the research universities in the sense that historically Finland has been for the pure objective research and truth and now we are here with applied research. At the same time, research universities are supposed to have more links to the real life. So, actually we are even a bit afraid that the idea of the objective truth might disappear from the Finnish higher education system (FPTM).

These developments represent the types of tensions/challenges that have emerged in both higher education systems and higher education institutions when trying to maintain the binary organisation and diversity of missions and profiles, while simultaneously competing for economic and social relevance and academic practices.

6.6 Conclusions

Binary systems were created to accommodate a high demand of students in higher education, to promote more diverse and inclusive training and to foster economic and social regional development. Within this system, diverse and complementary higher education institutions were created with distinct roles and missions. Historically, some of these institutions, specifically polytechnic institutions, were transformed into technical universities. In the last three or four decades, a public and political debate emerged on the pertinence of maintaining this organisation. To a great extent, the doubts about the usefulness of maintaining these systems resulted from the blurring of institutional missions among higher education institutions as a result of pressures associated with such diverse factors as the massification of the sector, the narratives on knowledge society, academic drift and professional drift, and the pedagogical restructuring (e.g., the Bologna process).

Professional drift and academic drift make polytechnics and comprehensive universities more alike, questioning their specific and complementary roles. Simultaneously, the stratification of binary systems induces key actors in these institutions to strive for different solutions. While in polytechnics and UAS actors tend to support a unitary system, in comprehensive universities the tendency is to argue for the reinforcement of the divide. The way binary systems may change is especially relevant since it may induce an increase in the number of technical universities in the unitary systems. Faced with different pressures, national governments resort to experts' advice through international organisations such as the OECD.

This chapter argues that the way higher education institutions are conceptualised and reconfigured is dependent on the national context. There is some tension between higher education key actors aims' to turn the systems more unified and the OECD reports that recommend different paths for the binary systems.

Reflecting on the extent to which diverse systems can evolve in such a way that allow non-university institutions to evolve to a technical university model, this chapter concludes that this possibility is highly dependent on the context. Based on the analysis of OECD recommendations and on the key actors discourses one can say that there is a higher tendency for non-university institutions to be perceived as evolving to technical universities in countries with higher levels of economic and technological development and with universal higher education systems. In countries with less economic development and with massified systems, as the Portuguese one, this tendency is less evidenced. What seems to be in place is a reinforcement of the distinctiveness of polytechnics, reinforcing its role as improving human capital.

The intent to create polytechnic institutions in Portugal and in Finland was aligned with the aim to increase students' participation in higher education and to promote economic regional development. Polytechnic institutions were framed by an ideal type that characterised them as oriented to short-term professional training and to applied research able to serve as an instrument for economic development.

Regarding common challenges such as professional drift and academic drift, the knowledge society and pedagogical restructuring, OECD recommendations propose a continuity for the traditional ideal type in Portugal and a discontinuity in Finland. In the first case, the government is advised to keep a different mission in polytechnics centred in specific training programs (and even specific students), and in research with a more applied orientation. In Finland, the recommendations frame UAS in an ideal type characterised by training programs similar to those in comprehensive universities (such as the PhD programs) and on research activities that are expected to be reinforced (even if aligned with the new modes of knowledge production), being even incorporated within training programs. The reasons for these distinct recommendations may lay in the different levels of development in the two countries. The lower economic development and qualification levels of the Portuguese population seem to influence the need to maintain the initial purposes of polytechnic institutions.

In Portugal the dominant construct of the OECD and national legislation on polytechnics' roles follow the traditional route based on a path of continuity. At the same time, in Finland the dominant construct can be defined as aligned with a path of discontinuity with the roles attributed to UAS representing a rupture with the traditional conceptions of its specific teaching and research activities, making it closer to the transformation in technical universities and also to knowledge society objectives and discourses.

While in Portugal this historical evolution is framed by a trend to maintain their traditional ideal type, in Finland polytechnic institutions have evolved into UAS, making them closer to technical universities, as there is a greater emphasis in research and especially in the teaching-research nexus. The fact that the training expansion in polytechnic institutions in Portugal has been more concentrated on educational and social sciences – and less on technical and research constructs – may justify their non-evolution to technical universities. The analysis of OECD reports reveals that the boundaries between comprehensive universities and professional higher education institutions, such as polytechnics, UAS, and technical universities are difficult to define and highly dependent on national contexts. Nevertheless, the evolution from polytechnics to UAS and to technical universities seems to be based on the level of commitment to research and on high-level training programmes, such as PhD degrees.

The OECD has no single cognitive construct on what a polytechnic, a UAS, or a technical university represents within a binary system, its recommendations being highly influenced by the national contexts. Despite the similar pressures binary systems are facing, it seems that a traditional ideal type of more professionally-oriented higher education institutions, these being polytechnics, UAS, or technical universities, is still interpreted as relevant in crisis environments, and environments of growing uncertainty, as that faced recently by Portugal. Nevertheless, the reinforcement of the traditional ideal type may strengthen the system stratification and, in this sense, may increase pressures of polytechnics' institutional actors to eliminate the divide as expressed by interviewees' discourses. More studies are needed to analyse the role of different actors and power negotiations to consolidate a single ideal type for professionally oriented universities.

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Appendix

Table 6.1 Comparing OECD perspectives on the Portuguese and Finnish higher education systems

Content Analysis' Dimensions	Portugal (2007)	Finland (2009)
Maintaining the binary structure	"In examining the national system and structures, the review team came to the firm conclusion that the binary divide (…) should be strengthened" (p. 12). "The binary system should be maintained and strengthened" (p. 55).	"Instead of blurring the boundaries between universities and polytechnics the vocational side of the tertiary system should be strengthened" (p. 36).
Operationalizing the divide	"Polytechnics must have considerable respect for themselves and their role" (p. 12). "The mechanisms for resource allocation, levels of institutional autonomy, programme accreditation procedures and human resource management policies, all need to be reformed to create a policy environment in which professionally orientated polytechnic institutions can create a sustainable future that is distinct from universities (p. 48)." "Universities should not be rewarded for entering programme areas that are outside their core area of business in an attempt to recruit students in an increasingly competitive market" (p. 49). "Existing inter-institutional co-operation initiatives should move from statements of intent to the implementation phase, with a clear emphasis on strengthening regional capacity, while respecting the distinct missions of universities and polytechnics" (p. 55). "It is recommended that the government should introduce comprehensive university and polytechnic legislation in which (…) the different roles of universities and polytechnics are specified. (…)" p. 55) "Universities should be specifically and unambiguously excluded from entering programme areas and levels of award that are outside their core area of business, and which properly reside within the polytechnic sector." (p. 55).	"There is an emerging feeling that simple duality may be overly simplistic and too much of a straitjacket for conceptualising the future configuration of the system, in terms of what is needed in different regions, and that a spectrum of possibilities should be considered" (p. 96). "The dual structure of the Finnish tertiary system should be upheld and profile of the two sectors should be developed further according to the principle "different but equal" (p. 35).

(continued)

Table 6.1 (continued)

Content Analysis' Dimensions	Portugal (2007)	Finland (2009)
	"Increasing polytechnics' emphasis on short-cycle programmes and ensuring that universities do not provide programmes that properly lie within the ambit of the polytechnics and, equally, that the polytechnic role in the research space should not encroach on the university role but should be complementary to it, by focusing rather on technology transfer and development" (p. 12). "Future growth in higher education participation should be overwhelmingly concentrated in the polytechnic sub-sector. This implies an acceptance of fundamental differences of mission of the sub-sectors in terms of student inputs, production costs and graduate outcomes. The review team cannot assess the extent to which the institutions and the various communities of interest (especially students, parents and employers) are willing to embrace differentiated expectations on a horizontal, rather than vertical, basis. On the one hand, history and culture are powerful forces; on the other hand, growth and survival depend on adapting to changing environmental conditions" (p. 82). "They [polytechnics] need to return to their core mission of developing employable graduates with practical know-how, underpinned by analytical and problem-solving abilities. They also need to see themselves, and have the community see them, as a major source of post-compulsory education and training for Portugal's new participants: the previously excluded youth and adult learners who are the subject of the New Opportunities initiative" (p. 78). "A more explicit statement of the role of polytechnics is needed, one that conveys their distinctiveness" (p. 82).	

New roles for vocational institutions		"(…) by further improving postgraduate education and professional continuing education" (p. 36)." "A sector reformulation of the generic research R&D expectations of polytechnics, no doubt encompassing a fresh paradigm which would include: – Orientation towards Mode 2 with all its many manifestations; – Professional practice focus; – Educationally related research – specific problem-based learning and research into pedagogies related to specific disciplines. Central government/national support for polytechnics in terms of: – a certain core funding for research; – Assistance in capacity development; – The possibility that polytechnics could be accredited to offer doctorates, as well as postgraduate professional doctorates, in areas of acknowledged expertise, under appropriate conditions of quality assurance, and attached to an appropriate graduate school" (p. 51). "Polytechnics should develop a research strategy, appropriate to their traditions, profile, expertise, competence and collaborating partners. (…) which would be likely to include, inter alia: – Research philosophy and positioning; Selected prioritised research themes/centres of excellence; – A robust human resources strategy for capacity development (including recruitment, staff development); – A support budget including use of research time in a focused manner;

(continued)

Table 6.1 (continued)

Content Analysis' Dimensions	Portugal (2007)	Finland (2009)
		– Inclusion of research in under- and postgraduate programmes and research training strategy; – Research contract generation priorities; – Essential items of internal research organisation and infrastructure; – Research collaboration priorities; (…)" (p. 52). "Research and R&D expertise is of immediate importance, given the obligation on polytechnics to conduct research. (…) Clearly the development of a research paradigm for polytechnics is a pre-requisite of a focused staffing programme for research" (p. 92). "Polytechnics had differing starting points, but their growth in maturity has been clearly, and their profile is being greatly expanded. We refer to possible developmental trajectories for polytechnics. Here, too, further conceptualisation will be helpful" (p. 114).

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Chapter 7
Technical Universities in Germany: On Justification of the Higher Education and Research Markets

Christian Schneijderberg

7.1 Introduction

Technical universities (TUs) have a prominent position in the German higher education (HE) landscape. Among the 86 public universities in Germany, 15 bear the name, and 18 can be considered as TUs. Some of the TUs, such as the RWTH Aachen and TU München, are among the most renowned and prestigious universities in Germany. TUs hold a special position in Germany. Not only are there not that many, but they are considered to be of major importance for research and development. TUs are valued as source for educating future engineers, computer, and natural scientists for key industries in Germany and elsewhere (Powell and Dusdal 2017). TUs in Germany do not consider themselves as a coherent group. The big, research-intensive TUs (Aachen, Berlin, Braunschweig, Darmstadt, Dresden, Hannover, Karlsruhe, München and Stuttgart) form the so-called TU-9 Network (see Annex 1). Not included in this network are nine TUs (Chemnitz, Clausthal, Cottbus-Senftenberg, Dortmund, Freiberg, Hamburg, Ilmenau, Kaiserslautern, and Magdeburg). In addition to the vertical stratification among TUs, the big TUs in particular make considerable efforts to set themselves apart and establish their brand on the global higher education and research (HER) markets. Examples of this are the RWTH Aachen building a university in Oman, and the TU München's overseas campus (TUM Asia) in Singapore with its slogan "the entrepreneurial university."

Despite being considered a pillar in the higher education system and the production of scientific knowledge and technology in science, technology, engineering, and mathematical disciplines (STEM), there is surprisingly little literature about TUs in Germany. Among the few publications about TUs is a *Festschrift* for the 175th anniversary of the Karlsruhe Institute of Technology (KIT). The articles in the edited volume by Kunle and Fuchs (2000) examine the historical development of

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KIT as well as research and teaching in the different disciplines offered at KIT. Other publications use a TU as a case study for explaining the use of quality assurance for strategic management (Münch 2015), and deal with teaching, studying, and key competences transmitted at TUs and their meaning for the world of work (Robertson-von Trotha 2009). Historians address TUs more from a general technical sciences perspective (e.g., Augustine 2007; Hänseroth and Mauersberger 1998).

As no overview on TUs in Germany could be found, this chapter will present a general picture on research, teaching, and connected knowledge and technology transfer (KTT) of TUs in Germany. To draw a picture of the "form" (Thévenot 1984, 2001; see also Cloutier et al. 2017; Jagd 2011), i.e., the organization, of TUs in Germany, the overview will be based on publicly available information, such as laws, reports, websites, and official statistics. By looking at the situation of TUs *as it is,* both the stability of the TU-form and the dynamic challenges to the TU-form by the education and research market can be analyzed for the period 2000–2014. This research is guided by the research questions a) "How do publicly set performance indicators empirically construct the form of TUs?" And b) "How does market evolution of education and research products alter the civic-industrial conventions of coordination?" The underlying assumption is that a form, like TUs, is not just there but is continuously constructed by both the civic and industrial order of organizing around meaning, for example, by performance indicators addressing research and teaching. Referring to metrical indications, it is important to be very conscious about the relativism embedded in performance indicators (Boltanski and Thévenot 2006: 341; see also Desrosières 2000).

Both TUs as a form and statistical measures are theoretically and methodologically defined as belonging to the industrial world by Boltanski and Thévenot (2006), in the same way as private companies.[1] According to Boltanski and Thévenot (2006: 331), research and teaching are considered as public services that are a "compromise between the civic world and the industrial world." Measures, such as performance indicators, are justified "by a concern for the common good of the users" (Boltanski and Thévenot 2006: 331) and with the intention to increase work efficiency. However, the industrial indication of the TU-form conflicts with the public, civic mission of higher education in Germany. The civic form of TUs is constructed by the investment of tax money in the higher education system, for example, for academics, research and higher education infrastructure, and equal access to higher education for qualified citizens. The civic form is also present in the expression of research and higher education purposes in the German constitution, hiring principles secured by laws, and the special position granted to full professors as civil servants for life. Accordingly, this paper argues that the civic-industrial compromise as a composite compromise both generates inner tensions between the civic and

[1] The industrial idea seems not to be limited to forms like universities but also to the state as well: Crozier and Friedberg (1980: 141–142) define the French public administration system as "a machine for manufacturing exclusions and privileges – which creates discontentment and malaise; but it is also a distribution mechanism, which spreads its favors around in such a way as to keep complaints below the danger level."

industrial orders and constructs a rather solid fit of the "main conventions of coordination" (Thévenot 2001: 411). The methodological approach of orders of worth by Boltanski and Thévenot (2006) is rooted in political and social philosophy, making it a two-in-one analytical approach to analyzing complex social phenomena. The civic-industrial compromise highlights the advantages of using the orders of worth framework for the exploration of TUs, to systematically study and understand the stable and steady evolution of TUs over time. The analytical orders of worth approach supports the observation of the investments in forms of TUs in Germany by looking at the impact of evaluation, valuation, and valorization practices (Lamont 2012; Vatin 2013). Therefore, this chapter offers a contribution to the study of TUs, using the case of Germany, as well as a theoretical and methodological contribution to how to study TUs and public organizations, i.e., forms, in general.

The development of TUs in the past decades under the governance of numbers expressed in indicators are the focus of the empirical part of this study in Sect. 7.5. In Sect. 7.3 of this chapter, primarily numbers or statistics (industrial order measures) are used for a definition of TUs, which is supported by an analysis of the historical development of TUs in Germany. The idea for the use of data provided by the German Federal Statistical Office (GFSO) to defining TUs was triggered by the theoretical elaboration of the civic-industrial compromise (see Sect. 7.4). Both theoretical and empirical sections help to approach the higher education and research form of TUs based on a solid definition and in an analytically rigorous way. The analytical rigor is based on a theoretical extension of the analytical framework by the *situation as it is* in the next section.

7.2 Studying TUs as Investment in Forms via a Situation *as it is*

The socio-constructive[2] orders of worth framework by Boltanski and Thévenot (2006) is based on an explicit mutual dependency of method and theory. Both are not independent but combined in the qualification of subjects and objects during analysis, i.e., analysis and result(s) are not separate steps of the research process (Boltanski and Thévenot 2006: 1–3). Therefore, the analytical categories of each order of worth, and the compromising terms are regarded not just as identifiers, but also as results of analysis (Boltanski and Thévenot 2006: 3–5). The goal of an analysis is to "uncover the common requirements shared by all orders, and to account for a variety of modes of acting that may qualify for public legitimacy" (Thévenot et al. 2000: 239). Legitimacy is rooted in the social affirmation and co-construction of plural orders of worth. Therefore, reflective actors have to "recognize the nature of the situation and apply the appropriate principle[s] of justice" (Boltanski and Thévenot 2006: 146), which belong to one or more orders of worth. The orders of

[2] For a pragmatic interpretation see Diaz-Bone (2011, 2017).

worth are generated by Boltanski and Thévenot (2006), drawing from political philosophy: civic (Rousseau), domestic (Bossuet), industrial (Saint-Simon), inspiration (Augustine), market (Smith), and opinion (Hobbes).

Like for reflective individual actors, recognition of the nature of the situation appears to be just as important for a form/organization as a collective of reflective actors.[3] As already pointed out in the introduction, the following analysis of TUs will build on the approach to organizations as investments in form by Thévenot (1984). In an interview, Thévenot explains the core idea of investment in forms as follows: "Making entities more common […] requires a sacrifice of other potentialities of these entities. If you think of the economic view of investment, the sacrifice is nothing but a cost. If you go more deeply, it appears to be the sacrifice of the immediate market use of money. […]. When you invest, you sacrifice this possibility for another one. Which is future-oriented, and involves what we [Boltanski and Thévenot 2006] developed later in terms of the industrial worth" (Blokker and Brighenti 2011: 385). Thévenot's (1984: 1) notion of coding for the investment in forms applies to indicators-led setting "of conventions which govern "regulated" communications between people". The research and higher education indicators regulate communications between the state(s)[4] and TUs as collectives of actors, and, therefore, the individual members of the collective form quantify the qualitative nature of research and higher education services. The coding for evaluation and valorization becomes an expression of valuation (Espeland and Sauder 2007; Lamont 2012; Mau 2018; Vatin 2013). In the end, the indicator-led quantification also allows the construction of money-equivalents for research achievements, student through-put, gender quotas, etc. In this process, the industrial order works as a turning table: The industrial order transforms civic goals and services in calculable products and services. The social construction of higher education and research as marketable is a political and value oriented quantification of qualities, as "there is nothing natural about turning things into monetary equivalents" (Fourcade 2011: 1727).

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[3] In Boltanski and Thévenot's (2006) *On Justification*, organizations – however, not as forms – are referred to frequently throughout the book, but neither discussed as a "legitimate form of agreement" (Boltanski and Thévenot 2006: 39) as such nor how an organization is constructed and justified. The omission of organization and of organizations as institutions in the joint work by Boltanski and Thévenot (2006) can be explained by the irreconcilable differences of Boltanski's (2012) domination approach and Thévenot's (1984) approach to institutions and organizations as investments in form. The basic understanding of a form by Thévenot (1984, 2001) is similar to other organizational theorists (e.g., Crozier and Friedberg 1980; Powell and Di Maggio 1991; Scott 2014). As such, organizations as ordered forms of coordination can, therefore, be considered as "men build organizations to solve problems that are otherwise intractable" (Crozier and Friedberg 1980: 4).

[4] The spelling 'state(s)' is used to stress the mixed influences of the federal states and the federation on higher education and science politics. Since 2005, the federal states – and not anymore the federation – are responsible for the respective HEIs in their territory. However, indicators, several initiatives, such as the German Excellence Scheme, etc. are jointly funded by the states and the federation.

Prior to the theoretical discussion of TUs as forms in the analytical orders of worth framework in Sect. 7.4, it is necessary to define the situation as the unit of analysis for form analysis. Understanding TUs as a dynamic but stable industrial operation run by the state(s), allows for elaborating on the comprehension of a situation in respect of socially-constructed, institutionalized structures (Honneth 2010). The explicit reflection of institutionalized structures expressed in a situation *as it is* as unit of analysis enables the elaboration of a definition of TUs in Sect. 7.3.

7.2.1 Analysis of a Form as a Situation **as it is**

Contrary to situated critique and justification among individuals described in *On Justification* (Boltanski and Thévenot 2006: 1, 16), the situation of a form of a TU can be perceived from a different perspective. This perspective is based on the understanding of organizations as compromise, composite assemblage or arrangement from different orders (Boltanski and Thévenot 2006: 18). In a later publication, Thévenot (2001) is more specific about the definition of organizations as "form" (Thévenot 2001: 407) and goes on to write about "composite organizations as composite devices" (Thévenot 2001: 410). As a "generalization of coordination" the "investment in form is costly and demands negotiation and material equipment, but the cost may be offset by returns in coordination which depend on the extension of the domain of time and space within which it is accepted" (Thévenot 2001: 407).

For the empirical analysis of TUs in Germany the six orders as "moral and political artifacts" (Thévenot 2001: 410) are analytically differentiated according to a) means of justification *in* a situation and b) justification *by* a situation *as it is*. Common to the justification in time and space *in* a situation and justification *by* a situation *as it is* is the retrospective analysis of a situation based on the orders of worth framework. Contrary to justification *in* a situation, justification *by* a situation *as it is* focuses on forms.[5] The second difference is that evaluation and valorization resulting in valuation *by* a situation *as it is* constructs the dynamic in connecting two or more situations separated in time. Accordingly, the valuation picture generated by linking justification *by* a situation *as it is* observes the valuation dynamic and produces insights into the (possible) evolution of valuation practices. The third difference is that justification *by* a situation *as it is* considers only the expressions of valuation, for example, provided by indicators and (statistical) reports about the subjects and objects represented by these indicators. Therefore, justification *by* a situation *as it is* allows the study of the impact of valuation practices and not the process of evaluating and valorizing, which is the goal of the study of justification (and critique) *in* a situation. In spite of the quantitative example of indicators, also qualitative empirical material appears suitable for the study of valuation practices

[5] At least for the moment, justification by a situation *as it is* excludes justification (and critique) *in* a situation between individuals and between several individuals and forms.

over time. Independent of the methodological approach, justification *by* a situation *as it is* is about temporary socio-constructive agreements and it disregards the ubiquitous processes of critique and discard of valuation processes.

7.2.2 Data: Civic-Industrial Measures

Justification *by* a situation *as it is* adds the analytical option for studying investments in form as a composite compromise *of* agreement – in the presented case of civic and industrial order of worth agreement. The significance of public HER in Germany is expressed by the special status of professors as civil servants, and the security of academic freedom. In article 5, 3, 1 of the German constitution (*Grundgesetzt*), the state grants freedom of research and of teaching to individual academics. Like all public HEIs, TUs in Germany are public forms, for example, which are to a very large extent tax-funded and charge no tuition fees.

The ideal of 'equality' (civic order) is frequently challenged by issues of efficiency and productivity (industrial order). For the justification of a form *by* a situation *as it is,* the annual industrial measures taken are just statistical evidence of the steady stable evolution of (technical) universities in Germany. Accordingly, for an institutionalized social structure, like a (technical) university, situations of conflict and ongoing disputes such as those about performance indicators, do not usually overthrow an established form. Institutionalized structures and orders are only threatened in the case of radical changes. The analysis of the situation *as it is* as justification of TUs the "requirement of demonstrating proof" (Thévenot et al. 2000: 238) will be done based on an empirical evaluation of the situation of TUs as it is presented in winter 2017/2018. This methodological approach is purely industrial: a systematic comparison of statistical information provided by the GFSO according to performance indicators set by the state(s) (e.g., Bogumil and Heinze 2009). The GFSO offers a provision of information for ministries and politics, but statistics and reports are also available online to the general public. More detailed information about universities and TUs is available from 2006 onwards. As the latest differentiated information about personnel at universities, EF, etc., is available for 2014, the year 2007 was selected for comparison, and, when possible, also the year 2000 thus allowing for an overview of general trends. The pre-2000 GFSO data is even less differentiated. Due to the focus on the civic-industrial compromise other data sources are excluded, such as rankings and ratings which focus on selected products and follow a market order (e.g., Hazelkorn 2015).

To answer the research questions "a) How do publicly set performance indicators empirically construct the form of Tus?" And b) "How does market evolution of education and research products alter the civic-industrial conventions of coordination?", a selective approach is used to avoid writing a book. The focus of analysis will be on Germany, and the *inter*organizational (Lemieux 2014: 161–162) or *inter*formal comparison of TUs and of TUs and comprehensive universities. Furthermore, the analysis will differentiate between individual Tus, and TU9-members and non-members, and between the *inter*formal comparison of TUs and comprehensive public universities. The comparative focus includes the products and services of education and teaching, and the shares of TUs expressed, for example, in numbers of graduates and research EF.[6]

The study of the situation of TUs *as it is* is separated in two parts. The following section will elaborate and present a definition of TUs in Germany in the year 2018 showing that historically they have a strong connection with the civic-industrial compromise. Contrary to the definition of TUs as a situation *as it is* in 2018, the second part of the analysis focuses on the situation *as it is* in 2007 and in 2014, and, in case of data availability in 1994 and in 2000 to observe the impact of the civic-industrial compromise. The civic-industrial compromise is theoretically constructed in Sect. 7.4 and the relative stability and evolution of the civic-industrial compromise is empirically substantiated in Sect. 7.5.

7.3 Defining Technical Universities in Germany

TUs are a special type among doctoral granting universities in Germany. Due to the organization of HER across a broader set of disciplines, TUs have more in common with comprehensive public universities than with other specialized HEIs, such as Universities of Education. Indeed, the title *Technische Hochschule* (Technical Higher Education Institution) or *Technische Universität* (Technical University) is not protected by state(s) law or trademarked. All HEIs offering HER have to be recognized by the state(s), and this, for example, is expressed in the higher education laws of the German *Länder*. By law, TUs are treated just like any other public university in Germany, with few exceptions, such as the individual autonomy law for the TU Darmstadt (Hesse 2004).

Historically, universities in Germany are closely connected to the state(s) (Boehm and Müller 1983). In order to meet some practical requirements by the state(s), the foundation of TUs is connected to both industry and economic development. As a result, the foundation of some of the TUs is closely related to local mining and steel-producing industries, as in the *Bergakademie* Freiberg (translated as: The University of Resources)[7] and TU Clausthal (Boehm and Müller 1983: 96–97, 142–143). Other

[6] The analytical approach excludes from the analysis other types of HEIs in Germany (e.g., UAS) as well as public research institutes such as the Max-Planck Institute and the Fraunhofer Institute. These aforementioned research institutions receive a considerable share of public research and development funding (GFSO 2017b; see Annex 3). Also excluded from the analysis is the international dimension, which encompasses, for example, TUM Asia and international network activities, both on the organizational level (e.g., CESAER (see: http://www.cesaer.org/en/home/) and CLUSTER (see: http://cluster.org/)) and on the level of study programs (e.g., CDIO (see: http://www.cdio.org/)). In addition, the analysis of transfer products, such as patents and spin-offs, is also excluded. This is due to missing (public) data for the university level.

[7] See: http://tu-freiberg.de/en/university/profile (last accessed 2017/11/22).

TUs, including the University of Hannover in 1831 and the TU Darmstadt in 1836, were founded as “Higher Trade Schools” (*Höhere Gewerbeschule*).[8]

Additionally, the state(s), and the former royalties, are also key actors in the promotion of technical schools and colleges to the status of a university. In 1869, the *Höhere Gewerbeschule* Darmstadt was elevated to “Grand-Ducal Hessian Polytechnic School” to provide “full academic, as well as the necessary artistic training, for the technical profession, supported by appropriate practical exercises.” In 1877, the polytechnic was renamed as *Technische Hochschule zu Darmstadt* (Technical Higher Education Institution) and later renamed *Technische Universität Darmstadt* (Technical University) in 1997. The TU Darmstadt was granted the right to confer doctorates in 1899. The authorities played a crucial role for the TU Darmstadt and for Hannover: in 1879 the school became the “Royal College of Technology” (*Königliche Technische Hochschule*) and in 1899 Kaiser Wilhelm II granted it, like all TUs in Prussia, the right to confer the *Diplom* and doctorates (Buchheim and Sonnemann 1990: 231–232). This right to confer doctorates then elevated the status of the college to a status equivalent to that of a university.

But not all contemporary TUs have a bicentennial history. The TU Hamburg was founded in 1978 and was directly conferred university status as a result of the efforts of the city state of Hamburg. The BTU Cottbus-Senftenberg was a 2013 state-driven merger of the BTU Cottbus and University of Applied Sciences (UAS) Lausitz, which were both founded after German unification in 1991 (Brandenburg 2013). None of the 18 TUs identified in this section is located in the *Länder* Bremen, Mecklenburg-Vorpommern, Saarland, and Schleswig-Holstein.

In addition to historical development, a second seemingly obvious way to identify a TU is by name: RWTH Aachen, TU Berlin, TU Braunschweig, TU Chemnitz, TU Clausthal, TU Cottbus-Senftenberg, TU Darmstadt, TU Dresden, TU Freiberg, TU Hamburg, TU Ilmenau, TU Kaiserslautern, KIT, and TU München. The RWTH Aachen is the only TU that kept the name of a Technical HEI, although in English it is referred to as “RWTH Aachen University” (see Annex 1). However, four universities do not bear TU in their name: Dortmund, Hannover, Magdeburg, and Stuttgart. The universities of Hannover and Stuttgart are members of the TU9 Network of Leading Institutes of Technology in Germany (see Annex 2). Hannover presents a rare case of abandoning the TU name. Indeed, Hannover had the name TU for only a short period of time from 1968 – in that year the “College of Technology” became the Technical University – to 1978. In 1978, seemingly fond of name engineering, and after integrating the college of education, the TU Hannover became the University of Hannover and then the *Gottfried Wilhelm Leibniz Universität Hannover*, in 2006.[9] The latest case of name engineering was in 2018 with the TU Hamburg-Harburg becoming the TU Hamburg.

[8] This and all of the following references in this paragraph are also taken from: https://www.tu-darmstadt.de/universitaet/selbstverstaendnis/profil_geschichte/geschichtetu/thema_geschichte_k6.en.jsp (last accessed 2017/11/22).

[9] See: https://www.uni-hannover.de/en/universitaet/geschichte/stichworte/ (last accessed 2017/11/22).

Taking into account the third university not bearing the name TU, its historical development has to be considered in regarding it as a TU. The University of Magdeburg was founded in 1953 as *Hochschule für Schwermaschinenbau Magdeburg* (literal translation: HEI for construction of heavy equipment Magdeburg) and received the status of technical HEI in 1961. The technical HEI Magdeburg was awarded the status of a TU in 1987. In 1993, after German unification, the TU merged with the teacher training college and the Academy of Medicine, and renamed to Otto von Guericke University Magdeburg.[10]

The only recognized TU never to bear the name TU is the University of Dortmund. Nevertheless, the English version of the Dortmund university website refers to the institution as "TU Dortmund University".[11] Studies at the University of Dortmund began in 1969 with chemistry. Other STEM-fields were then introduced in the years that followed. Subsequently, economics and social sciences were added, beginning in 1973.[12] At present, the university also accentuates "a comprehensive program of teacher training for all types of schools."[13]

To follow-up on the lead of the disciplinary composition of TUs, the analysis of STEM-fields will be used as a third indicator for defining a TU. As already highlighted, there is no definite way of defining what is a TU and what is not a TU – neither by name and/or historical development. Accordingly, empirical, industrial indicators will be analyzed to look for further patterned characteristics as a way to define a TU.

As this section has shown, the name and/or historical development provide only approximations for identifying TUs. For both categories, too many exceptions exist. To illustrate this point further, four out of 18 institutions do not bear the name-*signum* of a TU. To look for further categories for defining a TU, the empirical evidence presented in Tables 7.1 and 7.2 will be analyzed in the following section.

7.3.1 Generation of Empirical Categories for Defining a Technical University

According to the disciplinary categories of the GFSO (2016a, b), the following discipline groups will be referred to as STEM-fields: mathematics and natural sciences (M&NS) (disciplines group 04), and engineering (disciplines group 08). Professors employed at TUs as civil servants represent a stable number for

[10] See: http://www.uni-magdeburg.de/Universit%C3%A4t/Im+Portrait/Historisches.html (last accessed 2017/11/22). In the English version the history is much shorter starting only in 1993 with the founding of Otto von Guericke University Magdeburg and omitting the past in the German Democratic Republic.

[11] See: https://www.tu-dortmund.de/uni/en/Home/index.html (last accessed 2017/11/22).

[12] See: https://www.tu-dortmund.de/uni/de/Uni/Zahlen__Daten__Fakten/Chronik/Gr__ndung_und_Aufbau/index.html (last accessed 2017/11/22).

[13] See: https://www.tu-dortmund.de/uni/en/Home/index.html (last accessed 2017/11/22).

Table 7.1 The form of public technical universities as compromise of the civic and industrial orders

	Industrial						
Civic	Productivity, efficiency	Competence, reliability, planning	Measurable: criteria, statistics	(Infra)structure, project, plan, technical object, method	Professional, expert (e.g. engineer)	Long-term planned future	Cartesian space
Collective interest	**Mode of evaluation** Universal education, meritocracy, innovation potential, economic growth						
Equality		**Test** Education, research, and KTT					
Formal, official			**Format of relevant proof** Tax funding, performance indicators (e.g. grants and students), accreditations and evaluations				
Rules, regulations, fundamental rights				**Qualified objects** Laws (e.g. equal access) university			
Citizens					**Qualified human beings** Academics, students (and their parents)		

Perennial						**Time formation** Present and future	
Detachment							**Space formation** Durable organizing

Table 7.2 Categories and expressions of worth of the civic-industrial compromise

Categories	Civic-industrial compromise
Mode of evaluation (worth)	Collective interest-oriented productivity and/or efficiency
Test	Equality-oriented competence, reliability, and/or planning
Form of relevant proof	Formally and/or officially defined measures (e.g. criteria and indicator led statistics)
Qualified objects	Rules and regulations led (infra)structure, methods, projects, planning, and/or technical objects
Qualified humans	Fundamental rights, respect and collective policies support by professionals and/or experts
Time formation	Perennial and long-term planned future
Space formation	Detached Cartesian Space

counting.[14] When comparing professorships, the number of professorships in engineering is considered a primary predictor with those in M&NS a secondary predictor. This is especially the case when looking at the outlier of TU Hamburg with only 9 professorships in M&NS (GFSO 2016a). Disregarding the outlier bearing the name TU, there is a mean average empirical proportion of no more than 1 to 1.6 (with a median average proportion of 1 to 1.3) of professorships in engineering or M&NS at TUs under the condition of the existence of no less than 37 engineering professorships at a university.

The description of commonalities and differences among TU9 (see Annex 4, Table 7.6) and non-TU9 universities (see Annex 4, Table 7.7) has to consider exceptions of defining characteristics. For example, all TU9 universities are bigger than non-TU9 universities according to the number of professors. The exception is the University of Dortmund with 302 professors. However, the University of Dortmund, as well as the University of Magdeburg, is not as specialized in STEM-fields as other non-TU9 universities bearing the name TU. The three largest TUs, RWTH Aachen (professors n = 488; academic staff n = 6056), TU Dresden (professors n = 558; academic staff n = 5198) and TU München (professors n = 483; academic staff n = 5996) account for about the same number of professors and almost twice as many academic staff as all non-TU9s together (professors n = 1481; academic staff n = 9237). RWTH Aachen and TU München were awarded the title of University of Excellence"[15] in the first and second round of the German Excellence Scheme; the TU Dresden was awarded that title in the second round. The title, awarded to the TU Dresden in the second round, was possibly in response to KIT

[14] At TUs in arts, humanities, and social sciences the average ratio is one professor to four academic staff, in M&NS the ratio is one to seven, in engineering one to ten, and in medicine and health one to seventeen. Altogether, in 2015, in HEIs in Germany only 19% of scientific staff are in the rank of a professor, in 1995 it were 25% (GFSO 2016a, b).

[15] See: https://www.wissenschaftsrat.de/en/fields-of-activity/excellence_initiative.html and http://www.dfg.de/en/research_funding/programmes/excellence_strategy/index.html (last accessed 2017/11/24).

dropping out. Additionally, it may have been in an effort to not to overly represent TUs in the Universities of Excellence scheme – with three out of eleven institutions being TUs.

Obviously, TUs have a clear STEM-field focus. However, TUs are not exclusively STEM-field forms. Professors in STEM-fields account for an average of 71% (both professors and academic staff) of the scientific staff at TUs. A certain number of professorships in social sciences (including economics and law) are to be found at all of the 18 TUs.[16] The proportion of professors in STEM-fields varies considerably by size of TUs. A further indicator of the number of professors in STEM-fields is if the TU is able to offer medicine and health subjects. At smaller TUs, the proportion of professors in STEM-fields is, on average, much higher. The TU Kaiserslautern, for example, has 86% of professors in STEM-fields, with 90% at the TU Clausthal, which is the smallest TU according to the total number of professors. Due to a comparatively large medical and health faculty at the RWTH Aachen, professors in STEM-fields only account for 61% of all professors. The ratio is also lower at TUs without the TU in the university name. At the University of Hannover, for example, academics in STEM-fields account for 62% of all faculty and for 57% at the University of Dortmund. Stuttgart remains an exception among the non-TU name bearing universities with 81% of all professors belonging to STEM-fields.

7.3.2 Definition of a Technical University in Germany

It is worth noting at this point, the special case of the University of Magdeburg in the sample. The University of Magdeburg appears to be the most conflicting case when deciding if it belongs to the special realm of TUs or not. Summing up on the seven characteristics identified for the definition of a TU the *situation as it is* in case of the University of Magdeburg is presented as follows:

1. Recognition by state(s): The University of Magdeburg is recognized as a public university by the law of the *Land* of Saxony-Anhalt (2010: § 1, 1, 2).
2. Name of a TU: The University of Magdeburg does not bear the name of a TU.
3. History as technical higher school and/or HEI before being recognized as a university: This characteristic applies for the University of Magdeburg.
4. Number of professorships with an engineering priority, i.e. minimum number of professorships in engineering: At the University of Magdeburg there are 52 professorships in M&NS, and 49 in engineering. Among the non-TU9 there are three TUs with fewer engineering professors: TU Clausthal (37), TU Freiberg

[16] The selection of the 18 TU cases is not without doubt or saying there could be other TUs in Germany. There is quite number of universities in Germany which are, according to number of academics, strong in M&NS but not in engineering or vice versa. For example, the University of Erlangen-Nürnberg has a rather large number of academics in both M&NS (professors n = 158; academic staff n = 1062), and engineering (professors n = 80; academic staff n = 899); nevertheless, academic personnel in MNS, and engineering accounts only for 41% of all academics.

(38), and TU Chemnitz (44). Referring to these three TUs, the minimum threshold of engineering professorships is approximately 40. As for all industrial measures, the number of professorships is subject to alteration. This applies to the empirically derived categories 4, 5, 6 and 7.

5. Proportion of professorships in engineering to professorships in M&NS: Referring to the number of professorships in characteristic 3, the proportion of professorships is 1 (in M&NS) to 1.1 (in engineering), and way above the average mean of 1 to 1.6 or the average median of 1 to 1.3 of professorships in M&NS to professorships in engineering or *vice versa*.
6. About 60% or more professors in STEM-fields at a HEI: The minimum threshold of approximately 60% of professors in STEM-fields is set by, for example, the University of Hannover (62%) and RWTH Aachen (61%). The sample of 18 TUs, highlight the TU percentage of STEM-field professorships would be an average of 71% and above. At the University of Magdeburg, only 47% of the total number of professorships belongs to STEM-fields. Weighing up the medical and health fields, i.e., not counting the medical faculty and the ratio of professors in M&NS, engineering rises from 47% to 57%. This is the same proportion found at the University of Dortmund, which, unlike the University of Magdeburg does not have medical and health faculty. The importance of STEM-fields in research and education provides a much broader offer than the name TU suggests by, referring only to technical scientific fields.
7. Professorships in social sciences (including economics and law): The University of Magdeburg has 31 professorships in social sciences. The biggest number of social science professorships is found at the TU Dresden (n = 63) and the least at TU Clausthal (n = 8).

There is a strong likelihood that more and possibly better characteristics for identifying TUs will be found in the future. Projecting the seven characteristics on to the University of Magdeburg shows that a single characteristic is not enough, but rather a number of characteristics have to be considered for defining a TU. According to the empirical evidence, of the seven characteristics, two in particular seem to be not mandatory for defining a TU: Characteristic 1 the name of a TU, as shown by the exceptions of the universities in Dortmund, Hannover, Magdeburg, and Stuttgart; and characteristic 2 a history as technical higher school and/or HEI before being recognized as a university as, for example, in the cases of the BTU Cottbus-Senftenberg and TU Hamburg show.

In addition to the explicit exceptions to characteristics 1 and 2, the empirically generated characteristics are challenging. Among the seven identified characteristics, in particular, the numerical characteristics 3 (number of professorships with engineering priority), 4 (proportion of professorships in M&NS to professorships in engineering), and 5 (approximately 60% or more professors in STEM-fields at a HEI) have to be treated with care. However, looking at statistics alone, it may be an opportunity to improve the characteristics for the definition of TUs. For example, raising the number of professorships with an engineering priority (characteristic 3) would be particularly relevant to the traditional, but small TUs specialized in

STEM-fields, such as Clausthal and Freiberg. The STEM-field commonalities of TUs defined by characteristics 3, 4, and 5 have to be amended by the only other indisputable joint feature: all TUs have professorships in social sciences (characteristic 6).

The elaborate definition of a TU in Germany is also a justification for the sample of 18 TUs used in this chapter. The definition of TUs is the first element of the form of TUs. To answer the research question on the influence of the civic-industrial compromise on the form of TUs in Germany, the second element, i.e., the civic-industrial compromise will be empirically generated based on the compromise of the civic and industrial orders.

7.4 TUs and the Civic-Industrial Compromise

7.4.1 Theoretical Generation of the Civic-Industrial Compromise

"A compromise suggests the possibility of a principle that can take judgments based on objects stemming from different worlds [or orders] and make them compatible. It aims at a common good that transcends the two different forms [or orders] of worth in presence by including both of them: promoting 'techniques of creativity'." (Boltanski and Thévenot 2006: 278).

The "bridges" (Thévenot 2001: 412) between the industrial and civic orders are built based on all TUs in Germany being public forms. To generate the civic-industrial compromise, a categorical matrix is created (see Table 7.1). Focusing on the categories in the diagonal of the matrix, the core words of the civic and industrial grammars of worth are used to identify core elements (Boltanski and Thévenot 1999: 241). In the box 'mode of evaluation', the industrial worth of productivity and of efficiency finds a compromise with the civic worth of collective welfare by balancing the striving for innovation and economic growth and potential universal access to TUs for those qualified. TUs are supposed to respect the civic ideal of equality when their competences and reliability is put to the test in the delivery of the education and research services. With HER being a public good in Germany, the 'form of relevant proof' can be defined with the measurable amount of tax money spent on HER and the formal, equal definition of research indicators, such as grants and EF. The qualified objects of the civic-industrial compromise are the form of the TU as such, and laws defining access to studies respecting equal citizens' rights, general rules for hiring academics, etc. Laws in particular also define the expertise required from academics as professionals doing research and teaching in TUs, and potential students as qualified human beings to attend a TU.

According to the seven categories explained by Thévenot et al. (2000: 241), the compatibility of the civic and industrial orders is most obvious in the 'time' and 'space formation'. Both the civic and the industrial order for example, have a 'long term', durable approach to build 'infrastructures', 'invest' in staff and machinery, organize the operation of research and teaching, etc. Whereas, for example 'equality, is a permanent goal of the civic order, the long-term perspective of the industrial order is expressed in its aim to keep subjects ('qualified human beings') and objects working, and the 'proof' that both do is "grounded in a temporal regularity, the methodic repetition of measurement" (Boltanski and Thévenot 2006: 211).

As the civic-industrial compromise is defined as a composite compromise, i.e. an achievement of boundary work (Lamont 2012), it is considered similar to the composite situation of the "competitive public service" (Boltanski and Thévenot 2006: 278)[17], for further analysis the civic-industrial compromise is combined according to the categories presented in Table 7.2.

Generally, the civic-industrial compromise shows a good mediating fit in all categories. The categories-led composition of the civic-industrial compromise is not without obvious friction. An example of this friction is academic professionals and/or other TU/university experts (industrial order) being required to act, at least, as much as in their civic and as in their domestic capacity, i.e., with respect to 'fundamental rights respect and support of collective policies'. The composite fit of the civic-industrial compromise appears to be much less conflict loaded than, for example, compromises of the civic and market order (e.g., in category 'qualified human beings': 'equal citizens' vs. 'customers and consumers') or compromises of the industrial and market order (e.g., in category 'qualified objects': 'infrastructure' vs. 'freely circulating goods and services'). In addition, compared to the 'short-term and flexibility goals' of the market order (Thévenot et al. 2000: 241) the composite fit of the civic-industrial compromise appears to be much less conflict loaded in the category 'time formation'.

The compromise of the civic and industrial order of TUs bridges certain conflicts by adopting them. For example, based on the NPM-"doctrine" (Power 1999: 93), the idea of 'equality' (civic order) are part of the 'efficiency and productivity measures' evaluated via audits and performance indicators (industrial order), such as number of female and international students. As a theoretical consequence, the potential of conflicting situations of the civic and industrial order with other orders is altered. The different nature of compromises by the civic and industrial order with other orders will be explained by focusing on challenges by the market order (products of research and teaching). As part of the civic-industrial compromise, the industrial order becomes part of the evaluation – of both 'test' and 'form of relevant proof' – of competitive public services offered by TUs, which Boltanski and Thévenot (2006) defined as a compromise of the civic and market order.

[17] Boltanski and Thévenot (2006) define the competitive public service as a compromise of the public service (civic order) and competition (market order).

7.4.2 Research and Teaching as Products (Market Order) from the Perspective of the Civic-Industrial Compromise

The long-term and durable operations of TUs according to the civic-industrial compromise are continuously scrutinized regarding the cost (mode of evaluation) of its products by the market order. As Thévenot (2001: 416) acknowledges, the detachment of goods from people – and the domestic order – is particularly difficult in the case of the marketable goods being services, such as offering research expertise in KTT and teaching students. In Germany, the market competitiveness ('test') of degrees and study programs of TUs is measured rather indirectly, for example, money ('relevant proof') spent per student per degree and average duration of studies. The latter is a perfect example of an ideal short-term ('time formation') market-related compromise by the civic-industrial compromise.

Education and research are considered the products of a "so-called Fordian or mass production system" (Boltanski and Thévenot 2006: 333). In face of the NPM-doctrine, the civic 'mode of evaluation', 'collective interest' and 'test' of 'equality' are frequently challenged by industrial order expressions of 'efficiency and productivity' and 'reliability and planning'. This challenge is softened by the uncompromising 'mode of evaluation' ('collective interest-oriented productivity and/or efficiency') 'test' ('equality-oriented reliability and planning') of the civic-industrial compromise. But the quality image based on comparisons of numerical differences of performance indicators (Espeland and Sauder 2007; Heintz 2016), such as student intake and graduates, acquisition of competitive EF, TUs supported by German Excellence Scheme are not only market references intended to influence the (public) opinion order. The (growing) influence of the market order on the civic-industrial compromise is very much present in the entire public accountability of the political economics of public HER offered by TUs, and universities in general.

7.5 The Civic-Industrial Compromise and the Form of Technical Universities in Germany

7.5.1 On Justification of Higher Education

Going industrial on German HER and TUs, i.e., analyzing the statistics available on expenditures on research and teaching, EF generated, etc., means a reduction of complexity and expression of worth in numbers. Boltanski and Thévenot (2006: 43) define money as being a universal numbers reference used for abstraction in a market-based polity: "money is the measure of all things, and thus constitutes the form of evidence" (Boltanski and Thévenot 2006: 202). Money represents only a very coarse point of reference for the civic engagement in public HER (market 'form of relevant proof'). More differentiated, market-oriented indication according to the civic-industrial compromise is provided by looking at the products of higher education, i.e., diploma, teachers/state, bachelor and master exams. The presented measures appear to be referencing the defined teaching load of professors and academic staff aiming for collective interest productivity (see Table 7.2). The rising investment of the state(s) in higher education to assuring its ‘perennial and long term future’ (‘time formation’) match the rising cost of higher education products.

The political economy of higher education is very present when looking at the indicators of average duration of studies and tax money spent per degree. Comparing the years 2007 and 2014, the average duration of studies is rather stable (GFSO 2008, 2015; see Annex 5). The relative stability of the duration of studies makes the increase of tax money spent even more noticeable. Most striking are the increases in humanities and social sciences, and the comparably moderate increases of costs of engineering degrees.

TUs are, in general, urged by the *Länder* to use tax money efficiently (‘mode of evaluation’), in the same way as other public universities. A further indicator used for TUs is student drop-out rates. Drop-out rates, i.e., university bachelor students not continuing to study a subject for multiple reasons, have been reduced in engineering: of students starting in the winter term of 2006/2007 almost half (48%) dropped-out; this figure reduced to 36% of those starting in the winter term of 2008/2009 and then dropped to 32% of the freshmen starting in winter term 2010/2011. For the same years, in M&NS the drop-out rates were stable at 39%, which is quite above the average among university bachelors (35%, 33%, and 32%) (Heublein et al. 2017: 264). Drop-out rates from master programs are much smaller and further decreasing in engineering from 12% of beginners in 2010 to 4% in 2012. For students starting a master program in M&NS, in the same 2 years, the drop-out rate increased from 5% to 10%, which is still below average of the overall master students’ drop out of 11% (2010) and 15% (2012) (Heublein et al. 2017: 268).

An industrial number just as relevant for the civic-industrial compromise as well as the market order is the number of TU graduates (see Table 7.3). From 1994 to 2015, the number of graduates at TUs increased by 138%, whereas the number of graduates at all 76 comprehensive public universities about doubled (from 138,336 to 287,469).

The civic-industrial compromise also pays attention to citizens’ equal access of qualified humans and competence development in higher education. Defined indicators are, for example, the number of students and freshmen, and the respective

Table 7.3 Graduates in study fields present at all TUs, including percentage of graduates in STEM-fields of total, in 1994, 2000, 2007, 2014, and 2015

	1994	2000	2007	2014	2015
Engineering	13,792	11,074	11,591	30,416	33,628
Mathematics and natural sciences	7601	6066	8843	15,069	15,622
Social sciences (incl. Economics and law)	3025	4258	6262	10,002	10,077
Total	29,797	27,414	34,804	67,003	71,026
% STEM-fields of total	72	63	59	68	69

Source: GFSO (2018a)

percentages of female and male students (GFSO 2017a; see Annex 6). Among the 86 public universities[18], about 22% of all students study at TUs. At TUs, female students are still underrepresented with an average of 36% (compared to 51% at all public universities). The percentage of females is even lower among international students at TUs (market 'space formation': 'global'). Altogether, the percentage of international students is a slightly higher than at other public universities (18% to 14%).

7.5.2 On Justification of Increasing Civic/State(s) Spending on Academics Positions

Effects of the civic-industrial compromise as reactions to market competitiveness ('test'), and the 'short-term', 'flexible investments', especially of private EF in public HER, are visible when observing numbers of academics and the funding sources of positions. EF from business and industry has become less important for the funding of primarily temporary positions for academic staff (GFSO 2009, 2016b; see Annex 7). Comparing the years 2007 and 2014, the proportion of academic staff funded by EF from business and industry declined from 28% (n = 35.152) to 7% (n = 12.915). Unfortunately, no data is available for public comprehensive universities and TUs only.

In between 2007 and 2014 the number of academic staff employed in HEIs on public EF increased by more than 500%. The increase of academic staff numbers in temporary positions is primarily due to the larger amount of civic competitive EF in 2014 compared to 2007. This increase of civic competitive EF can be interpreted as being influenced by the market order referring to competitive public services. For the time being, the sustainability of growing EF, for example distributed via the Excellence Scheme, cannot be evaluated. In the civic-industrial compromise, this could mean a loss of capacity with a long-term planning perspective, which is fundamental for the industrial order (Boltanski and Thévenot 1999: 372–373). However, the overall increase of (temporary) positions both for professors and academic staff is mainly due to civic/basic funding by the state(s). The increase of civic/state(s) funding for academic positions can be interpreted as affirming the commitment to public HER and its contribution to "collective interest productivity" ('mode of evaluation'). At the same time, the civic-industrial compromise controls "costs" (market 'mode of evaluation') by substantially increasing non-permanent positions for academic staff (from 9% to 32%), possibly inspired by the NPM-doctrine.

The industrial numbers game also provides a detailed account of the increasing civic expenditure on HER per student, per academic staff, and per professor (GFSO 2008, 2015; see Annex 8). In the STEM-fields, the expenditure per academic staff and per professor has roughly doubled from 2000 to 2014. Looking at the

[18] Classification 13 and 14 of the GFSO.

expenditure per student in engineering, the amount in 2000 and 2014 are at the same level with a temporary high in 2007. Unlike engineering, expenditures per student in M&NS show a steady increase of costs for the same period. Altogether, expenditures on STEM-fields per student, per academic staff, and per professor are not the highest at universities, this would be in medicine and health fields, but is considerably higher than in humanities and social sciences.

The empirical evidence brings forth the conflicts of the civic-industrial compromise caused by the market order. This shows that the particularity of another order, in this case the market, is both challenging the compromise of the civic and industrial order and contributing to the dynamic boundary work in a compromise of two orders. The contribution and, to a certain extent, the dominance of one order within the civic-industrial compromise, will be theoretically and empirically further carved out in the following section. The background of the discussion of the justification of research is the national market evaluating the competitive public service of research and the global market valuing research excellence reported via bibliometric indictors (Butler 2010).

7.5.3 Justification of Research in TUs

While expenditures in HER are increasing, also the amount of EF per academic staff and per professor is increasing. On average, from 2000 to 2014, the amount of EF roughly tripled for each non-professorial academic staff member (henceforth academic staff member) and for professors. The proportion of basic funding and EF in STEM-fields has increased from 2007 to 2014. On average, in 2014, academics in engineering can conduct research with an additional 79 cents for every Euro of civic/basic funding, and in M&NS with 52 cents for every Euro of civic/basic funding. Compared to academics in humanities and social sciences, the additional money for research in M&NS is twice as much, and in engineering, even three times as much. Of course, some of that more EF money might be due to the higher costs of materials and machinery in engineering and M&NS. Nevertheless, looking at public expenditures for research and innovation, the proportion of money spent on academic personnel is about the same in M&NS and engineering compared, for example, to social sciences. The major difference is the much higher amounts of money invested in engineering and M&NS, which accounts for 63% (in 2007) and 62% (in 2014) of the tax money spent (GFSO 2017b; see Annex 9). Indeed, more civic money in the pot for engineering and M&NS is, firstly, a competitive advantage for STEM-fields research and secondly for TUs with the STEM-fields focus (see Sect. 7.3.2).

The competitive advantage of TUs in acquiring research EF can be further differentiated by analyzing the size of forms. To do so, the sample of 76 universities was divided into three groups based on the number of professors: small universities with up to 200 professors (n = 23, including 4 TUs; TUs = 17%), medium universities with 201–400 professors (n = 31, including 11 TUs; TUs = 35%), and large universities with more than 401 professors (n = 22, including 3 TUs; TUs = 14%). Compared to 2014 (GFSO 2018b; see Annex 10, Table 7.9), the results presented for the year 2007 (see Annex 10, Table 7.8) are pre Excellence Scheme time. Among disciplines, the amount of EF and income generated in medicine, especially by hospitals attached to universities, varies considerably from other disciplines (see Annex 8). To present a more coherent picture regarding sources and amounts of EF, medicine and hospitals will be excluded from further analysis of EF.

Altogether, in 2007, the percentage of private EF (e.g., business and industry, and foundations) accounts for about one third of all EF. The proportion does not vary greatly for either of the years with reference to size of universities: large universities = 29%; medium universities = 31%; and small universities = 34%). In comparison to 2007, in 2014 this percentage decreases to about one quarter (large universities = 24%; medium universities = 23%; and small universities = 24%). Despite the increase in EF, the proportion of money from private business and industry decreases substantially from 2007 to 2014: At large universities from 23% to 16%, at medium universities from 24% to 17%, and at small universities from 21% to 17%.

The proportional decrease of EF by private sources is mainly due to the substantial increase of EF spending by the civic order. Most striking, is the increase of money spent by the federation and civic EF distributed by the DFG. As in from private sources, EF by the federation and DFG, increased substantially in amounts of Euros. Nevertheless, unlike EF from private sources, particularly EF distributed via the DFG, did not decrease in proportion of the total amount. At large universities, DFG EF accounted for 42% of EF in 2007 and 43% of EF in 2014, at medium universities for 34% and 35% of EF, and at small universities for 28% and 24% of EF. The relative stability of the percentage of DFG EF indicates a shift in spending EF most obviously with funding long-term strategies of universities in the Universities of Excellence Scheme.

These amounts present a substantial increase of the EF total comparing the years 2007 and 2014. Despite the actual increase of EF, the percentage of EF from business and industry is smaller in 2014 compared to 2007. Particularly for medium sized TUs, the proportion of the total dropped from 29% to 19%. This percentage drop for medium TUs is mainly due to increasing amounts of EF acquired from the federation and DFG. Of the DFG EF total, the proportion of EF acquired from the Excellence Scheme is comparably small. The Excellence Scheme seems to favor large TUs (9% of EF total) compared to medium sized TUs (only 3% of EF total and small TUs 0%). A size effect in the distribution of DFG total EF can also be observed comparing TU9 members and non-TU9 members. TU9 members also seem to be the favorite recipients of EF from business and industry, both in 2007 and 2014.

Comparing the three groups of TUs, the main funding sources of federal funding, of DFG, of business and industry are of differing importance. Compared to a big TU, in 2007 and 2014, the percentage of EF from the federation is twice as high and accounts for two fifths of total EF. Conversely, DFG EF accounts for almost one third of total EF of large TUs and only one tenth at small TUs in 2014. This is a drastic reduction in comparison to 2007, when DFG EF accounted almost for one fourth of all EF (see Table 7.4).

Compared to comprehensive universities, and with very few exceptions, TUs are significantly above average in acquiring research EF in total, and in receiving funding from the main EF sources, i.e. the federation, DFG, and business and industry (see Annex 9). The competition among TUs and comprehensive universities seems fiercest for medium sized forms: the 11 (out of 31) TUs do acquire almost twice as much EF as small (4 out of 23) and large (3 out of 22) TUs. Best equipped for the competition with TUs appear to be large comprehensive universities. In addition to the large amount of tax money spent on STEM-fields research, TUs have a competitive advantage in acquiring EF from business and industry compared to comprehensive universities.

Comparing TU9 and non-TU9 members shows that the size of the institution correlates with amounts of EF (with the exception of one TU9 member). Size effects can also be observed by looking at research excellence money: of the 43 research clusters funded by the Excellence Scheme in 2006/2007 and 2012, ten are at TU9 forms, and only one at the TU Chemnitz. The apparent cascade of competitive advantage of TUs is again supported by the primacy of STEM-fields. Of the 43 clusters, nine from engineering, eleven from natural sciences, 17 from life sciences and only six from humanities and social sciences.[19]

7.6 Conclusion

For TUs benefiting disproportionally high from main sources of EF, several explanations and interpretations can be sought, such as being well known (Boltanski and Thévenot 2006: 178ff.; Leahey 2007). The EF money measure cannot be considered as an exclusive sign for (high) quality of research (Laudel 2006), but is also subject to the “Matthew Effect” (Merton 1968) both at the level of the individual scientist, as well as forms. This is a psycho-sociological diagnosis of the workings of science as a social institution. Aiming to foster economic growth via research EF, the civic order represented by the federation in Table 7.4 obviously supports TUs more than comprehensive universities. The focus on STEM-fields seems to be in the ‘perennial and long-term interest’ (‘time formation’) of civic-industrial compromise, aiming for ‘collective interest productivity and efficiency’ (‘mode of evaluation’), to assure ‘equality-oriented reliability and planning’ (‘test’), and to ‘fundamental rights respecting’ and (economic) interest policies supported by ‘(STEM-)professionals’ and ‘(STEM-)experts’ (‘qualified human beings’). The states’ favorable evaluation of the form of TUs seems to be shared by providers of EF from business and industry.

[19] See: http://www.dfg.de/gefoerderte_projekte/programme_und_projekte/listen/index.jsp?id=EXC (last accessed 2017/12/15).

Table 7.4 Disproportionally high share of TUs of main sources of EF and EF in general in 2007 and 2014

	Year	Business and industry	DFG total	Federation	total
Small TUs (share = 17%)	2007	51%	32%	36%	36%
	2014	55%	15%	37%	37%
Medium TUs (share = 35%)	2007	61%	44%	51%	55%
	2014	57%	45%	51%	57%
Large TUs (share = 14%)	2007	40%	22%	29%	29%
	2014	52%	19%	29%	29%

Source: GFSO (2018b)

The indicator-led TU/university external evaluation has a rather different meaning for the form and its academic professionals public research and education services. Answering research question b) "How does market evolution of education and research products alter the civic-industrial conventions of coordination?", the results show how the qualitative to quantitative transformation mechanism of public research and education services is similar to the artificiality of turning damage in nature into money equivalents (Fourcade 2011). However unnatural the turning of things, such as research and higher education into money or indicator equivalents is, it is processing evaluation to valuation. Referring to Simmel, Fourcade (2011: 1728) underscores that "the relationship between subjective and objectified value is not unidirectional but dialectical." Therefore, especially the award of EF stimulates the exchange process of tuning the object "into something highly personal and therefore magnify the value we attach to this object" (Fourcade 2011: 1728). This impact of indicators on individual academics is a pressing research issue (Rijcke et al. 2016). Contrary to the personal reward of EF for individual academics, rising student numbers, student through-put, student drop-out, and other higher education defining indicators turn things – who are actually qualified human beings – and magnify the value indicators attach to this object primarily for the form of TUs and universities in general. Accordingly, the analysis shows that criteria-led standardization measures of evaluation as social constructs of accounting techniques "gain authority in particular social contexts and only make sense in relation to the systems of expertise, social relations, and cultural narratives prevalent in these contexts" (Fourcade 2011: 1728).

The dynamism of social relations and cultural narratives was also observed in the construction of characteristics for defining a TU, which cannot be done by name alone (characteristic 3). TUs have a history as technical higher schools and/or HEIs with reference to trading, mining, heavy industry, etc. (characteristic 2) before being recognized as a university (characteristic 1). In 2017, TUs have a strong focus on engineering, hosting a minimum of 40 professorships in engineering (characteristic 4). More empirically generated parameters are a certain proportion of professorships in engineering to professorships in M&NS (characteristic 5), the dominance of professors in STEM-fields with about 60% at a TU (characteristic 6), and that all TUs have professorships in social sciences (including economics and law) (characteristic 7). Characteristics 4 to 7 present the outcome sought with research question “a) How do publicly set performance indicators empirically construct the form of TUs?”

The seven characteristics present a picture of the construction of the form of TUs as a mix of historical facts, naming, and publicly set industrial justifications, i.e., performance indicators. The performance indicators set by the civic-industrial compromise co-construct what a TU in Germany is and reassure its competitive advantage, which is closely linked to the focus on STEM-Fields of TUs. The empirical evidence provided in this chapter demonstrates that the form presented as TUs in Germany generally do well on the HER markets – and TU9 members do even better – in respect of the civic-industrial compromise. This is particularly visible when looking at the disproportional share of public and private EF accumulated at TUs compared to other comprehensive universities (see Table 7.4). TUs also benefit from the increase in professorships and increased civic/state(s) funding of academic staff in STEM-fields, and the relatively stable cost per student in STEM-fields. Of course, these empirical trends only hold true for the analyzed period from (1994 to 2000 to) 2007 to 2014. The knowledge embedded in the interplay of performance indicators and statistics can be regarded as co-constitutive for the legitimacy of the governance of HER. Generally, research literature about Germany provides very little account for judging the legitimacy of performance indicators among academics and HEIs (Orr et al. 2007; Sieweke et al. 2014). However, as shown in this chapter, HEIs (have to) play along and the legitimacy of performance indicator use for HER governance by the state(s) is well covered by the NPM-“doctrine” (Power 1999: 93). The outcomes of the use of performance indicators, such as increasing competition and stratification among universities in Germany, already became visible in analyses of the first round of the Excellence Scheme (e.g., Hartmann 2010; Kehm 2013).

To sum up, the indicators specify the investments in the form of TUs (and other HEIs) as a governance tool. Indicators disclose certain characteristics of research and higher education and support as codes the regulated communication between people and forms. The indications address specific inputs in and outcomes of research and higher education activities, which over the course of time sacrifice other potentialities of research and higher education. According to Thévenot (1984), the sacrifice of other potentialities is also a governance mean to control costs of research and higher education – possibly at cost of research and higher education and university ideals (e.g., Münch 2013; Schimank and Winnes 2000).

The methodological and theoretical focus on the civic-industrial compromise as core for analyzing the *inter*formal level being challenged by the particularity of the market order was an empirical test of a “way of solidifying a compromise” (Boltanski and Thévenot 2006: 278). The civic-industrial compromise in form of a TU is based on “objects composed of elements stemming from different worlds [or orders] at the service of the common good and endowing them with their own identity in such a way that their form will no longer be recognizable if one of the disparate elements of which they are formed is removed. Transformed in this way, the compromise is more resistant to critiques, because it now relies on indivisible objects” (Boltanski and Thévenot 2006: 278). As shown in this article, such an indivisible object is the form of a TU based on the civic-industrial compromise. For the competitive public services of HER provided by TUs, the compromise between the higher common principles of the civic-industrial compromise ('organized public service') and the market order ('competition') is enforced.

As empirically shown, with focus on research and higher education this represents the *situation as it is* organized in the form of TUs. The analytical benefit of the differentiation of a) means of justification *in* a situation and b) *by* a situation *as it is,* lays in the additional option of the theoretically guided analysis of justification with reference to orders of worth. This results in a two-step analytical process making the analysis of moral and political justification in a polity very explicit by identifying the modes of coordination. Admittedly, this analytical approach takes much of the dynamics of justification *in* a situation (Boltanski and Thévenot 2006: 1). However, looking at historical developments and empirical trends, the somehow static situation *as it is* also presents a dependency of dynamic characteristics from one static moment in time to another to comprehend and explain the construction of a social reality (Berger and Luckmann 1967) and its conventions of coordination.

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Annexes

Annex 1: TU9 – Excellence in Engineering and the Natural Sciences – Made in Germany

TU9 President Prof. Dr. Hans Jürgen Prömel:

> Technical Universities are drivers of economic growth and they secure employment

TU9 is the alliance of leading Institutes of Technology in Germany: RWTH Aachen University, TU Berlin, TU Braunschweig, TU Darmstadt, TU Dresden, Leibniz Universität Hannover, Karlsruhe Institute of Technology, TU München, University of Stuttgart.

The TU9 Universities are excellent in research: According to the Federal Statistical Office, TU9 members attract a fourth of all third-party funding. In the DFG ranking for research funding in engineering, the TU9 Universities are to be found in the top groups. Nationwide 57% of all doctorates in engineering are awarded at TU9 Universities.

Furthermore, TU9 Universities were very successful in the German government's Excellence Initiative. RWTH Aachen University (2012, 2007), TU Dresden (2012), Universität Karlsruhe (TH) (now Karlsruhe Institute of Technology, 2006) and TU München (2012, 2007) were awarded the status of "University of Excellence".

TU9 Universities lead the way in teaching: In Germany 51% of all engineers with a university degree come from TU9 Universities. Ten percent of all students at German universities are registered at TU9 Universities.

TU9 Universities are international: 15% of the students at TU9 Universities are international students. In addition to that, the Humboldt Foundation's ranking demonstrates how attractive the TU9 Universities are to international scientists.

Further USPs [unique selling points] of TU9

[are not displayed as the further USP are available only in German]

Source: http://www.tu9.de/en/index.php (last accessed 2017/11/22)

Annex 2: Mission Statement by Nine Leading Institutes of Technology in Germany

All of the TU9 universities have a long tradition to look back on and enjoy an excellent reputation among universities at home and abroad. Founded in the age of industrialisation, they have played a significant part in the development of engineering science ever since. Their scientific potential, range of courses and student numbers have grown continuously over a period of almost 200 years. This common ground forms the basis of their cooperation in the university association TU9.

Of paramount importance to TU9 is the promotion of science and research in engineering and natural science.

TU9 fulfils this aim by:

- strategically coordinating and positioning scientific development at technical universities in Germany,
- staging scientific events,
- supporting young scientists and students,
- cooperating with the federal states of the respective universities, scientific organisations and organisations promoting science,

- cooperating with the State Rectors' Conferences and the German Rectors' Conference (HRK),
- cooperating with industry and business to promote and maintain Germany's international pre-eminence in technology,
- formulating university and educational policies and communicating them,
- cooperating with foreign universities and taking care of scientists visiting German technical universities.

TU9 is especially committed to furthering a positive attitude to technology in society at large.

TU9 is currently focussing on the following topics:

- Quality assurance and accreditation
- Doctorates in engineering
- Funding research and teaching
- Admission of national and international university applicants
- Structural development
- Transition to bachelor/master
- Cooperation with external research centres
- Standardised German tests for international university applicants
- Human resources development
- International matters

The TU9 members co-ordinate their activities

- when cooperating with national, European and other international organisations
- in international marketing
- in offshore projects, in the form of university start-up ventures or the export of study programmes and structures
- in quality assurance, with great value being placed on the international relevance of quality assurance programmes
- in benchmarking

Source: http://www.tu9.de/tu9/en/1473.php (last accessed 2017/11/22).

Annex 3: Public Expenditures on Research and Innovation (Table 7.5)

Table 7.5 Internal Expenditures of scientific organizations of the public sector in 2015 according to groups of organizations and type of organizations

	2002	2007	2014	2015
	1000 Euro			
Public Organizations for Sciences, Research, and Development	2,003,384	2,409,488	3,178,352	3,076,322
Federal Research Organizations	1,527,409	1,850,540	2,701,816	2,581,892
State- and communal Research Organizations (excluding Leibniz-Society)	475,975	558,948	476,536	494,430
Joint Federation and State sponsored Organizations for Sciences, Research, and Development	5,551,844	6,536,156	9,620,454	9,760,259
Helmholtz-Centers	2,356,756	2,739,532	4,127,556	4,190,320
Institutes of Max-Planck-Society	1,132,057	1,289,897	1,821,279	1,831,231
Institutes of Fraunhofer-Society	1,046,878	1,319,326	2,060,313	2,084,769
Leibniz-Society (“Blue List”)	937,214	1,107,429	1,507,430	1,546,713
Academies (ac. to academy programm)	78,939	79,972	103,876	107,226
Other Publicly supported not for profit Organizations for Sciences, Research, and Development	1,067,391	1,142,272	1,374,108	1,520,133
Scientific Libraries and Museums (excluding Leibniz-Society)	808,074	937,085	1,129,342	1,189,894
Organizations for Sciences, Research, and Development total	**9,430,693**	**11,025,001**	**15,302,256**	**15,546,608**
Among these: Institutes at Higher Education Institutions	448,038	537,727	732,249	758,062

Source GFSO (2017b)

Annex 4: Academics (Professors and Academic Staff) According to Disciplines

For the empirical display in tables, the 18 TUs are separated by TU9 members (see Table 7.6) and non-TU9 members (see Table 7.7). The practical justification of this separation is the fit of the tables on one page each. The analytical justification of this separation allows for drawing a more differentiated picture within the two groups as well as among the two groups of TUs when discussing the orders of worth.

Table 7.6 Academics (professors and academic staff) according to disciplines at TU9 forms in 2014

	U Stuttgart		TU München		TU Berlin		TU Darmstadt		TU Braunschweig		U Hannover		RWTH Aachen[a]		TU Dresden		Karlsruhe Institut of Technology		Total	
	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff
Humanities	29	206	14	104	24	85	27	118	32	137	53	156	41	174	82	327	14	59	316	1366
Sports	6	35	10	81	–	–	5	15	1	2	–	–	–	–	–	–	2	42	24	175
Law, economics, and social sciences	15	107	26	168	17	75	35	131	13	82	62	241	36	240	63	268	34	208	301	1520
Mathematics and natural sciences	94	722	167	1597	113	939	131	822	88	530	109	702	160	1316	137	977	140	1238	1139	8843
Medicine and health	–	–	74	1544	–	–	–	–	–	–	–	–	106	1658	98	1520	–	–	278	4722
Veterinary medicine	–	–	–	–	–	–	–	–	–	–	–	–	1	13	–	–	–	–	1	13
Agriculture, forest, and nutrition	1	16	48	465	–	–	–	–	–	–	20	59	–	–	20	87	1	15	90	642
Engineering	129	1778	140	1827	191	1420	114	1188	84	958	78	910	140	2387	148	1794	97	1171	1121	13,433
Arts	1	5	–	–	–	–	–	–	1	3	2	3	1	6	5	25	3	6	13	48
Central units (without medicine)	2	324	2	198	3	106	–	20	2	38	5	193	3	197	4	165	5	177	11	1418
Central units (medicine)	–	–	2	12	–	–	–	–	–	–	–	–	–	65	1	35	–	–	3	112
Total 2014	**277**	**3193**	**483**	**5996**	**348**	**2625**	**312**	**2294**	**221**	**1750**	**333**	**2271**	**488**	**6056**	**558**	**5198**	**296**	**2916**	**3297**	**32,292**
Total 2007	**242**	**2472**	**396**	**4061**	**368**	**1722**	**267**	**1672**	**236**	**1326**	**316**	**1622**	**385**	**3966**	**457**	**2721**	**255**	**2178**	**2922**	**21,740**
Shift 2007–2014 in %	**+ 14**	**+ 29**	**+ 22**	**+ 48**	**– 5**	**+ 52**	**+ 17**	**+ 37**	**- 6**	**+ 32**	**+ 5**	**+ 40**	**+ 34**	**+ 52**	**+ 22**	**+ 91**	**+ 16**	**+ 34**	**+ 13**	**+ 49**

Source: GFSO (2016a)

[a]Awarded the title of Excellence University in the second round of the German Excellence Scheme

Table 7.7 Academics (professors and academic staff) according to disciplines at not-TU9 forms

	TU Cottbus-Senftenberg		TU Hamburg		TU Clausthal		U Dortmund		TU Kaiserslautern		TU Chemnitz		TU Bergakademie Freiberg		U Magdeburg		TU Ilmenau		Total	
	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff	Prof	Staff
Humanities	4	3	2	5	–	–	64	178	2	8	35	189	–	–	38	103	1	11	146	497
Sports	–	–	–	–	–	–	4	10	2	6	4	50	–	–	3	22	–	–	13	88
Law, economics, and social sciences	37	82	12	62	8	44	43	146	25	75	35	143	14	73	31	79	21	59	226	763
Mathematics and natural sciences	53	142	9	35	34	100	86	487	103	445	52	333	38	319	52	231	31	132	458	2224
Medicine and health	3	7	–	–	–	–	–	–	–	–	–	–	–	–	38	726	–	–	41	733
Veterinary medicine	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	0
Agriculture, forest, and nutrition	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	1	1
Engineering	114	440	70	460	37	278	84	600	80	415	44	793	38	583	49	369	51	442	567	4380
Arts	5	4	–	–	–	–	11	17	–	–	–	–	–	–	–	–	–	–	16	21
Central units (without medicine)	–	37	–	38	–	134	9	38	–	75	–	87	–	16	2	23	–	54	11	502
Central units (medicine)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	28	–	–	2	28
Total 2014	**216**	**715**	**93**	**600**	**79**	**556**	**302**	**1477**	**212**	**1024**	**170**	**1595**	**90**	**991**	**215**	**1581**	**104**	**698**	**1481**	**9237**
Total 2007	**122**	**479**	**94**	**388**	**82**	**430**	**289**	**1416**	**164**	**715**	**156**	**875**	**89**	**586**	**218**	**1332**	**86**	**558**	**1300**	**4031**
Shift 2007–2014 in %	**+ 77**	**+ 49**	**+ 1**	**+ 55**	**- 4**	**+ 29**	**+ 4**	**+ 4**	**+ 29**	**+ 43**	**+ 9**	**+ 82**	**+ 1**	**+ 69**	**- 1**	**+ 19**	**+ 21**	**+ 25**	**+ 14**	**+ 129**

Source: GFSO (2016a)

Annex 5: Duration of Studies and Tax Money Spend in Selected Disciplines 2007 and 2014

		Duration of study in years	Tax money spend in 1000 EUR	Duration of study in years	Tax money spend in 1000 EUR
Disciplinary groups	Type of exams	2007		2014	
Humanities	*Diplom* and equivalent degrees	5.9	16,8	6.7	35,3
	Teaching/state exam	4.7	13,2	3.8	20,2
	Bachelor exam	3.4	9,6	3.5	18,5
	Master exam	2.2	6,3	2.5	13,0
Social sciences (incl. Economics and law)	*Diplom* and equivalent degrees	5.3	11,6	6.2	29,4
	Teaching/state exam	4.6	10,0	3.5	16,5
	Bachelor exam	3.4	7,4	3.5	16,4
	Master exam	2.0	4,4	2.3	10,9
Mathematics and natural sciences	*Diplom* and equivalent degrees	5.9	38,6	6.3	72,5
	Teaching/state exam	4.6	30,5	3.8	43,7
	Bachelor exam	3.5	22,7	3.5	39,6
	Master exam	2.3	15,3	2.4	27,6
Medicine (human) and health	*Diplom* and equivalent degrees	6.4	195,8	6.2	184,2
	Teaching/state exam	4.8	145,6	2.8	82,3
	Bachelor exam	3.2	97,7	3.2	95,4
	Master exam	2.4	72,8	2.3	69,2
Engineering	*Diplom* and equivalent degrees	6.0	40,2	7.2	54,6
	Teaching/state exam	4.5	30,0	3.7	27,9
	Bachelor exam	3.9	25,9	3.9	29,4
	Master exam	2.6	17,7	2.4	18,1
Universities total	*Diplom* and equivalent degrees	n.d.a.	n.d.a.	6.5	54,7
	Teaching/state exam	n.d.a.	n.d.a.	3.8	32,2
	Bachelor exam	n.d.a.	n.d.a.	3.5	30,0
	Master exam	n.d.a.	n.d.a.	2.4	20,2

Source: GFSO (2008, 2015)

Annex 6: Number of Students at Technical Universities in Winter Term 2016/2017 (German Citizens, International Students, and Total)

	Students (German citizens)			International students			Students total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Aachen	24,692	11,325	36,017	5671	2858	8529	30,363	14,183	44,546
Berlin	18,415	8525	26,940	4424	2714	7138	22,839	11,239	34,078
Braunschweig	10,662	6596	17,258	1756	1015	2771	12,418	7611	20,029
Chemnitz	4341	3861	8202	1952	739	2691	6293	4600	10,893
Clausthal	2631	699	3330	963	426	1389	3594	1125	4719
Cottbus-Senftenberg	3547	2374	5921	1080	781	1861	4627	3155	7782
Darmstadt	15,483	6191	21,674	3135	1553	4688	18,618	7744	26,362
Dortmund	16,595	13,726	30,321	1837	1435	3272	18,432	15,161	33,593
Dresden	16,382	11,975	28,357	2622	1954	4576	19,004	13,929	32,933
Bergakademie Freiberg	2398	1056	3454	687	337	1024	3085	1393	4478
Hamburg	4517	1576	6093	1076	397	1473	5593	1973	7566
Hannover	14,084	9750	23,834	2381	1376	3757	16,465	11,126	27,591
Ilmenau	3705	1307	5012	832	409	1241	4537	1716	6253
Kaiserslautern	7487	4654	12,141	1511	766	2277	8998	5420	14,418
Karlsruhe	14,350	5234	19,584	3720	1780	5500	18,070	7014	25,084
Magdeburg	6694	5115	11,809	1443	940	2383	8137	6055	14,192
München	19,875	10,355	30,230	6151	3206	9357	26,026	13,561	39,587
Stuttgart	14,816	6683	21,499	3597	2270	5867	18,413	8953	27,366
Total TUs	200,674	111,002	311,676	44,838	24,956	69,794	245,512	135,958	381,470
All public universities[a]	733,139	751,611	1,484,750	114,177	117,587	231,764	847,316	869,198	1,716,514

Source: Federal Statistical Office (2017a)

[a]Comprehensive universities without art, music, pedagogic and other specialized universities

Annex 7: Academic Staff and Professors at Universities According to Funding Source in 2007 and 2014

		Total		Civic/basic funding		External Funding				(Former) Student tuition fees[a]		Not Specified	
						Civic/public		Private					
		2007	2014	2007	2014	2007	2014	2007	2014	2007	2014	2007	2014
Professors	Male	31,847	35,687	28,932	32,543	1025	797	570	604	344	976	976	767
	Female	6173	10,062	5490	8905	305	423	129	154	68	366	181	214
	Total	38,020	45,749	34,422	41,448	1330	1220	699	758	412	1342	1157	981
	% total	100	100	91	91	3	3	2	2	1	3	3	2
Academic staff	Male	77,672	104,059	40,575	58,993	6627	34,887	21,958	7652	5690	325	2822	2202
	Female	45,873	73,469	22,922	43,723	4521	22,572	13,194	5263	3418	483	1818	1428
	Total	123,545	177,528	63,497	102,716	11,148	57,459	35,152	12,915	9108	808	4640	3630
	% total	100	100	51	58	9	32	28	7	7	1	4	2

Source: GFSO (2009, 2016b)

[a]For a few years some of the *Länder*, ruled by Christian Democratic Party and Free Democratic Party introduced tuition fees of € 500 per semester. Non tuition fee *Länder*, governed by the Social Democratic Party, The Greens, and The Left, compensated by paying an extra amount to HEIs. After being abandoned in all *Länder* the governments continued to pay about the amount to HEIs to improve the conditions of teaching and studying (Krücken and Hüther 2014)

Annex 8: Expenditures (Civic/Basic Funding), External Funding, and Earnings in € 1000 in Selected Disciplinary Groups at Public Universities in Germany in 2000, 2007, and 2014

		Expenditures (civic/basic funding)			External funding			Earnings (e.g., services)	
	Year	Per student	Per academic staff	Per professor	Per academic staff	Per professor	Per € 1000 of expenditures (civic/basic funding)	Per academic staff	Per professor
Humanities	2000	2,95	69,02	215,33	10,64	33,19	n.d.a.	n.d.a.	n.d.a.
	2007	4,67	103,12	360,50	18,97	66,33	0,18	11,86	41,46
	2014	5,31	119,63	473,08	32,00	126,55	0,27	7,93	31,36
Social sciences (incl. economics and law)	2000	2,03	70,58	232,49	12,68	41,78	n.d.a.	n.d.a.	n.d.a.
	2007	3,75	111,11	399,47	22,12	79,52	0,20	24,10	86,66
	2014	4,49	129,80	511,26	31,12	122,58	0,24	9,16	36,07
Mathematics and natural sciences	2000	7,68	94,99	333,22	35,52	124,61	n.d.a.	n.d.a.	n.d.a.
	2007	10,45	136,79	514,96	55,54	209,07	0,41	14,35	54,01
	2014	10,07	153,42	623,35	80,08	325,35	0,52	10,61	43,11
Medicine (human) and health	2000	28,27	79,87	801,86	20,88	209,64	n.d.a.	n.d.a.	n.d.a.
	2007	31,93	89,88	1.072,83	31,61	377,32	0,35	307,31	3.668,27
	2014	30,98	87,26	1.159,99	42,80	568,94	0,49	373,07	4.959,26
Engineering	2000	8,18	89,74	399,30	52,94	235,58	n.d.a.	n.d.a.	n.d.a.
	2007	10,76	133,46	620,69	84,34	392,27	0,63	14,80	68,84
	2014	8,15	151,49	831,63	119,01	653,31	0,79	14,68	80,58
Universities total average	2000	8,14	105,65	489,38	26,78	124,04	n.d.a.	n.d.a.	n.d.a.
	2007	8,54	112,00	553,55	39,02	192,84	0,35	115,16	569,16
	2014	8,53	122,44	667,53	55,77	304,06	0,46	131,80	718,57

Source: GFSO 2008, 2015)
n.d.a. no data available

Annex 9: Public Expenditures in 2015 According to Disciplines and Research Fields

	2002	2007	2014	2015
	1000 Euro			
Humanities (incl. sports)	940,581	1,142,279	1,304,176	1,100,409
Social Sciences (incl. Economics and law)	414,166	522,715	804,938	855,440
Mathematics and Natural Sciences	3,708,207	4,246,268	5,916,616	5,728,455
Mathematics, Information Science	384,534	392,340	678,699	710,186
Physics, Astronomy	1,217,250	1477 103	2,195,528	2,306,936
Chemistry	476,729	563,628	703,439	779,720
Pharmacology	26,016	37,276	49,917	27,774
Biology	886,301	925,071	1,258,569	1,309,145
Earth Sciences	717,377	850,851	1,030,465	982,165
Medicine (humans)	574,990	703,439	1,304,949	1,410,199
Medicines (animals)	44,680	49,917	132,541	130,005
Agriculture, Forestry, and Nutrition Sciences	511,714	1,258,569	578,699	541,906
Engineering	2,272,913	2,658,933	3,532,406	3,934,948
Architecture, Civic Engineering	114,354	184,593	277,875	220,465
Electro-technology	313,808	483,463	538,008	564,864
Other Engineering	1,844,751	1,990,876	2,716,523	2,762,148
Arts	194,604	228,446	353,063	382,247
Central Units	768,838	878,630	1,374,868	1,395,500
Total	**9,430,693**	**11,025,001**	**15,302,256**	**15,546,608**

Source: GFSO (2017b)

Annex 10: External Funding of Small (>200 Professors), Medium (201–400 Professors) and Large (<401 Professors) Sized TUs According to Sources Compared to Other Public Comprehensive Universities in 2007 and 2014

Table 7.8 External funding of small (>200 professors), medium (201–400 professors) and large (<401 professors) sized TUs according to sources compared to other public comprehensive universities in 2007 (in € 1.000; all without hospitals)

	Federation	*Länder*	Civic other	DFG total	DFG Research Infrastructure	DFG Graduate Schools	DFG Excellence Initiative	DFG indiv. Grants & coordin. Programs	European Union	other (e.g., foundations and int. organizations)	Business and industry	Total
TH Aachen	23,079	4,606	13,924	51,054	12,983	2,762	0	35,309	11,981	5,095	58,590	168,329
TU Dresden	29,243	6,579	2,143	26,677	13,936	946	0	11,795	10,775	8,918	17,637	101,973
TU München	20,347	6,144	0	58,753	14,775	0	0	43,978	5,694	6,542	57,105	154,586
Total large TUs	**72,669**	**17,329**	**16,067**	**136,484**	**41,694**	**3,709**	**0**	**91,082**	**28,450**	**20,556**	**133,332**	**424,888**
large TUs in %	**17**	**4**	**4**	**32**	**10**	**1**	**0**	**21**	**7**	**5**	**31**	**100**
Total large univ.	**252,266**	**29,497**	**36,024**	**614,593**	**214,459**	**82,825**	**0**	**317,308**	**101,125**	**88,615**	**333,703**	**1,455,823**
Average large (n = 22)	**11,467**	**1,341**	**1,637**	**27,936**	**9,748**	**3,765**	**0**	**14,423**	**4,597**	**4,028**	**15,168**	**66,174**
BTU Cottbus-Senftenberg	4,027	1,606	199	2,153	565	0	0	1,589	530	455	7,372	16,342
Karlsruhe Institute of Technology (KIT)	20,355	3,816	0	46,794	17,331	2,552	0	26,911	8,970	4,094	21,461	105,490
TU Berlin	17,228	1,072	4,332	23,650	8,300	1,254	0	14,096	13,921	3,242	17,822	81,267
TU Braunschweig	15,322	0	478	15,947	6,201	645	0	9,101	3,668	2,445	13,872	51,733
TU Chemnitz	10,168	2,618	205	8,506	3,445	623	0	4,438	1,079	426	6,772	29,775
TU Darmstadt	11,916	156	2,566	25,849	6,277	2,785	0	16,787	4,373	2,942	26,481	74,282

TU Kaiserslautern	5,622	0	1,461	9,310	538	2,579	0	6,192	1,376	2,792	7,530	28,090
U Dortmund	10,986	591	3,499	18,435	7,969	732	0	9,734	2,463	6,815	9,154	51,943
U Hannover	17,905	1,224	796	14,971	4,631	821	0	9,518	3,375	1,148	23,243	62,663
U Magdeburg	7,674	1,413	1,747	4,123	76	494	0	3,553	1,310	286	7,545	24,098
U Stuttgart	27,316	0	2,247	25,466	9,084	1,464	0	14,918	23,353	1,352	45,433	125,166
Total medium TUs	**148,519**	**12,497**	**17,530**	**195,203**	**64,417**	**13,949**	**0**	**116,837**	**64,418**	**25,998**	**186,686**	**650,850**
medium TUs in %	**23**	**2**	**3**	**30**	**10**	**2**	**0**	**18**	**10**	**4**	**29**	**100**
Total medium univ.	**272,091**	**28,918**	**30,068**	**439,522**	**151,461**	**50,276**	**0**	**237,785**	**114,025**	**82,274**	**306,548**	**1,273,446**
Average medium (n = 31)	**8,777**	**933**	**970**	**14,178**	**4,886**	**1,622**	**0**	**7,670**	**3,678**	**2,654**	**9,889**	**41,079**
TU Freiberg	8,101	0	6	3,616	112	3,503	0	0	0	0	11,193	22,916
TU Clausthal	4,835	286	373	5,575	1,920	0	0	3,656	1,706	12	8,230	21,017
TU Hamburg	11,881	0	0	7,983	65	737	0	7,181	1,115	0	1,767	22,746
TU Ilmenau	10,127	0	13	4,439	1,291	0	0	3,148	1,999	74	4,891	21,544
Total small TUs	**34,943**	**287**	**392**	**21,613**	**3,388**	**4,240**	**0**	**13,985**	**4,820**	**86**	**26,081**	**88,223**
small TUs in %	**40**	**1**	**1**	**25**	**4**	**4**	**0**	**16**	**5**	**1**	**30**	**100**
Total small univ.	**59,830**	**3,445**	**6,059**	**68,211**	**18,345**	**11,902**	**0**	**37,964**	**25,694**	**31,408**	**51,558**	**246,205**
Average small (n = 23)	**2,601**	**150**	**263**	**2,966**	**798**	**517**	**0**	**1,651**	**1,117**	**1,366**	**2,242**	**10,705**

Source: GFSO (2018b)

Table 7.9 External funding of small (>200 professors), medium (201–400 professors) and large (<401 professors) sized TUs according to sources compared to other public comprehensive universities in 2014 (in € 1.000; all without hospitals)

	Federation	*Länder*	Civic other	DFG total	DFG Research Infrastructure	DFG Graduate Schools	DFG Excellence Initiative	DFG indiv. Grants & coordin. Programs	European Union	other (e.g., foundations and int. organizations)	Business and industry	Total
TH Aachen	37,385	8,765	35,956	82,074	8,517	0	19,333	54,224	15,120	10,607	110,292	300,199
TU Dresden	59,700	2,225	1,166	52,811	12,397	3,531	18,211	18,672	36,830	9,365	33,185	195,282
TU München	55,710	21,798	0	79,507	16,523	3,773	26,559	32,651	15,233	6,114	72,161	250,522
Total large TUs	**152,794**	**32,788**	**37,122**	**214,391**	**37,437**	**7,304**	**64,103**	**105,547**	**67,184**	**26,086**	**215,638**	**746,003**
large TUs in %	**20**	**4**	**5**	**29**	**5**	**1**	**9**	**14**	**9**	**3**	**29**	**100**
Total large univ.	**518,497**	**50,471**	**82,799**	**1,108,836**	**257,450**	**61,600**	**283,969**	**505,817**	**215,864**	**194,627**	**416,669**	**2,587,762**
Average large (n = 22)	**23,568**	**2,294**	**3,764**	**50,402**	**11,702**	**2,800**	**12,908**	**22,922**	**9,812**	**8,847**	**18,940**	**117,626**
BTU Cottbus-Senftenberg	15,374	3	5,552	3,152	0	0	0	3,152	2,388	1,991	5,048	33,509
Karlsruhe Institute of Technology (KIT)	51,612	0	1,838	43,030	8,933	7,629	4,106	22,362	11,583	9,629	25,537	143,230
TU Berlin	54,907	150	10,896	53,820	18,759	4,624	7,323	23,114	27,611	7,198	19,265	173,848
TU Braunschweig	28,309	124	166	18,603	3,767	485	0	14,351	9,533	2,981	21,752	81,467
TU Chemnitz	23,766	7,750	37	20,280	2,517	1,424	6,628	9,712	12,764	1,349	8,587	74,534
TU Darmstadt	31,588	0	5,502	45,078	12,085	2,480	3,991	26,522	11,063	3,764	29,683	126,678

TU Kaiserslautern	11,452	0	3,150	19,659	5,347	2,368	0	11,944	3,663	3,234	6,343	47,501
U Dortmund	19,644	407	1,492	20,687	9,887	777	102	9,922	6,429	6,265	8,931	63,855
U Hannover	28,880	16	0	36,867	8,877	2,945	1,860	23,185	13,410	1,936	28,575	109,685
U Magdeburg	11,657	2,654	33	8,468	2,239	691	0	5,537	1,301	1,898	9,691	35,702
U Stuttgart	48,098	0	2,732	45,185	10,238	1,681	6,437	26,829	12,831	2,617	34,012	145,476
Total medium TUs	**325,287**	**11,104**	**31,399**	**314,831**	**82,651**	**25,103**	**30,447**	**176,629**	**112,577**	**42,861**	**197,424**	**1,035,483**
medium TUs in %	**31**	**1**	**3**	**30**	**8**	**2**	**3**	**17**	**11**	**4**	**19**	**100**
Total medium univ.	**573,570**	**23,957**	**51,688**	**701,987**	**181,024**	**76,260**	**66,713**	**377,990**	**199,086**	**112,970**	**348,942**	**2,012,202**
Average medium (n = 31)	**18,502**	**773**	**1,667**	**22,645**	**5,839**	**2,460**	**2,152**	**12,193**	**6,422**	**3,644**	**11,256**	**64,910**
TU Freiberg	31,536	973	311	0	0	0	0	0	17,773	1,490	14,477	66,560
TU Clausthal	9,792	0	969	5,195	56	0	0	5,139	4,114	47	12,694	32,813
TU Hamburg	14,990	101	484	5,393	1,540	1,225	0	2,629	1,746	2,604	8,524	33,841
TU Ilmenau	14,906	8,710	266	5,987	0	1,803	0	4,184	1,871	2,381	6,968	41,089
Total small TUs	**71,224**	**9,784**	**2,030**	**16,576**	**1,596**	**3,027**	**0**	**11,952**	**25,505**	**6,521**	**42,663**	**174,303**
small TUs in %	**41**	**6**	**1**	**10**	**1**	**2**	**0**	**7**	**15**	**4**	**24**	**100**
Total small univ.	**145,258**	**14,573**	**8,691**	**111,150**	**13,011**	**8,689**	**26,354**	**63,096**	**75,400**	**35,242**	**77,485**	**467,798**
Average small (n = 23)	**6,316**	**634**	**378**	**4,833**	**566**	**378**	**1,146**	**2,743**	**3,278**	**1,532**	**3,369**	**20,339**

Source: GFSO (2018a, b)

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Chapter 8
Integrating the Academic and Professional Values in Engineering Education – Ideals and Tensions

Kristina Edström

8.1 Introduction: The Dual Nature of Higher Engineering Education

Higher engineering education is simultaneously *academic*, emphasising theory in a range of disciplines, and *professional*, preparing students for engineering practice. Harvey Brooks called this a *fundamental dilemma between science and art* in professional education. The term *art* implies that engineering is more than just applying science:

> To the professional belongs the responsibility of using both existing and new knowledge to provide services that society wants and needs. This is an art because it demands action as well as thought, and action must always be taken on the basis of incomplete knowledge (Brooks 1967b p. 89).

When historian Bruce Seely studied several decades of consecutive curriculum reforms promoting *either* the theoretical *or* the practice-oriented side, he likened the effect to a swinging pendulum (1999). Given how this tension remains and seems to spark new curriculum reforms for each generation, he has also remarked that *"many of the challenges facing engineering educators have remained remarkably consistent over time"* (Seely 2005, p. 125).

The argument made in this chapter is that the theoretical knowledge and practice-oriented aspects should not be seen as opposites, nor as separate components. The ideal is a curriculum in which they are also in a meaningful *dual nature* relationship. By exploring how the theoretical and professional aspects can be integrated in the curriculum, this chapter suggests interpretations which can offer more productive understandings and opportunities for handling practical matters. The swinging pendulum metaphor is also disputed, since it reinforces the common misconception that

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engineering education must necessarily lean *either* to the academic *or* to the professional side. Rather than seeking balance and compromise, as the pendulum imagery would suggest, we should seek syntheses and synergies (Edström 2018). In particular, engineering education would benefit from fewer trench wars over “how much” should be theoretical or practice-oriented, and more effort to strengthen the meaningful relationship between these aspects in the curriculum.

This chapter explores how technical universities create opportunities for addressing the dual nature ideal in initiatives for curriculum reform, but also some associated challenges on the organisational level in the faculty. More than just a conflict within the curriculum, this dilemma is tied to, and often plays out as, a *“tension between scholarly autonomy and societal responsiveness”* of the university (Brooks 2001). It could be argued that this duality is what defines the niche for technical universities. They draw their strength from adual legitimacy that comes from successfully combining academic autonomy, the university as academia, with societal responsivity, the university as public service. But if the raison d’être is to straddle these aims, no wonder if some tensions are felt inside the technical university, and inside the engineering curriculum.

The aim of this chapter is to deepen the understanding of the dual nature ideal and its associated tensions by analysing them as expressions of different *institutional logics* in engineering education (Thornton et al. 2012). The issue under investigation is first how the dual nature ideal is addressed in curriculum development, and then how this work is limited by some related tensions in the organisation of the technical university.

The chapter is structured as follows: First, a concept for engineering education reform is described, the CDIO initiative, which illustrates curriculum development aiming to address the dual nature ideal. This is followed by a theoretical exposition to explore the organisational conditions for such ideal curricula. The institutional logics perspective is outlined and used to analyse the tensions in the engineering curriculum and in the faculty of the technical university. The tensions are interpreted in the light of the institutional logics of *the engineering profession* that we educate for, and of *the academic profession* of the educators. Finally, the CDIO initiative is revisited, and seen as a site for institutional innovation on the level of the organisational field.

8.2 The CDIO Initiative

8.2.1 Foundation

Within the engineering education community, the CDIO approach can be seen as a major attempt to productively integrate the academic and professional aims, according to the dual nature ideal. The initial idea was conceived at the Aero-Astro department at MIT, starting from the recognition that engineering education had become increasingly distanced from engineering practice, as engineering science had replaced engineering practice as the dominant culture among faculty in the past decades (Crawley 2001). The ideas appealed to Swedish industrialist Peter Wallenberg, who encouraged MIT and three Swedish universities – KTH Royal Institute of Technology, Chalmers University of Technology, and Linköping University – to apply for a grant to develop a framework for engineering education reform (MIT 2000). The four project partners, calling themselves *the CDIO Initiative*, started jointly developing and testing a methodology through application in pilot programmes: at MIT the aerospace programme, at KTH vehicle engineering, at Chalmers mechanical engineering, and in Linköping the applied physics and electronics programme. The aim was to educate students in developing and deploying technology, or, using the words that gave the CDIO acronym: to *conceive, design, implement, and operate* technical products, processes and systems.

Soon after the CDIO Initiative started, other universities expressed interest to participate in the endeavour. From a four-year project with four partners, the CDIO Initiative evolved into a community, which kept growing. By 2018, more than 150 institutions have formally joined as collaborators. The annual international CDIO conference started in 2005, aiming to discuss and develop the ideas and methods for implementation, and to document and report experiences. Peer-review of conference contributions was introduced in 2009, and a track for engineering education research opened in 2016 (Edström 2019). A book about the CDIO approach is in its second edition (Crawley et al. 2007, 2014).

8.2.2 The Integrated Curriculum

The CDIO community advocates improving professional competence, and making the professional and disciplinary preparation mutually supporting. The first aim is to support students in achieving a *deeper working* understanding of disciplinary fundamentals, not least crucial as a preparation for practice. What sets CDIO apart from other concepts for engineering education development is the focus on combining and improving the contributions of both discipline-led and problem- or project-led (PBL) approaches in the curriculum (Edström and Kolmos 2014). This approach was intended to replace the constant tug-of-war over the curriculum, with its underpinning binary view on theory and practice. It also implied critique of any one-sided solution: just as a purely project-based curriculum risks resulting in fragmented knowledge, a purely discipline-based approach risks resulting in

> poorly designed curricula, at worst consisting of disciplinary courses disconnected from each other, and as a whole, loosely coupled to espoused programme goals, professional practice, and student motivation (Edström and Kolmos 2014, p. 549).

The strategy formulated by the CDIO community is to develop a curriculum that integrates disciplinary theory and other professional aims, on the programme level, on the course level, and in faculty development (Crawley et al. 2014). The objective is to achieve an *integrated curriculum*, meaning that students should develop professionally relevant competences hand in hand with their acquisition of deeper working understanding of disciplinary knowledge, throughout the programme. The CDIO approach is also programme-centric, intended to create the interconnected curriculum structures identified by Graham (2012) as a key factor associated with successful and sustainable change. An outcomes-based approach is used, and the integration of theoretical knowledge and professional competences applies to every stage of this system:

- The starting point is to formulate a vision of what engineers from this programme will be able to do.
- What students therefore need to learn is expressed as intended learning outcomes at the programme level.
- These are apportioned as the course learning objectives of both subject courses and project-based courses.
- The course learning objectives are finally reflected in the design of learning activities and assessment of student learning outcomes.
- These links are continuously improved through cycles of evaluation and development involving programme stakeholders.

8.2.3 Micro Case: Mechanical Engineering at Chalmers

The programme-centred approach in CDIO can be studied at Chalmers, one of the four founding universities. The Mechanical Engineering programme is a five-year combined Bachelor and Master of Science in Engineering. Here, the CDIO methodology is implemented to keep the programme unified, despite being a composite of courses from several departments and disciplines. The team has created capacity for programme development, enabling the programme leaders to constantly set new goals and pursue them in a relatively agile process.

The Mechanical Engineering curriculum is well documented in the programme description, showing how skills, such as communication, teamwork, and ethics are integrated in several courses with progression throughout the years (Malmqvist et al. 2006). One of many interesting developments in this case is the integration of computational mathematics, aiming to modernise the mathematical content while also strengthening the connection between engineering and mathematics. The rationale was that students need to learn to solve more general, real-world problems, while they can spend less time *"solving oversimplified problems that can be expressed analytically and with solutions that are already known in advance"* (Enelund et al. 2011). One of the guiding principles was that students should work on the complete problem: from setting up a mathematical model and solving it, to simulation of the system, using visualisation to assess the correctness of the model and the solution and make comparisons with physical reality. The interventions in the programme involved new basic math courses including an introduction to programming in a technical computing language and environment (Matlab); production of new teaching materials (since few textbooks take advantage of the development in computing); integration of relevant mathematics topics in fundamental engineering courses such as mechanics and control theory; and cross-cutting exercises, assignments and team projects shared between the mechanics and strengths of materials courses and mathematics courses. Instead of framing this as a task for mathematics teachers to solve within the mathematics courses, the programme-driven approach was applied, where making connections to mathematics in engineering subjects was at least as important as making connections to engineering in mathematics. Similarly, the integration of sustainable development demonstrates how the programme approach enables systematic integration of important cross-cutting topics in several courses, linked to overall programme learning outcomes and ensuring progression (Enelund et al. 2013).

This programme was developed and refined over a long time, by a team of faculty with high legitimacy and the resource allocation system in their hands. The coupling between the programme and its courses creates both structural capital and agility, which allows the programme team to set and reach new goals. There is no doubt that many other programmes, despite similar intentions, have failed to achieve such development.

8.2.4 CDIO and Faculty Competence

A key component of the CDIO framework is a recognition of the need to enhance faculty competence. This is because the implementation of the integrated curriculum is enabled and limited by faculty *engineering competence* and faculty *teaching competence*. First, on the course level, the success of the integration strategy depends on the willingness and ability of individual faculty members to unite the theoretical and the professional aspects. This works only to the extent that the educators are prepared to attend also to professionally relevant aspects that are not necessarily part of the teaching traditions of their subject. Then, on the programme level, CDIO devises a process for establishing structures to hold the curriculum together, making the programme a joint collegial project, where every course has an explicit function towards the programme goals, and where a programme approach can be used to address learning needs, like in the Chalmers case above. Whether the integration can be realised and sustained on the programme level is then also dependent on the capacity to coordinate the work of faculty members.

One general challenge when recommending faculty development as part of a programme-centred reform concept is that although it is an important condition for success – often the most critical – it can be a domain in which the programme has little influence. This is also the area where least progress has been reported by CDIO implementers (Malmqvist et al. 2015). At Chalmers, a programme commissions courses from departments but has no formal influence over the processes that ensure teacher competence, such as hiring and promotion (Malmqvist et al. 2010).

Nevertheless, in many institutions implementing CDIO, cautious steps are taken on the university-wide level to strengthen faculty engineering competence. At MIT, a limited number of *Professors of the Practice* can be hired (de Weck 2004; MIT 2017). To support faculty development of engineering competence, some strategies implemented by CDIO collaborators are: sabbaticals to work in industry and public sector, partnerships with industry in research and education projects, allowing and encouraging consultancy work, and professional development activities at the university (Malmqvist et al. 2008). Other activities aim to strengthen faculty teaching competence. At Chalmers, the appointment regulation specifies Lecturer positions based on professional skills, as well as positions up to Professor (not holding a chair) with emphasis on pedagogical expertise (Chalmers 2013). Further, in every hiring or promotion case at Chalmers, at least one of the external evaluators is a teaching expert focusing on candidates' teaching competence. In the Swedish context, most universities also offer courses on teaching and learning to faculty. One reason is that 10 weeks of such education was for many years a national eligibility requirement for senior lecturers and professors (Lindberg-Sand et al. 2005) and the practice was continued even when this regulation was removed in a reform to increase autonomy.

8.3 Organisational Conditions – A Theoretical Framework

8.3.1 An Organisational Perspective Is Needed

Up to this point, this chapter has discussed how a global community of engineering educators created and adopted the CDIO approach to develop the integrated curriculum, in order to pursue the dual nature ideal. While there is great awareness of the importance of faculty competence, the endeavour has still been quite focused on the curriculum development in itself. It is possible to critique the CDIO approach for being too limited, just like Harvey Brooks admonished engineering educators in 1967 for focusing too much on the curriculum and course content:

> What kind of faculty? What kind of research? What kind of curriculum and courses? I raise these questions in that order because I think this is the order of their significance and importance. In fact, I would say that the main fault of engineering education is the excessive preoccupation with curriculum… In my view, the heart of the problem lies in the character and orientation of the engineering faculty. In the long run the courses and curriculum, and the knowledge and motivations of the students, are bound to reflect the research interests, the consulting experience, and the values of the faculty (Brooks 1967b).

Following Brooks' advice, the next section will place the issue on the organisational level, by considering the forces that shape the faculty and the setup of the organisation. A theoretical framework is then needed to understand the university as organisation, and in particular as an environment for the kind of educational development that is in focus here. The ability to develop the integrated curriculum depends on how well the organisational conditions are understood.

8.3.2 The University Is Not a Machine

The mental models, concepts, and theories that we hold can function as lenses for discerning and interpreting things that may otherwise have gone unnoticed, or they may limit our view, because to highlight some aspects is also to relegate others to the background. A technical university is dominated by engineers, who, at least according to Picon (2004, p. 429), have a strong tendency to see functionalist rationality as the natural guideline for action. A suitable metaphor for the organisation would then be a factory or a machine, suggesting an organisation optimised for effective operation, structured along the organisational chart, and designed to coordinate its activities *"in a routinized, efficient, reliable and predictable way"* (Morgan 2006, p. 13). While this view is not necessarily wrong, it lacks explanatory power for many aspects of university life. Weick (1976, p. 1) observed that people often find that their experiences in educational organisations *"prove intractable to analysis through rational assumptions"*, as the rational view simply does not *"explain much of what goes on within the organisation"*. An alternative framework will be needed, that is more appropriate to analyse the university as an organisation and to assess the implications for educational development.

8.3.3 Institutional Logics

The following section draws on theory that describes organisations as embedded in and infused by *institutional logics* (Friedland and Alford 1991; Thornton and Ocasio 2008; Thornton et al. 2012). Institutional logics can be succinctly expressed as *"the way a particular social world works"* (Jackall, cited in Thornton et al. 2012, p. 46). If the machine metaphor focuses on the formal and visible structures, resources, activities and outputs, the institutional logics perspective helps explain organisational behaviours that defy rational assumptions, because it *also* takes into account the subtler roles played by norms, values, culture and identities. A comprehensive definition shows that both the material and normative dimensions are incorporated in the institutional logics:

> the socially constructed, historical patterns of material practices, assumptions, values, beliefs, and rules by which individuals produce and reproduce their material subsistence, organize time and space, and provide meaning to their social reality (Thornton and Ocasio 2008, p. 101).

On the highest level, Thornton et al. (2012, p. 73) list seven ideal types of institutional logics in society: *state, market, community, profession, corporation, family, and religion*, each with its own set of norms and sources of legitimacy and authority. On the next level is the institutional field, where combinations of these societal logics are at play. For instance, in the higher education sector, some practices are shaped by professional logics (e.g. peer review is shaped by the academic profession), while other aspects are shaped by market logics (e.g. technology transfer) or state logics (e.g. degree frameworks). An individual university may have its own instantiation of the field-level logics. In a complex institutional environment with incoherent demands, there may be tensions between different logics, leading also to tensions between the logics embedded within any particular university. In the following, the institutional logics of two different professions will be in focus: the engineering profession and the academic profession.

8.3.4 Practices and Identities

Practices are intimately connected to the institutional logics of the organisation, in

> a fundamental duality between logics and practice, where constellations of relatively stable practices provide core manifestations of institutional logics (Thornton et al. 2012).

Practices may reflect the institutional logics differently, as they align with different parts of the institutional environment, for instance, uncoordinated constituents. This can create tensions between practices, within practices, and between institutional rules and the effectiveness of the practice. Further, practices may be conceptualised as interdependent, so that changes in one practice may have ramifications for other practices in the organisation (p. 141). Here, the interdependence of education and research is in focus. There is also a close relationship between practices and identities; we can say that they are co-produced.

The availability of standardised social identities in higher education has great importance. Henkel (2005) refers to Bernstein in saying:

> identities are strongest and most stable within the context of strong classification, the maintenance of strong boundaries protecting the space between groups, disciplines or discourses.

The classifications of individuals are important in higher education; it is something that university organisations pay much attention to and spend much effort on. In fact, education can be seen as a process where students pass through a series of stages, with carefully controlled transitions, e.g. admission, examination, degrees. The classification of academics is no less important; just think of disciplines, titles, appointments and promotions.

The tight link between identity and practice is also evident when we consider how *status* is attached to both. Complex institutional environments can generate patterns of differentiated status between organisations, and between practices and groups within the organisations. Status also affects the relationships with the resource environment. Kodeih and Greenwood (2014, p. 10) note that high-status actors can be expected to have priority access to the most valuable resources. This applies to the organisation as a whole, such as when high-status universities attract funding, and the most talented researchers and students; it also applies to groups and individuals on the inside. In summary:

> each institutional field consists of one or more available logics, as well as an array of appropriate collective organizational identities and practices from which individual organizations assemble their particular identities and practices (Thornton et al. 2012, p. 135).

8.3.5 Identity and Status in Curriculum Change

The development of engineering education advocated by the CDIO initiative is precisely an attempt to change one of the practices of the university. As we saw above, both the practices in the organisation, *what we do,* and the identities, *how we see ourselves,* are related to each other and to institutional logics. It is then a key concern how the proposed curriculum models relate to the institutional logics, to other practices – research in particular, and to identities in the organisation. If we consider the curriculum also as an expression of educators' identity, it is clear that changes can be seen as more or less valuable and meaningful, or improper and threatening. Status plays an important role, and change may be strongly resisted if it is perceived as a threat to the status of organisations, groups, or individuals. Status can, however, also favour change, since those who are perceived as successful and legitimate are role models likely to be imitated by peers – and this applies to organisations (DiMaggio and Powell 1983) as well as to individuals and groups within the organisation (Deephouse and Suchman 2008, p. 61). In her influential study of academic identities, Henkel concluded that the *discipline* and *academic freedom* were the two things that mattered most, *"in many cases the sources of meaning and self-esteem, as well as being what was most valued"* (Henkel 2005, p. 166). Seeing the curriculum as an expression of faculty identity, it is also obvious that any change in practices and structures will be strongly resisted if it is perceived to threaten these values. In the light of Henkel's findings, CDIO programme development seems particularly challenging, as the strategy to integrate professional aspects in courses will most likely differ from the traditions of the discipline, and the need for coordination across the curriculum can be seen to limit academic freedom.

8.4 Analysing the Dual Nature Ideal

8.4.1 Competing Professional Logics in Engineering Education

Drawing on the institutional logics theory, we will now consider the academic-professional duality in engineering education, the ideal as well as the tensions. We saw that institutional logics – patterns of material practices, assumptions, values, beliefs, and rules – are embedded in the practices and identities within the university. The dominant *practices* in higher education – in principle the practices that define a university – are research and education, with intimately related *identities* for faculty, as researchers and educators (see Fig. 8.1).

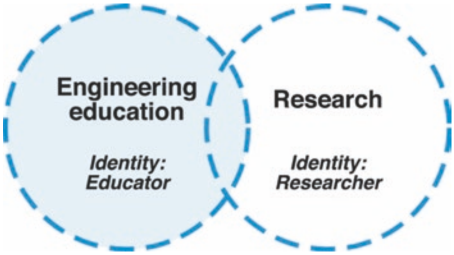

Fig. 8.1 The major practices in higher education and the co-produced faculty identities (Edström 2019)

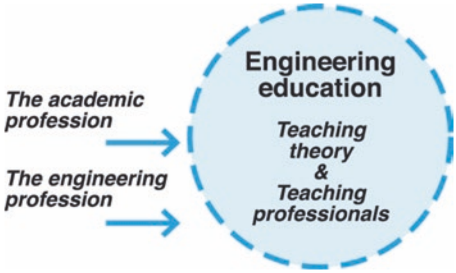

Fig. 8.2 Education as a practice expressing two professional logics (Edström 2019)

In complex institutional environments, the logics embedded within a particular practice can contain contradictions. The proposition here is that the engineering curriculum expresses tensions between the institutional logics of two professions: *the logics of the engineering profession* that we educate for, and the *logics of the academic profession* of the educators. These logics come with slightly different assumptions, beliefs and values regarding the educational mission and the role of the educators. The logic of the engineering profession reasonably assumes that the educational mission is about teaching the next generation of engineering professionals. Drawing on the logic of the academic profession it could instead be reasonable to see the teaching mission as conveying the theory of their discipline (see Fig. 8.2).

To elaborate some aspects in which the institutional logics of the two professions differ: In the logics of the *engineering profession*, the educator teaches future professionals. Some educators will embrace the engineering profession as a part of their identity, and they may therefore have a more positive attitude to integrating professional aspects. The engineering identity of faculty can be strengthened if they have experience of professional practice. Knowledge is seen as relevant if it is useful for engineering practice, for industry and society. Education should prepare students for professional practice, i.e. working on real problems in real contexts, which includes a deep working understanding of theory, and the ability to integrate and apply it. In contrast, according to the logics of the *academic profession*, the educator mainly teaches disciplinary theory. Educators' academic identity is developed through a PhD in a discipline, followed by a research career. Knowledge is seen as relevant if it is part of the disciplinary canon, and problems and questions are interesting if they have a potential to lead to new discoveries furthering the disciplinary

Table 8.1 Analysis of different curriculum emphases, in the logics of the engineering profession and the academic profession (Edström 2019)

Institutional logics	The engineering profession that we educate for	The academic profession of the educators
The role of the educator	Teaching future engineers	Teaching theory
Relevant knowledge	Knowledge useful for engineering practice	The disciplinary fundamentals
Interesting problems and questions	Real problems, consequential issues in industry and society	Pure problems, close to the disciplinary frontier
Students are prepared for	Engineering practice, through deep working knowledge and professional competences	Engineering practice, through theoretical knowledge Research education – disciplinary depth

frontier. Engineering students should learn disciplinary theory, and become prepared for research education. These factors are summarised in Table 8.1.

This analytic scheme is not meant to set these two sides of education against each other. Instead, the point here is precisely that *both sides are necessary*, and that according to the dual nature ideal, they should also be in a *meaningful relationship*. This does not, however, prevent contradictions and tensions between the logics. Simply put, the capacity to teach disciplinary theory is strengthened by the academic logics, while the professional logics strengthen the capacity for addressing also the other necessary aims of the curriculum. When the professional logics are weakly represented among the faculty, it is more difficult to satisfy the related aspects in the curriculum – for instance, integration, application, and real problems in context.

8.4.2 Competing Logics in Research

Research, the other defining practice in the technical university, can be characterised by a similar tension within its institutional logics, where two beliefs about the aims of research exist simultaneously: one that research aims to further knowledge for its own sake, and one that research is guided by a consideration for usefulness in society. The first belief can be expressed as *the university as academia*. Because the academic career depends on peer recognition, seeking knowledge "for its own sake" quickly translates to the same thing as furthering a discipline. Peer approval is a *sine qua non,* and those whose work does not pass peer review, the disciplinary quality control, will be marginalised. Quite aptly, Gibbons et al. (1994) called disciplines the *"homes to which scientists must return for recognition or rewards"*. The disciplines can be seen as sites for controlling the resources necessary for survival in academia. The academic capital comes in hard currency, such as having publications accepted, passing a thesis defense, being appointed and promoted, and receiving grants, prizes and invitations. These academic decisions contribute to classifications of individuals, which is a particularly important component of identity. Research merits dominate every step in the career system (see, for instance, Geschwind and Broström 2015)and the academic pursuit can become very personal:

> A key element for many academics is the narcissism involved in doing and publishing research. The self is invested in the work and research publications function as reinforcers and stabilizers of a sense of self susceptible to the insecurities and vulnerabilities of a profession constantly exposed to assessment and a level of competition where failures greatly outscore successes for most people (Alvesson et al. 2017).

All this helps explain the strong socialisation of faculty into the discipline-based identity, values and beliefs.

The other prevailing belief, *the university as public service,* implies that research is guided by *consideration for use*. The challenge is then how to evaluate the usefulness dimension of the work, and who should be seen as the legitimate judge. It is quite suggestive that even funding for highly applied research is often dispensed based on academic peer review. While there are efforts to pay more attention to societal impact in academic career evaluations, it seems seldom conceptualised as a main consideration within research and education, but as a separate third task, service, and the discourse often has a distinctly commercial character (cf. Dill 2012) (see Fig. 8.3).

Because the resources under academic control are so vital, the proposition here is that "university as academia" has stronger support in the institutional logics than does the "university as public service". While the former is highly consistent with the logics of the academic profession, the latter has strong similarities with the logics of the engineering profession, for instance, the values attached to integration, application, the interest in real problems that are consequential in society and industry, and their real solutions. These two beliefs are not mutually exclusive, as research can simultaneously be directed toward applied goals and lead to significant new understandings (Brooks 1967a; Stokes 1997). There is, however, still a core distinction, similar to the description by Williams (2002, p. 44):

> In science, the fundamental unit of accomplishment remains the discovery; in engineering, the fundamental unit of accomplishment is problem-solving.

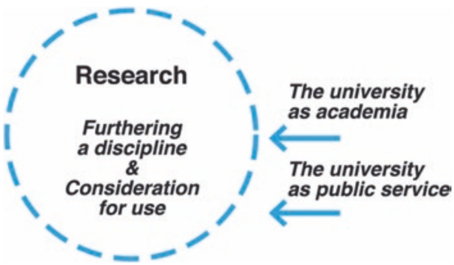

Fig. 8.3 Two aims of research, with corresponding beliefs (Edström 2019)

The conclusion here is that in the research practice, *the logics of the academic profession enjoy the strongest support in the institutional environment*, both normatively and materially.

8.4.3 Interplay Between Education and Research

Education and research have until now been discussed separately, focusing on some tensions within each practice due to inconsistent demands in the embedded logics. What remains is to consider their *interdependence* (see Fig. 8.4). There is much scholarship addressing the relationship – often called the *nexus* – between research and teaching (for a recent overview, see Geschwind 2015). In focus here, following the theoretical framework, are the different conditions for the practices, and how research influences the dual nature of engineering education. Due to inconsistent institutional demands, we can expect patterns of *differentiated status* between these practices and between groups within the organisations. According to Meyer and Rowan (1977), we can further expect tensions *between* practices, and between institutional rules and the *effectiveness* of the practice.

When a technical university is viewed from the outside, research and engineering education both enjoy high status. The research activity corresponds to the role of the university as producer of new knowledge and is an important source of status and identity, not least for the international reputation and brand. Engineering education is a prominent source of legitimacy for the technical university, as a supplier of elite professionals to society and industry. However, *within* the university, while there is certainly status in excellent teaching, the status of research is generally higher. We are reminded of the imperatives created by the "university as academia" described above. While teaching merits are increasingly emphasised in hiring and promotion criteria, it seems sufficient from a career point of view to be above a threshold level (Graham 2015). Another reason can be found in the different resource environments. Education funding is distributed internally, often based on quantitative factors without rewarding quality. Research funding varies considerably between research fields, in terms of availability, and whether a grant affords freedom or

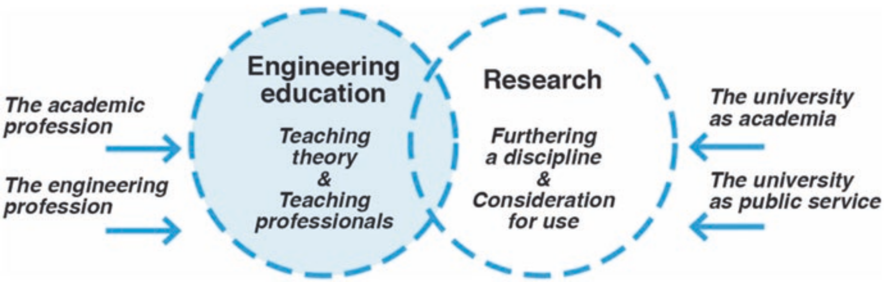

Fig. 8.4 Competing institutional logics in education and research (Edström 2019)

comes with strings attached. But in contrast to education, research funding is often sought externally and in competition based on peer review; here, the rewards for excellence are considerable both in terms of resources and status. In short, the dominance of research is guaranteed by the reproduction and socialisation of the faculty, as well as strongly incentivised by the resource environment. In conclusion, *research has stronger institutional support than education, both normatively and materially*. This affects the conditions for education generally, including related matters such as the attention paid to teaching competence, teaching quality, and educational development.

8.4.4 Imbalances in Engineering Education

While the imbalance between education and research is important for shaping the conditions of engineering education, the focus here is the dual nature of engineering education. The academic-professional duality was conceptualised above as competing logics *within* the education practice: teaching theory and teaching professionals. Because of the crucial role played by research in shaping the faculty, research will also come to limit and enable what is possible in education. If it has been perceived as provocative that the needs of education are increasingly taken into account in the appointment and promotion of faculty, it seems even more daring to make suggestions about the research. But the interdependence of education and research does raise the question about what kind of research could strengthen the educational mission in a university, since the reproduction of the faculty in a technical university is largely under the auspices of the research enterprise. It should be interesting for funding agencies to consider how the research they support affects conditions for the professional aspects of engineering education. While some research and researchers focus on endeavours emanating from a purely academic interest, furthering a discipline, there are also researchers who work on matters with a more direct consideration for use. The analysis above suggested that such research shares some key aspects with the engineering profession, e.g. the values attached to integration, application, and focus on real problems in naturalistic contexts. In the technical university, there are applied and cross-disciplinary fields closer to professional practice. It can be presumed that faculty with such research interests can have more engineering capital, for instance, through contacts with industry (including the public sector). In their *role as educators* they might therefore find it more natural to take on also the role of educating professionals (see also Table 8.1).

The suggestion here is that the institutional logics of research, being the dominant practice, strongly influences the institutional logics of the education, by shaping the faculty. Hence, *the more the research practice is dominated by the academic logics*, over the consideration for use*, the more it will also tilt the balance in education, in favour of teaching theory*, rather than teaching professionals. When the balance is too heavily tilted, it will be difficult to achieve the productive relationship between the academic and professional aims. It is possible to see the initiatives like CDIO as attempts to address precisely this imbalance.

8.5 CDIO as Institutional Innovation

8.5.1 Active Institutional Innovation

After highlighting the tensions within the practices inside the university, we will now return to the institutional logics theory. Some additional conceptual tools are needed to consider the role of the CDIO initiative as an actor in the organisational field.

It is easy to think of institutional norms and rules as mostly limiting the autonomy of organisations and individual actors. Focusing instead on the opportunities, institutional logics can also be seen as *resources that can be invoked* for making identities and practices legitimate. For instance, a reform may increase its chances of success if it manages to draw on values aligned with the prevailing institutional logics. Especially in organisations with multiple institutional logics, there are also opportunities for individuals and organisations to actively exploit any inconsistencies and contradictions (Thornton et al. 2012). Opportunities for institutional innovation are available at all levels, for a whole organisation, for any particular activity, or for individuals:

> Logics are not purely top-down: real people, in real contexts, with consequential past experiences of their own, play with them, question them, combine them with institutional logics from other domains, take what they can from them, and make them fit their needs (Binder 2007, p. 568).

Actors and sub-groups can, and do, utilise such opportunities selectively, making the organisation a mosaic of groups, with more or less potential for enabling or resisting change (Greenwood and Hinings 1996).

8.5.2 The Organisational Field as a Site for Mobilising

Actors within an organisation can turn to the institutional field as a source of institutional innovation. For instance, Thornton et al. (2012, p. 110) mention how people with experience from different institutional contexts are less likely to take things for granted in their local organisation, and therefore may have capacity to create institutional change. Greenwood et al. (2002) pointed out the role of professional associations in legitimating change, by hosting debate, justifying and endorsing new practices. This is the function of *theorization*, *"the process whereby organizational failings are conceptualized and linked to potential solutions"* (p. 58). Such collective sense-making can support change in organisations by recognising the weakness of existing arrangements and building the capacity for action. This means, for instance, developing sufficient understanding of the new conceptual destination, the skills and competencies required to function in that new destination, and the ability to manage how to get to that destination (Greenwood and Hinings 1996, pp. 1039–1040). The organisational field can also offer concrete exemplars of structures and practices that reflect ideas and values in the institutional field. Thornton et al. (2012, p. 159) refer to field-level *vocabularies of practice*, which

> guide attention, decision making, and mobilization, and provide members of social groups with a sense of their collective identity.

This can create common ground, and facilitate sense-making and collective action.

8.5.3 CDIO as a Driver of Institutional Innovation

Taking a new look at CDIO in the light of these concepts, the CDIO initiative can now be seen as a driver for institutional innovation, situated in the organisational field, and promoting new logics through collective mobilisation. It is a site for jointly crafting and sharing narratives, and for developing certain vocabularies of practice. Successful implementations serve as exemplars and proofs-of concept, and individuals as role-models. When the CDIO community shares experiences from different institutional contexts, it also exposes individuals to a wider repertoire of institutional values, practices and identities, which can then also make them less likely to take things for granted in their home environment. Local innovators can invoke CDIO as a legitimate template, to strengthen the legitimacy of their local work, and as a part of their identity. The legitimacy of CDIO is also partly mimetic, as the presence of high-status technical universities among founders and adopters has played an important role in the growth of the community. Whether CDIO can also achieve normative or cognitive legitimacy depends on the match between the values and norms that are communicated by the CDIO community, and the prevailing institutional logics.

The strategy to embrace discipline-led teaching as the major part of the integrated curriculum can make CDIO a more legitimate innovation, in the sense that it is understandable and consistent with widespread practices. It is therefore potentially less threatening to faculty identities, than, for instance, advocating educational models purely based on PBL. While CDIO obviously does challenge programmes that consist of loosely coupled theoretical courses, the proposed interventions still stay on common ground. PBL is an important component of the integrated curriculum, but CDIO does not advocate a pure PBL curriculum. CDIO could thus be seen as balancing different expectations with compromise strategies (cf. Oliver 1991). Another compromise is to stress the need for a deeper working understanding of disciplinary theory. This is acceptable to those who emphasise disciplinary theory, as well as those who emphasise what students can do with their understanding. The rhetoric is aligned with both the academic and engineering professional logics.

8.6 Conclusions

The theme of this chapter was the dual nature ideal for engineering education, or the idea that the academic and professional preparation can be productively combined. The argument was that it is feasible to realise the ideal in engineering curricula, by integrating disciplinary theory and professional aims in a meaningful relationship. Both types of learning outcomes are already present in the stated aims of engineering curricula, and there are approaches that readily support such implementation, for instance the CDIO model with its integrated curriculum. There are however limitations. First, the productive relationship can be realised and sustained in courses only to the extent that individual faculty members are willing and able. Then, whether the integration can be realised and sustained on the curriculum level further depends on the capacity to coordinate the courses, or in other words to coordinate the work of faculty members. Hence, the challenges facing the integrated curriculum lie on the organisational level.

Using an institutional logics perspective, a tension was discussed within the technical university, between the engineering profession that we educate for, and the academic profession of the educators. Their respective institutional logics were analysed separately, showing two ways to see engineering education, but making the point that both sets of values are needed. An image of the university organisation was elaborated, where research holds a primary position and education is positioned as a secondary practice. The academic profession seems to have the upper hand, not only in research, where disciplinary interests take priority over considerations for use, but also in education, where disciplinary theory takes priority over other aspects of professional preparation. This "spill over" happens through the faculty, whose academic identity is stronger than their engineering identity. This is unsurprising, as disciplinary research is the birthplace of new faculty, and research success is crucial for survival in the university. While it is understandable that the organisation needs to spend considerable attention to its own academic reproduction processes, there is a point where this takes a life of its own and precedence over the educational mission of the university. The rise of a movement like the CDIO initiative can be seen as a sign of these imbalances inflicted on engineering education, and its dynamic growth shows efforts to defend the dual nature ideal.

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Chapter 9
Technical Identity in a Merger Process—Between a Rock and a Hard Place

Tea Vellamo, Elias Pekkola, Taru Siekkinen, and Yuzhuo Cai

9.1 Introduction

This chapter studies how the identity of a single-faculty technical university is represented and reframed in the context of a merger process with a multi-disciplinary, comprehensive university that focuses on the social sciences and a professionally oriented university of applied sciences. In particular, we study how the identity of the technical university is formed in relation to the other higher education institutions taking part in the merger and in relation to the identities of different technical disciplines within the organisation. We focus on the organisational identity of the technical university, as the academics and managers within the organisation perceive it.

Empirically, our study focuses on the merger process between two Finnish universities, namely the University of Tampere (UTa) and Tampere University of Technology (TUT), and one polytechnic, Tampere University of Applied Sciences (TAMK). Through the merger, a new university is formed that in turn will own the university of applied sciences.

The analysis is based on nine thematic interviews of selected professors and academic managers at TUT who have been actively involved in the merger process. Our research questions are: how the academic leaders and high-level managers represent TUT as a technical university in contrast to the other types of institutions involved in the merger and how they see the merger affecting the technical identity. In the analysis, we look at the main attributes associated with TUT and whether they

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coincide with those associated with technical universities as an organisational identity category in general. This chapter addresses the lack of research on the organisational identity of technical universities, particularly in Finland. This merger context is also especially interesting because it involves institutions from both sectors of the higher education system, namely research universities and universities of applied sciences.

9.2 History of Higher Education in Tampere

In Finland, the first technical institute established in Tampere in 1911, remained the only one until the establishment of the institutes in Turku and Helsinki in 1943. During the 1910s and 1920s, the number of students in technical institutes remained small, and the operation, studies and programmes were centrally regulated by the Ministry of Trade and Industry. Because of growing demand in the industry, new programmes in technical fields were established in the 1930s, and the number of students increased until World War II curbed this growth. After the war, the number of technical students rose, and new institutions were established around the country in the 1960s. In the mid-1990s institutes were merged and transformed into polytechnical institution. In 1996 the Tampere Polytechnic Institute, together with forestry, art and communication and business institutes, formed the Tampere University of Applied Sciences (Talvitie 1962; Valovirta 1986; see also Sotarauta et al. 2017; Ortega-Colomer et al. 2017).[1]

Tampere was also one of the beneficiaries of the regional expansion of the Finnish higher education system in the 1960s. The Societal Institution of Higher Education (later University of Tampere) was transferred from Helsinki to Tampere, and in 1965, a branch campus of the Technical University (of Helsinki) was established in Tampere with a statute from the Ministry of Trade and Industry. This institution was the predecessor of Tampere University of Technology. The development in Helsinki and Tampere was thus different as the two technical institutions evolved into new institution of different educational sectors: the technical institute in Tampere became the Tampere University of Applied Sciences and the branch of the technical institute in Helsinki became Tampere University of Technology. In 1972, the branch campus gained its independence by an act of parliament and started its operations under the auspices of the Ministry of Education. The newly established technical university took a role as an active regional and societal actor by emphasising further education and product development as two strategic goals. It was given a mission to ‘provide highest education in technology and architecture, carry out scientific research and product development in addition to the other technological advancement’ (cf. Häikiö 2015; Ortega-Colomer et al. 2017).

[1] For more detailed summary of the development based on documented history of technical education in Tampere, see Ortega-Colomer et al. (2017).

Since 2010, Tampere University of Technology, TUT operated as a foundation, an identity which differs from universities operating as public entities, and fits well with TUT's principles of industry-related cooperation and fee-based research. When established, the TUT Foundation raised a capital of € 137 million, which consisted of private investments[2] of € 40 million, and state investment of almost € 100 million. The proceeds of the foundation capital have also made it possible for the university to invest both in research and teaching, especially in new learning environments and the development of its quality and operations management.

9.3 Higher Education Mergers in Finland

The higher education system in Finland was expanded and regionalised when the universities of applied sciences were established in the 1990s. Already some two decades later, because of a demographic shift, there is a need to decrease the number of higher education institutions. In addition, larger institutions are seen as more competitive and more likely to reach a higher level of regional and international impact. Following this, several mergers have been implemented in Finnish higher education since the mid-2000s (Aarrevaara and Dobson 2016; Ursin 2017), and the trend continues. This 'structural development of the Finnish higher education system,' was ministry driven, except for Aalto University (Ursin 2017, p. 308), and has been limited within the sectors of the binary-system, so that universities of applied sciences have merged with universities of applied sciences and universities with universities. Currently, mergers initiated by the institutions themselves are challenging the boundary between the two sectors. Although the ministry supports mergers, the dual system and different roles of the universities and universities of applied sciences have still been emphasised in the ministry's resolutions. The plans involving both universities and universities of applied sciences have spurred a need to change legislation restricting the possibility to buy parts of the teaching from another institution. In late 2017, a law was passed to facilitate teaching cooperation between the two sectors, so that universities could, for example, buy teaching from universities of applied sciences even though the legislation governing the degrees remains separate, and the responsibility of the content of the degree is on the institution conferring it.

From the point of view of mergers that involve technical education, the creation of Aalto University in 2010 set the standard. When Aalto was formed, it also became a foundation university, as allowed by a new universities act in 2009. Aalto University was modelled as an innovation university with a strategically new and

[2] The main investors were Technology Industries of Finland the lobbying organisation for technology industry companies, Academic Engineers and Architects in Finland TEK, the trade union for highly educated professionals in technical fields., Tampere Chamber of Commerce and the Åkerlund Foundation, which focuses on supporting the development of expertise and education in the field of media.

interdisciplinary approach to technology, design and economics (Tienari et al. 2016, p. 25). The merger was initiated from within and strongly supported by industry. The government also invested a significant amount of fresh money into the new university.

Now, Aalto is known nationally and internationally and has created a brand. Despite this, as Aarrevaara and Dobson (2016) argue, it has not reached the world-class expectations placed on it. Organisationally, in Aalto University, there were three schools initially, and six from 2011 onwards, which have remained quite autonomous with many decisions being made on school-level. Thus, there are relatively few university-level regulations and practices (Tienari et al. 2016). Although Aalto has not quite reached all the goals set for it in the merger, it remains the main competitor of post-merger Tampere University in the field of technical education and research within Finland.

According to Tienari et al. (2016), the ‘main integrative mechanisms deployed in the Aalto University merger in 2005–2011 included crafting a bold and forward-looking strategy, introducing a new common university brand, and developing a new tenure track career system for academic faculty’. Some of these aspects, such as the tenure track system, have been adopted by other universities, including TUT. The foundation model piloted by Aalto and TUT was chosen as the organisational form for the new Tampere University.

9.4 Tampere3 –Merger Process

The Tampere3 merger is constituted of two aspects. First, the merger of the two universities Second, the creation of a university consortium where the Tampere University owns the majority of the stocks of the Tampere University of Applied Sciences (TAMK). The Tampere3 process began as a voluntary merger with strong support from the Ministry of Education and Culture. The initial idea is attributed to the former presidents of the two universities. However, already at an early stage, there were political tensions about the effects of this merger on the dual system of Finnish higher education. This has become a national higher education policy issue rather than a threshold question for the merging institutions.

The three higher education institutions have developed shared teaching in certain overlapping fields (such as biomedicine, civil engineering and sustainable development, to name a few), but the university and polytechnic degrees must be issued by the university and university of applied sciences, respectively. Because of this, the new merged university and the university of applied sciences will remain organisationally separate entities. This has also caused some perceptions that the functions and administration of TAMK would remain almost unchanged within the university consortium. As a part of the increasing level of cooperation in Tampere3, teaching in each higher education institution has been opened up to the students of the other institutions as cross-institutional studies. This means that the students of all three institutions may take optional studies from the offering of the two other institutions.

As part of the curriculum planning process of all three higher education institutions, more shared and complementary skills and knowledge are discovered and defined together so that teaching of programmes will be offered more and more together in the future. These changes challenge the educational separateness of the polytechnic and university degrees.

Although Tampere3 is said to build on the existing strengths of the three higher education institutions, certain focus areas are emphasised, whereas others are not. The education and research visions of Tampere3 indicate that it expected to become 'the most significant undertaking to reshape the higher education landscape in Finland to date' and 'provide a unique hub for the interdisciplinary research on the economy, technology, health and society' (Tampere 3 web page). Even with these pronounced profile areas, there have been worries within TUT regarding the future of the role of technology in the new university compared with how technical education and research have been undertaken in TUT so far.

In addition to the changes in the organisational structure, education, institutional profiling and vision statements, there will be a change in the organisational culture and values. We approach the issue from the perspective of organisational identity. The experiences of university mergers elsewhere have suggested that the key to a successful merger lies in human factors (Eastman and Lang 2001; Cai and Yang 2016); mergers are always associated with a mixing and changing of people's values and cultures. Thus, the implementation of a merger can be understood as a process of institutionalising a new set of organisational values (Cai et al. 2016). Mergers have been seen as one tool for increasing interdisciplinary higher education and the overall efficiency and international competitiveness of the system, which are seen as significant to both institutional and academic identity.

Forming a large multi-disciplinary, comprehensive university brings about changes to organisational identities and cultures that are based on disciplinary divisions. In addition, a new division of labour in higher education is simultaneously challenging the traditional discipline-based academic identities as the one and only source of academic identity. In relation to disciplines, we reflect on how the different technical sub-fields at the technical university affect these representations of organisational identity from a disciplinary perspective. In order to study the formation of an organisational identity, we need to take a closer look at organisational identity as a concept.

9.5 Organisational Identity in a Merger Process

We are interested in identity as a collective social concept, where being a member of a group is key to a shared organisational identity. The identity of the group 'us' is defined in relation to others, and identity is built through social inclusion and exclusion. There are many theoretical attempts to describe this duality of identity or belonging. The distinction between friends and enemies has been used as a starting point for analysing any collective identity formation in political science (Schmitt

1927). The difference between ‘us’ and ‘them’ as the most significant segregation between groups of humans has been further elaborated by Bauman (2004), who shows that the difference is not referring just between two different groups of people, but rather between two totally different kinds of attitudes: trust and distrust, security and insecurity or cooperation and combativeness. ‘Us’ refers to a group of people that one belongs to; one would feel safe and secure in this group, feel at home and understand what is happening. Whereas, the ‘other’ represents the group in which one does not or cannot belong. From this point of view, understanding of the other group is diffuse and limited, and their behaviour appears unpredictable or even frightening (Bauman 2004).

The categories of ‘us’ and ‘them’ need each other to exist. The two polarities complete each other, and they exist because of that juxtaposition: this is the term of their existence. In both groups, identity is based on that polarity; the ‘outsiders’ are the force that ‘insiders’ need to build their identity and its coherence and solidarity (Bauman 2004). ‘We’ and ‘they’ are also formed through dichotomies where the other often receives negative connotations and through which a group can represent itself in a positive way. This way of using difference for identity construction is, to some extent, an oversimplification, ignoring any continuities and discontinuities between the opposites. Thus, it is possible to associate positive aspects to the other and negative to the self, respectively.

Although the differentiation between ‘us’ and ‘them’ is the analytical starting point, it should not be forgotten that this identity is a constructed representation evoked in the current study’s interviews when asking for definitions of identity. This representation of ‘we/them’ regarding the technical identity is now brought about in contrast to other academic and organisational identities. Organisational identity differs from the individuals’ personal identity because it is closely connected to the organisation’s perceived properties and the collective of the members of the organisation. When analysing organisational identity, the organisation or members of the organisation constitute the collective identity, ‘we’. The characteristics that particularly set the organisation as different from other (similar) organisations are defined as distinctive (Albert and Whetten 1985). These distinctive aspects of differentiation are the ones we are interested in regarding the representation of the identity of TUT as ‘we’.

The organisational identity and image of universities have often appeared in higher education literature (see Stensaker 2015 for an overview), but few studies deal with the organisational identity of universities in the context of university mergers. Tienari et al. (2015, p. 4) studied the Aalto merger and the formation of identity of ‘individuals and groups rather than the organization as a whole’. Another contribution to organisational identity in university mergers is Yuzhuo Cai’s doctoral thesis on mergers in Chinese higher education (Cai 2007). In the following, we look at previous research in this area, which is mainly based on Cai’s dissertation.

In organisational studies, the concepts of organisational identity and organisational image are interrelated and sometimes even used interchangeably. This approach has also been adopted in some organisational merger studies (Daniel and Metcalf 2001, p. 27). The definitions of the concepts are varied and should therefore be differentiated. Identity primarily refers to the internal perception of 'us' in the organisation, whereas image is related to the external perceptions of how others view the organisation or what is presented to them.

Organisational identity as an analytical concept was first introduced by Albert and Whetten, who state that the characteristics associated with organisational identity are 'central, distinctive and continuous over time' (Albert and Whetten 1985). Organisational identity is the self-definition of the members of the organisation or their understanding of themselves (Whetten 2006), which may be based on different aspects of the organisation, such as its history or function. Thus, the elements constituting organisational identity may be teased out by asking the members of the organisation to define who they are as an organisation. Organisational history, or 'saga', is a 'collective understanding of unique accomplishment in a formally established group', where history also maps the direction for the organisation's future (Clark 1972). According to Zundel et al. (2016), history is seen as a fundamental resource for establishing or maintaining organisational identity, which may be used to 'induce coherence in times of crisis, uncertainty and challenge'. Thus, history may have particular relevance to organisational identity when a merger brings about change and when the old organisational identity will be reflected on in anticipation of a new emerging (possible) identity. From this point of view, it is interesting to see how members of TUT describe the organisational identity of TUT when it is being challenged by the merger with higher education institutions that are inscribed with both similar and different characteristics.

Another aspect of organisational identity is defined through what the organisation does, or its function and task. This is often voiced in the organisation's mission and more closely related to the environment and market it caters to (Tierney 1991). Appropriateness to external environment, or the process of conforming to the demands placed by external stakeholders on the organisation (DiMaggio and Powell 1983; Meyer and Rowan 1977), are crucial to the task of universities.

In the case of higher education institutions, the relationships with society, industry and the market, have relevance through the way they contribute to what is known as the third mission, which is especially crucial for technical universities. In general, higher education institutions develop both their self-perceptions and external images through the realisation of the third task. From a higher education policy perspective, this is also a function that confers legitimacy to the institutions' actions. This concerns the values on external development of the organisation, such as the role of universities in society and the kinds of research, innovations and graduates the university should produce (Cai 2007).

As noted by Stensaker (2004, p. 24), 'organizational identity is a social institution the organization adapts to.' Thus, identity reflects the organisation's conformity to appropriateness in its environment. Universities are affected by the external factors of governmental policies, which, for example, aim to enhance the university's third mission or encourage mergers to create larger units and multidisciplinary education and research. On the other hand, the appropriateness may be derived from mimicking successful international or national higher education institutions and the aspects associated with the ideal of the technical entrepreneurial university. These aspects of identity that are related to the role of the university vis-à-vis society are also aspects often described in the mission statement and vision of the university (Cai 2007).

Organisational image is seen as something projected and represented by internal organisation members toward others. Organisational image, although a concept more rarely used in higher education studies, has significance in the context of an institution's reputation, ranking and prestige, but also in external beliefs on what the university is like. The image of a higher education institution in the current study can be understood to be how the institution is perceived by outsiders, whether in academia or in society, and what characteristics are associated with it. Ivy (2001) studied universities' organisational image in relation to marketing and student recruitment, arguing that higher education institutions need a distinct image to be competitive in the market and attract students and external funding. Thus, for universities, the image that needs to be projected is that of perceived excellence (Ivy 2001, p. 277).

In higher education studies, organisational identity has been studied often in shifting landscapes, and one of the major findings has been that new identities are not needed in changing times, but rather, what is needed is the ability to re-change identity to align with new work domains (Clandin et al. 2009 cit. Billot and King 2015). Seeing identity as a 'fluid and unstable concept' allows it to adapt when needed (Gioia et al. 2000, p. 63). Organisational identity may be different in a relational context, depending on what it is compared with, but also on who defines it. The event of an upcoming merger is a fruitful time to analyse organisational identity because change invites 'a heightened sense of belonging to the merging organization' (Tienari et al. 2015, p. 4).

In the current study, organisational identity refers both to the internal identity and external image as they are perceived and represented by the academics and high-level managers of TUT. Here, internal identity refers to how the managers of TUT perceive the identity of TUT within TUT, whereas the external image relates to how TUT is represented to and perceived by others. In the interviews, the identity of TUT is constructed internally as a technical university in relation to its history and organisational saga and externally based on its reputation and image, function and relation to society and external stakeholders and what kind of research and graduates it produces. All these aspects are contrasted against the aspects of UTa and TAMK, respectively. There are also institutional layers and organisational complexity within TUT that affect the representation of its organisational identity.

9.6 Organisational Identity and Entrepreneurialism—The University–Industry Nexus

As stated in Chap. 1 in this volume, universities already have an institutionalised organisational identity and technical universities have a particular entrepreneurial identity, which can be contrasted with the ideal of the Humboldtian comprehensive university. Often, technical universities are seen as closely connected with their environment, stakeholders and industry.

For the last three decades, literature and policy practices have emphasised the importance of university–industry relations, the importance of the relevance of academic work and research and the role of universities in national and regional innovation systems (Gibbons et al. 1994; Etzkowitz and Leydesdorff 1997; Lundvall 1992; Edquist 2005). These aspects have had a major impact on the organisational identities and images of universities and technical universities especially. In policy discourse, labels such as 'innovative universities' or 'entrepreneurial universities' (see Clark 1998) often have a positive connotation when it comes to technical universities. The two main approaches toward the role of universities in innovation systems, or more specifically in regional development, are the following:

1. Generative role, that is, the role of an organisation in supporting regional development by providing the knowledge, training and services required to support regional actors, strategies and traditional university–industry links. The main aim of collaboration is the capitalisation of knowledge.
2. Developmental role, that is, the role of an active organisation in shaping the regional development by participating in knowledge production in different arenas and different ways. The aim of universities is not to capitalise the research and teaching outputs but rather to engage with society (third mission). (Gunasekara 2005)

These two categories are not exclusive but overlapping. A generative role is more exogenous, where universities produce knowledge and research that in turn is utilised by society, whereas, in the developmental role, universities are seen as an integral participant in regional development (Gunasekara 2005, p. 102).

The culture related to university–industry links has also had a major impact on the constellation of academic identity. "Jain et al. (2009) describe the identity work of individual academics in the context of the commercialisation of science, noting on the contrast of the traditional (Mertonian) academic and entrepreneurial role identity." They emphasise that scholars who have engaged in active identity work have hybrid identities with relation to outreach (commercial) activities (Table 9.1).

From the perspective of individuals, both identities may exist simultaneously but require the tactics of '*delegating* and *buffering' to* constitute 'a hybrid role identity that comprises a focal academic self and a secondary commercial persona' (Jain et al. 2009, p. 922). In reference to the institutional role, there may be similar challenges and a need to consolidate these conflicting roles of being a research-focused

Table 9.1 Academic and entrepreneurial role identities compared (Jain et al. 2009, p. 924)

	Academic	Entrepreneurial
Norms	Universalism Communism Disinterestedness Skepticism	Uniqueness Private property Passion Optimism
Processes	Experimentation Long-term orientation Individualistic/small groups	Focus Short-term orientation Team management
Outputs	Papers Peer recognition/status	Products Profits

university and an entrepreneurial university that is actively involved in technology transfer.

9.7 Engineering Identity

There is relatively little research on identities in the specific context of technical universities. However, there are many studies on the identity of engineering education as a newly emerging 'discipline', building its own identity (cf. Gardnerer and Willey 2016). One U.S. study on the engineering identity of faculty was found, providing a narrow (but deep) qualitative approach of a single case study (Pawley 2009). From her interview data, Pawley distinguishes three 'universal' homogenic narratives of engineering faculty identity. According to Pawley (2009), these narratives simultaneously model and construct 'engineering' for the faculty members themselves and for others within the disciplinary space of academia. The narratives are as follows (Pawley 2009):

1. Engineering as applied science and math. Engineering was contrasted to science and math and described as an obligatory passage point between science and society.
2. Engineering as solving problems. Engineering is solving real problems that might be received from outside the university. However, there is a difference between the work of academic engineers and actual applications and solutions.
3. Engineering as making things. Engineers, unlike science graduates, are making highly technical and mechanised products.

It seems that the applicability and relevance of the nature of engineering work of academics is the most significant constructing characteristic of engineering identity in academia. Engineering is also considered multidisciplinary in its approach to solving actual problems.

As such, engineering identity has been studied widely. To introduce the literature, we refer here to a systematic literature review by Morelock (2017). According to his mostly qualitative data, engineering identity research (published in engineering education forums) has boomed. Most of the studies concern students in different school levels and higher education, as well as professional engineers. Engineering identity seems to be related to an academic background, profession, gender and engineering experiences. According to Morelock's (2017) analysis, eight aspects of engineering identity (of students) can be recognised:

1. Problem-solving ability
2. Technical knowledge in math and science
3. Creativity and innovation
4. Communication
5. Integrity and ethics
6. Positive social impact
7. Lifelong learning
8. Application of knowledge

When analysing the empirical data, we shall also see whether these aspects of engineering identity described above are present in the self-representation of the aspects of the organisational identity and technical disciplines of TUT and how these aspects are contrasted to the representations of UTa and TAMK as the 'other'.

9.8 Academic Identity

Academic identity in technical universities is constructed of two dimensions: education and research. Additionally, the institutional logics of engineering education consist of two professional logics, which are based on different assumptions, beliefs and values. The first one is the logic of the *engineering profession* based on the teachers' mission of educating the next generation of engineering professionals. Here, the emphasis in engineering education is to prepare students to work on practical issues, meaning they should be able to apply and integrate their theoretical knowledge in practice. The second logic is the *academic profession*, which is the logic of the academic educators, where the mission is more transferring the theory of their discipline; students should learn disciplinary theories and be prepared for a research career. The academic identity of the educators is strengthened by the fact that they all have PhD degrees in a technical discipline. These two logics—the engineering profession and the academic profession—constitute the dual nature of engineering education, which comprise a meaningful relationship because both sides are necessary. However, there are contradictions and tensions between the logics. Edström (2017, p. 75) gives an example: 'the capacity to teach disciplinary theory is strengthened by the academic logics while the professional logics create capacity for addressing also the other necessary aims for the curriculum'.

There is also a similar kind of tension in doing research at a technical university, making it challenging to form a researcher identity. Research can be considered a knowledge for its own sake, one that aims to further the discipline or to be useful in society. Therefore, the university can be considered as having two beliefs: the university of academia, where the aim of the research is to further the discipline and the university as a public service, where the aim of the research is guided by consideration of use (Edström 2017, pp. 73–75). Consequently, the academic identity in technical universities involves aspects of research and teaching, as well as tensions between foundational academic science research versus applied research. In this sense, technical identity emphasises the relevance and practical applications of knowledge (Fig. 9.1).

Technical universities oscillate between scientific and practical orientation and between foundational sciences and applied sciences. Although engineering sciences are seen as a distinct discipline from the natural sciences, they are considered to be based on them. It may be questioned whether engineering sciences are only applied natural sciences or if they have their own methodologies and epistemological criteria (Hansson 2015, p. 20).

Another distinction between these disciplines is that the natural sciences are categorised as hard and pure sciences, and engineering sciences are defined as hard but applied (see also Becher and Trowler 2001), more professionally oriented and more oriented towards application and solution. In previous research, engineering identity is often related to student identity or professional identity, but not necessarily to institutional identity (Hansson 2007; Edström 2017; Myers et al. 2012; Tonso 2006).

Technical universities usually combine both natural sciences and engineering disciplines. According to the Government Decree on University Degrees, the degrees awarded at TUT are all in the field of engineering (technology), but the teaching responsibility includes also natural sciences (1439/2014).[3] Technical universities may seem homogenous in their fields and disciplines from the outside, whereas internally, differences and disciplinary divisions are distinguished both within natural sciences and engineering sciences.

According to international comparisons, organisationally, many technical universities have separate science and engineering faculties to accommodate for the

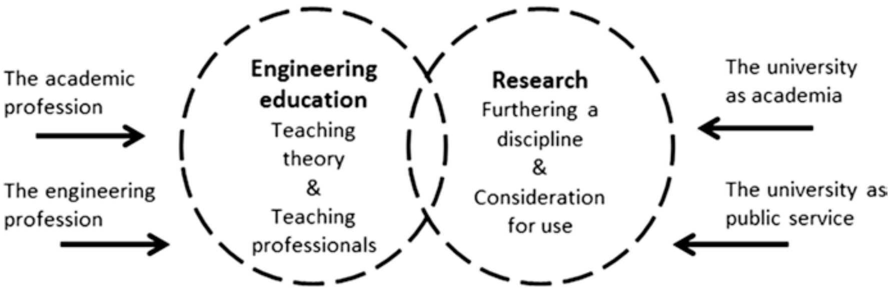

Fig. 9.1 The two logics of engineering education (Edström 2017, p. 77)

[3] 'Tampere University of Technology had responsibility for natural science education in fields specified in the Ministry of Education Decree. The degree title is, however, always one used in the field of Technology' (1439/2014, p. 16).

differences between the foundational and applied sciences. However, the structure of TUT only partially complied to this distinction.

9.9 Data and Methods

With this case study, our assumption is that an organisational perception of the aspects of ‘technical’ and ‘academic’ are constructed in such a way that these two overcome the differences between the different fields of natural science and engineering and categories of staff. When depicting the technical university’s organisational identity, we approach identity formation from an organisational point of view and therefore chose to interview mostly senior academics who have been actively involved with the merger process. They are in a key position to reflect the identity of TUT and contrast it against those of UTa and TAMK. Summing up, we are more interested in internally converging identities than in diverging identities.

The empirical data for this chapter consist of nine interviews conducted at TUT between April and June 2017. The interviewees were professors, deans and the upper managers working in TUT. The interviews were conducted at TUT campus, except one that was done by phone. The interviewees were mostly people who had been working their whole career in a technical university or at least at some university with a technical faculty and many years at TUT afterwards. The interviewees were in the position that they had a good perception of the organisational identity and image of TUT and were involved in the construction of the organisational image.

The interviewees were asked to reflect on the differences and similarities of the merging organisations and present their views regarding the perceived threats and opportunities that the merger process posed regarding the technical identity. The anonymity of the interviewees has been secured by presenting more analysis of what they have said rather than direct quotes.

The interviews were analysed using qualitative methods by utilising a data triangulation method. One of the authors analysed the interviews by approaching them from the perspective of comparing TUT with UTa. The second author was doing the same data-driven analysis but approaching it from the perspective of comparing TUT with TAMK. The third author went through all the interviews and constructed an overall understanding of TUT’s organisational identity and image. As a result, the tables in the appendix and Figs. 9.2 and 9.3 were constructed to define how the identity of TUT was built within the interviews. The fourth author summed up the discussion in the context of the merger process. After an independent analysis, the other authors went through the findings, and finally, the four authors discussed the findings and wrote the conclusions.

Some of the differences between TUT and the other institutions are based on dichotomies where TUT is represented clearly as the positive norm and the other higher education institution as deviating from the norm. However, when some aspects of TUT are described without contrasting them to the other, it may be an over-interpretation to then see the other as implicitly the opposite; however, in some instances, this may be implied. The representations of TAMK and UTa when contrasted to TUT are also based on the perceptions of academics at TUT and thus do not reflect the organisational self-images of TAMK and UTa, respectively. Comparing TUT with UTa and TAMK was approached from following perspectives:

- Organisational identity in a merger process (organisation)
- Organisational identity and 'technical entrepreneurialism' (university–industry nexus)
- Academic identity and the research-oriented technical university (academic, technical)
- Practical orientation and engineering identity (engineering)

If the academics at UTa or staff at TAMK had been interviewed with similar questions on organisational identity in contrast to the other two higher education institutions, the results would have been quite different. It should also be noted that the interviewees were asked about their identities in relation to research, teaching and organisation; thus, these are also the aspects they mostly describe when discussing TUT's organisational identity.

It must be acknowledged, that the interviewees occasionally questioned the shared identity and unity of the organisation and said that there was internal variation and differences within TUT. Some of the dichotomies between TUT and the other institutions are alleviated by saying that these representations are based on stereotypes or over-simplifications. In some interviews, the interviewee distances him- or herself from TUT or from the natural scientific or engineering discipline when talking about the organisation or the discipline generally but saying that she or he represents an exception to this.

9.10 Organisational Identity of TUT Compared with UTa

At the beginning of the interview, the interviewees were asked how the disciplines at TUT differ from the corresponding disciplines at UTa and TAMK. The interviewees quite often started to answer this by relating to engineering identity as a discipline, thus representing the organisational identity of TUT as closely linked to engineering sciences. The identity of engineering sciences as an academic discipline and the professional identity of university-educated engineers (MSc in technology) is strong when contrasted against the representation of UTa as the other. Engineering identity is described quite precisely in the interviews, whereas the academic identity of UTa remains somewhat elusive although it is seen mostly based on social sciences and humanities. When considering its academic and disciplinary base, TUT has a shared foundation in mathematics and natural sciences, whereas the disciplines at UTa are diverse, and their foundations differ from one another. This difference between shared and diverse disciplinary foundations was an evident aspect brought up by all of the interviewed academics. There might be two reasons for the clarity of the definition of engineering sciences as a discipline. First, this may be because the definition is asked from those representing the discipline themselves, and second, it may also be because engineering is a highly paradigmatic discipline. According to Gardner and Wiley, engineering 'research is typically positivistic in outlook and dominated by quantitative methods' and thus is seen as unified when contrasted with other less paradigmatic fields, such as education or social sciences, where there is little 'agreement on appropriate research questions' and 'appropriate methodology' (Gardner and Wiley 2018, p. 235).

Reflecting on the theoretical definitions of engineering identity, two of the three narratives of engineering identity described by Pawley (2009) are found in some form in all the interviews: 'engineering as applied science using natural sciences and math' and 'solving problems for society'. One of the interviewees defined both narratives as follows: '…what is engineering? Well, it is problem solving. And there is a mathematical and natural sciences base, so it is problem solving through mathematical and natural sciences'. However, despite the aim of the research in technical universities to be usefull in society, there is also the aim to further the discipline (Edström 2017, pp. 73–75). The emphasis between these two was different in TUT compared with UTa, which was seen as more theoretical in its research.

From the perspective of education, engineering discipline and the degree of Master of Science in Technology were the foci of identity definition. The degree is seen as being associated with a strong brand and having a good reputation among employers. Degrees at TUT included numerous mathematics and natural science courses, and this was seen as a strong basis for technical fields and something that should not be diluted; if the extent of these studies is diminished, the Master of Science degree's reputation will be lost. Similarly, some of the core aspects Morelock (2017) identifies as part of engineering identity were found in the interviews. The most eminent aspect was that of 'problem-solving ability', but also the 'applicability of knowledge'. Another strong aspect was 'the shared scientific or educational basis of math and science'. Regarding creativity and innovation, two interviewees mentioned the latter as typical for the organisational identity of TUT and it was mentioned as a characteristic of teaching at TUT by one interviewee. In technical universities, the emphasis in engineering education is more on how to prepare students to work with practical issues and apply their knowledge in practice rather than teaching them disciplinary theories and preparing them for academic careers (Edström 2017, pp. 73–75). Additionally, this difference is seen as significant between these two universities.

The aspect of 'communication', which Morelock defines as more related to individual engineering identity, was mentioned in terms of organisational identity associated to TUT. Engineering identity was not referred to as communicating, but the organisation of TUT was seen as communicating; there was a low level of hierarchy, and communication between different levels of the organisation was both direct and efficient. In addition, 'positive social impact' was attributed to the close relationship TUT was described to have with society. This part of organisational identity is related closely to the university's function and appropriateness to its environment, which is mentioned in the theoretical framework of organisational identity and contributed to the representation of TUT as an entrepreneurial university. Two of the dimensions Morelock sees as distinctive for engineering: ‘integrity and ethics’ and ‘lifelong learning’ were not mentioned at all in the interviews.

One of the interviewed academics summed up that technical fields do not constitute a discipline, but rather, an applied field based on natural sciences where the dividing line between the different disciplines is artificial. These aspects of engineering identity depict the discipline, the education and the ensuing identities of the researchers and graduates as much more uniform than those of the researchers and graduates of the comprehensive university. In some of the interviews, the identity based on engineering sciences was somewhat questioned by representing TUT as multidisciplinary and creating a division between the foundational natural sciences and applied engineering sciences.

There were also organisational aspects that TUT and UTa share, which seemed to be mostly associated with the organisational identity of universities as organisations. TUT and UTa were both described as scientifically oriented and academic, but the differences in these two were highlighted in their external relations, that is, their contributions to science and society. TUT was seen as more entrepreneurial and industry-oriented: the impact to society came naturally from its close collaboration with companies in society, whereas UTa was somewhat aloof, analysing or trying to influence society from the outside and focusing more on basic research done inside the university. This reflects the developmental role in knowledge production and engaging with society associated with entrepreneurial universities (Gunasekara 2005). TUT was also represented as more internationally research oriented, and the research was done to solve real technical problems together with specific industry. Research done in UTa was defined as done for the sake of research itself, and if it had an external interest, it was mainly contributing to Finnish society.

When discussing the differences between TUT and UTa, the organisational identity of TUT was seen as being strong compared with the organisational identity of UTa. In its self-representation, TUT was an autonomous foundation university that was well-organised and professionally lead, whereas UTa was a state-governed university with internal discussions and inclusive aims for democracy, which lead to little unity in the organisation and a decentralised, weak leadership. Thus, it seems that in addition to the organisational identity aspects associated with technical universities in general, such as entrepreneurialism and engagement with society, the organisational aspects of TUT were complemented with the identity of a foundation university.

Based on our analysis, the organisational aspects that the interviewees used for identifying TUT compared with UTa were: (1) industry relation, (2) organisation, (3) relation to society, (4) discipline, (5) research, (6) motivation for research, (7) paradigm, (8) students/student union, (9) evaluation of results (in research), and (10) teaching/student selection. These aspects cover almost all aspects of academic work. The major differences are described in Table 9.2 in the appendix. By summing up these reflections, the major aspects of UTa were as follows:

- Variety of disciplines/multidisciplinarity, mainly social sciences and humanities

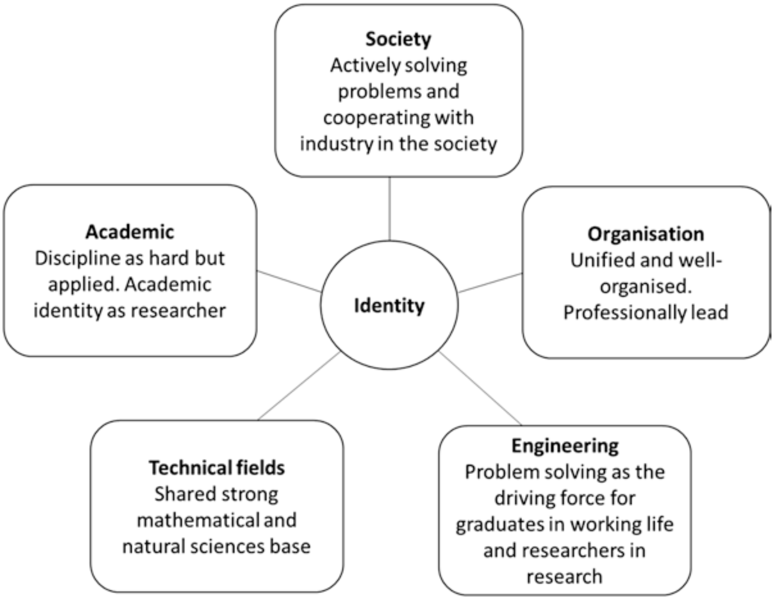

Fig. 9.2 Organisational identity of TUT when compared with UTa

- Finnish society and the public sector as stakeholders
- Research on and contributing to Finnish society
- Organisationally less organised

In comparison, the major aspects of TUT were the following:

- Shared disciplinary basis of mathematics and natural sciences
- Industry relations
- International science and research
- Organisationally well-organised with strong leadership

These aspects reflect quite well the disciplinary aspects of engineering sciences and the aspects associated with the entrepreneurial university. In addition, we see an association with international research compared with an association with research contributing to Finnish society as a distinctive characteristic of this particular case.

In Fig. 9.2, the major building blocks of the identity of TUT are described when compared with UTa.

9.11 Organisational Identity of TUT Compared with TAMK

When considering the academic and disciplinary base, TUT had a shared foundation in mathematics and the natural sciences in both research and education, whereas the disciplines at TAMK were considered more applied. The identity of engineering sciences and university-educated engineers (MSc in technology) was strong when contrasted against the representation of TAMK as the other, as the polytechnic degree was seen as a more practical, hands-on degree. The participants noted that after the merger, the best students from the polytechnic degree studies could be enrolled in academic engineering studies (BSc or MSc in technology), and university students who do not have academic ambitions could finalise their studies in the polytechnic. From the perspective of education, the degree of Master of Science in Technology was the focus of the identity definition. It was considered an academic degree providing generic problem-solving skills, not just professional competencies. Thus, the engineering identity aspects (Morelock 2017) were more associated with TUT than the TAMK degrees in engineering.

When discussing the differences between TUT and TAMK, the organisational identity did not play a significant role. The main dimension of differentiation came from the research intensiveness of TUT compared with the more applied and teaching-oriented TAMK. TUT took on the academic, even elite, university identity, but did not emphasise the entrepreneurial identity as much.

In the analysis we looked at the aspects of: (1) industry relation (2), organisation, (3) relation to society, (4) discipline, (5) research, (6) motivation for research (knowledge interest relevance), and (7) student selection and whether the interviewees used these for comparison between TUT and TAMK.

It must be acknowledged that the comparison was not as rich as it was with UTa. In addition, only one interviewee mentioned the organisational differences, and the relation to society was narrowed down to industry only, and the comparison of students was qualitatively different. Summing up the major differences (see Table 9.3 in the appendix) the major aspects of TAMK were the following:

- The importance of teaching (over research)
- Regionalism and professionalism with a service-orientation
- Lower academic quality of students
- Staff as workers

In comparison, the major aspects of TUT were the following:

- More abstract theoretical and methodological approach in teaching
- International science and research
- Planning and finding new solutions, not implementing and developing professional skills
- Elite academics

In certain aspects, TUT and TAMK were described to be equally important, different types of institutions but overall, the TUT identity was considered superior

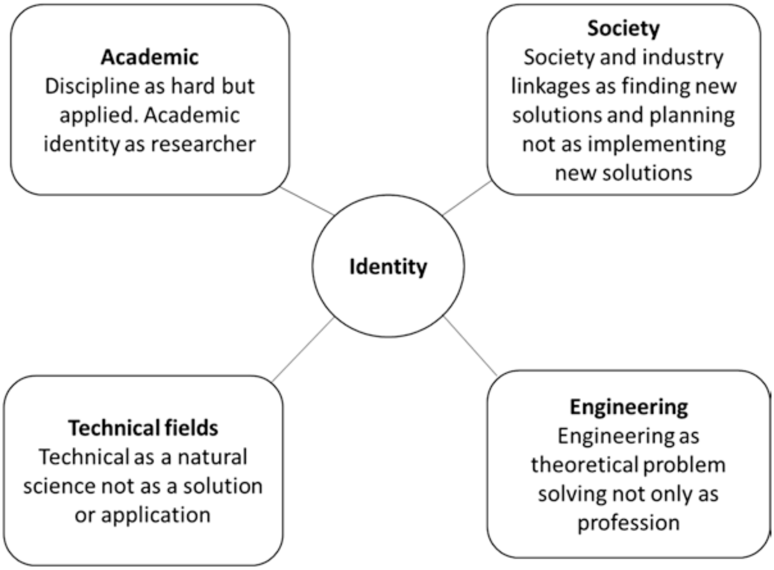

Fig. 9.3 Organisational identity of TUT when compared with TAMK

and more scientific. The major difference was seen in the main function of the institution (teaching vs. research). Yet the answers were not nuanced, and there was no major discussion on the organisational differences other than teaching versus research intensiveness. The research done at TAMK was considered applied and not as creative as what was done at TUT. The scientific natural sciences foundation, as represented particularly in the level of mathematics, was considered a significant characteristic in separating the teaching in these two institutions that otherwise were not considered that different. Figure 9.3 describes the major building blocks of the identity of TUT when contrasted against TAMK.

9.12 Conclusions

In this chapter, we have discussed how the identity of a technical university was challenged in the context of merging three Finnish higher education institutions. Despite the relatively long merger process and finding similar content in the teaching of the three institutions, the identity of the technical university was represented as quite strong and separate from the other two institutions and that of UTa in particular. The comparisons with TAMK seemed somewhat less important. This may be because TAMK is already categorised as an institution of a different type (polytechnic) and as serving a different purpose, that of a more practical orientation.

According to the nine interviews conducted at TUT, the most important dimensions of identity were engineering identity, scientific academic identity, technical identity and relation to the wider society. Contrary to our assumptions, it seemed that the organisational identity was important for the identity of a technical university only when compared with a multidisciplinary university. Confrontation with UTa brought out TUT's strong shared basis on the natural sciences, impact on society, close collaboration with industry, solution-oriented thinking and strong organisational leadership. When comparing the identity of the technical university with TAMK, the interviewees from TUT emphasised their scientific academic identity, which is based more on research, not teaching. In addition, the Master of Science degree was emphasised as trusted among employers and as a degree with a special prestige.

In the merger process, TUT's position and its technical identity can be seen as between a rock and a hard place—neither UTa nor TAMK are providing a similar and attractive partnership for identification in the future that would provide more prestige than being a single-faculty technical university. However, many of the interviewees emphasised some new interesting opportunities for future collaboration after the merger although this collaboration was often mentioned with a research field with similar interests. Collaboration with TAMK would include more emphasis on the technical fields in the new higher education institution but at the same time focusing more on teaching and educating the professionals for a first-cycle degree. Collaboration with UTa would include a more academic aspect, but it would not bring more prestige to technical fields; however, it could be argued that multidisciplinary research is valued in the current research landscape, especially when it provides new perspectives in solving societal challenges. This is also the approach taken in the strategic plans concerning the Tampere merger. The positive views of the merger may be because the interviewees were all actively involved in the planning and implementation of the merger. Had we asked other members of TUT, the answer might have been completely different.

Organisational identity will change because of the merger, but how much will this affect the academic identity of TUT's current disciplines of natural sciences and engineering? At TUT, the academic identity seemed to converge to large extent with the university's organisational identity. It will take some time for the new organisational identity of Tampere University to emerge. It would be interesting to see some years after the merger what kind of technical identity is defined and represented within the new university and whether the aspects are similar as those represented in this research or if they have changed. It may also be possible that the natural sciences and engineering sciences find new identity categories and that their shared identity based on TUT's organisational identity will not carry over to the new merged university. It remains to be seen which aspects will still be associated only with the technical fields and which aspects of the technical university cannot be reconciled with the organisational identity of the new comprehensive university.

Appendix

Table 9.2 Summary of the interview findings comparing TUT and UTa

Term used by interviewed	TUT	UTa	Mentions (interview numbers)	Theoretical aspect
Industry relation	Close relation to industry Industry driven External funding	Non-existent, vague or loose relation to industry	1, 2, 3, 4, 5, 6, 7, 9	Society
Organisation	Well organised Leadership driven Linear organisation Unified Low hierarchy Openness Straight forward Open to change/ efficient/agile Private foundation, autonomous Budget conscious/ economic	Not organised No or little leadership Democratic, collegium Diverse Authoritarian Individual Defensive, old fashioned, stabile State bureau State-steered	1, 3, 4, 5, 6, 7, 8, 9	Organisation
Identity, culture	Technical Master of Science (Engineering) Engineering student Homogenous	Not named Master of Philosophy Heterogeneous	1, 4, 6, 9	Engineering
Relation to society	Part of society, working within and together Industry	'Outside of society' Trying to influence society Public sector	1, 2, 3, 4, 5, 7	Society
Discipline research	Science/natural sciences Mathematics Hard Applied Technical Engineering Research oriented	Social sciences Humanities Soft Basic Multidisciplinary Teaching oriented	1, 2, 4, 6, 8	Academic

(continued)

Table 9.2 (continued)

Term used by interviewed	TUT	UTa	Mentions (interview numbers)	Theoretical aspect
Motivation for research Paradigm	Solution driven, Solving real problems Building, innovation driven change driven Practically oriented Shared/common International Experimental, machine/laboratory Measurable objective results	Theoretically driven, Research for research sake problematising, critical Methodologically oriented Diverse/freedom to choose Domestic, local Theoretical Method Subjective results not evaluated as good or bad	1, 2, 4, 6, 8	Academic
Students/ student union	Not politicised Implicitly right wing? Good relation with students and the university	Politicised Leftist Hippies Overtly green values, 'tree huggers' Anarchist traits	4, 9	Organisation
Evaluation of results (in research)	Exact indicators, numbers on personal level	General indicators on school level	1	Organisation / Academic (research)
Teaching/ student selection	More pragmatic Demanding/more work compared to credits Number of applicants relevant Attractive programmes/ modern teaching methods	(implicitly) Traditional/ old-fashioned teaching methods	1, 4, 5, 6, 7, 8	Organisation / Academic

Table 9.3 Summary of the interview findings comparing TUT and TAMK

Term used by interviewed	TUT	TAMK	Mentions (interview number)	Theoretical aspect
Industry relation	Solutions/new knowledge	Application	5, 8	Society
Organisation	Closer to TAMK than UTa	More managerial	4	Organisation
Identity	Research (academic staff) Engineering, theoretical	Teaching (staff) Engineering, practical	1, 2, 5, 6, 7, 8, 9 4, 5, 7, 8	Engineering
Relation to society	Not mentioned	Relation to society narrowed down to industry only	5, 8	Society
Discipline research	International engineering science	Regional engineering profession	3, 7	Academic
Motivation for research Paradigm	Solution driven, theoretically driven, methodologically (natural science, mathematics) oriented Planning	Application-driven services, tailoring Implementation	1, 2, 3, 6, 8 3, 4, 6, 7	Academic
Student selection	Social 'elite status' Academic ethos Better students	Social 'workers status' Professional ethos More challenging students	8 4 3	Organisation/ Academic

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Chapter 10
Engineering Academisation: The Transition of Lower Level Engineering Education from Upper Secondary School Level to Higher Education

Per Fagrell and Lars Geschwind

10.1 Introduction

By the end of the 1980s, engineering education in Sweden was being provided in two main forms: a relatively practice-oriented engineering degree at the upper secondary school level (Technical College Graduate, *gymnasieingenjör*) and a more theoretical engineering degree at the technical universities (master of science in engineering, *civilingenjör*). However, this was changed by a decision in the Swedish parliament (*Riksdagen*) in 1989 that upper secondary engineering would be transferred to the higher education level in the early 1990s and at the same time be extended. The reasons for the reform explained that Technical College Graduate education needed to be more internationally viable and comparable, and that the labour market and technology development demanded this extension. The decision in parliament had been preceded by around 15 years of investigations, lobbying and try-out periods.

Like the old Technical College Graduate programme (henceforth called T4), the new engineering education system would be spread geographically throughout Sweden and run at technical universities, comprehensive universities and university colleges. Traditionally, engineering education at the university level was concentrated in the existing technical universities, which ran educational programmes awarding the degree of master of science in engineering (hereafter 'master's programmes'). This was a timely and welcome decision for many university colleges in Sweden that had been created after the Swedish higher education reform of 1977. Most of these were small and usually had very limited activity in the field of technical education. The decision gave them an opportunity to broaden and expand their

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activities within this field. As for the technical universities, this decision created an opportunity to expand activities within a short period. Upon completion, the reform would mean an approximate doubling in the number of students enrolled in the field of technical/engineering education.

Many other countries had already implemented similar reforms to elevate their domestic, traditionally more practically oriented, engineering education, such as Germany and France in the 1960s (Delahousse and Bomke 2015), even if they organised engineering education within two different educational systems. In several European countries, similar systems were developed at the same time, that is, a dual education system for engineering programmes, with engineering master's programmes at the university level on the one hand, and more practically oriented engineering programmes on the other. The latter often had their own organisational forms – Teknika (Denmark), Regional Technical Colleges (Ireland) and Universities of Applied Science (The Netherlands) (see Christensen and Newberry 2015, for more about the Danish, Dutch and Irish examples) – and were separate from the university. Svein Kyvik (2009) calls this phase of the development of engineering education 'horizontal integration', characterised by a transition to a dual system consisting of research universities and professional colleges, sometimes referred to as polytechnics or universities of applied sciences.

In fact, in 1974, the Swedish Higher Education Authority (UKÄ) had already suggested to the Swedish government that a new type of shorter engineering programme should be established within the universities. One of the reasons for the proposal was that other countries had already implemented this type of reform. While the proposal was turned down by the government, it can still be considered the starting point for a period of investigations and discussions that lasted for 15 years. It was also the starting point for the historical study underlying this chapter, in which the main research question concerns the technical universities' response strategies to the proposals for reform of engineering education, a reform that could have a huge impact on the activities at the technical universities, potentially even changing their organisational identity.

10.2 The Settings

10.2.1 Political and Social Developments

The Swedish economy experienced rapid growth after World War II, boosted by the fact that the country, and especially the industry, were more or less unharmed by the war. However, growth slowed in the early 1970s when global events, particularly the 1973 oil crisis, triggered a recession throughout the western world that went on into the 1980s. In Sweden, the recession revealed several structural problems within society, not least in industry. Even before the recession, a global left-wing movement had depicted private industry as an 'enemy of society'. In combination with an emerging environmental movement, this affected society's – and not least young people's – view of technology and industry in a negative direction. In concrete terms, the interest in science, engineering and technology studies decreased (Feldt 1991; IVA 1985).

A new Social Democratic government began its term in 1982 with a firm devaluation of the Swedish krona (16%), mainly to strengthen the competitiveness of Swedish industry. This, together with a generally improved business climate in key export countries, led to an increase in industry's demand for labour, including engineers. In order to determine whether this growth in demand was cyclical or more structural and consequently persistent, the government issued an investigation assignment to the Royal Swedish Academy of Engineering Sciences (IVA) in 1984 to map labour market needs and propose measures to ensure the availability of qualified technicians (IVA 1985, p. 67). In our study, it has been assumed that, as a stakeholder, IVA had a close relationship with the technical universities, thus making it relevant for this study. The IVA report presented in the autumn of 1985 is cited frequently in other studies and reports addressing changes in engineering education (T4) and is thus considered an important piece of the puzzle addressed in this study.

10.2.2 The Higher Education Institution Landscape

Compared with the Swedish higher education system of today, that of the 1960s and 1970s was more centrally controlled by parliament and government. The State (i.e. the parliament and government) made decisions at a detailed level about, for example, a university's internal organisation, professorships, salary levels, and premises and equipment (Askling 2012). However, the detailed regulations required less administration in the form of follow-up, reporting and reports, a consequence of today's New Public Management–influenced control system (ibid.). In 1977, a comprehensive higher education reform was implemented that aimed to connect higher education more closely to the labour market and its needs for skilled labour. The reform implied even greater central control, but at the same time, universities and university colleges received relatively greater local/regional freedom and responsibility to design and distribute their educational activities (Andrén 2013, pp. 85–86).

However, at least for the society outside the universities, the biggest change was the creation of more university colleges in Sweden. Ten cities received their own university college units instead of hosting branches of existing universities. Several undergraduate programmes were associated with these new university colleges and with existing universities, mainly in professionally-oriented education, which previously had no higher education status, such as preschool education, nursery education and art education. The new university colleges could initiate shorter technical education programmes but did not have the opportunity/permission to offer master's programmes. However, the 4-year Technical College Graduate engineering course, which formally consisted of a 3-year programme at the upper secondary school level with one vocational year on top, was not included among the new higher education qualifications. In practice, this meant that the new university colleges had few opportunities to build activities in the field of technical education with any kind of volume.

10.2.3 Technical Education in Sweden

At the end of World War II, there were master's programmes in engineering in two cities in Sweden: at KTH in Stockholm and at Chalmers in Gothenburg. As in most other countries, the focus of the technical universities had up to that point been on engineering programmes that were aimed at a future for graduates as reasonably practically oriented engineers working outside the academy. The teachers, and thus the programmes, were supposed to be scientifically anchored but there were no resources allocated for research (Björck 2004; Lindqvist 1992).

After World War II, a rapid change took place in technical universities globally. Technological developments during World War II, not least the development of the nuclear bomb, had shown that efforts were needed in science and technology research to conquer new knowledge domains. Essentially, this was solved in two different ways; either the research was mainly placed at research institutes, more or less linked to the universities and their educational programmes, or the research was expanded at universities, thus closer to engineering education. In Sweden, the latter option prevailed, and KTH and Chalmers were developed in the 1950s, 1960s and 1970s into research-intensive technical universities with international ambitions (Lindqvist 1992).

By the mid-1970s, there were well-established master of science in engineering degree programmes in six cities in the country, with approximately 3500 students enrolled every year (Utbildningsdepartementet 1989; IVA 1985, p. 33). No other engineering degree programmes existed at Swedish universities or university colleges before 1977, with the exception of a very small number of operations & maintenance engineers and marine engineers (a total of about 150 new students per year) (Utbildningsdepartementet 1986, p.109). Of the six cities with master's programmes, two were the well-established technical universities KTH and Chalmers. Another two were strong and rather independent technical faculties within the comprehensive universities of Lund and Linköping. These were organised and acted in many ways as independent technical universities, and in the following we will treat them as that. The remaining two were a technical department joined to a large science faculty within the comprehensive university of Uppsala and lastly the master's programmes in engineering at the (then) university college in the city of Luleå.

As mentioned earlier, T4 was a 3-year technical programme at the upper secondary school level with a vocational year on top, resulting in a 4-year Technical College Graduate degree (hence T4). The initial engineering education at this level had a long history and had developed in parallel with the technical universities'

Table 10.1 Number of new students in T4 education, 1973–1984 (Utbildningsdepartementet 1986, p. 106)

Year	Total	% Female
1973	6260	5
1975	6448	8
1977	7671	12
1979	9798	13
1981	11,315	14
1983	12,649	21
1984	12,490	22

master's courses, although T4 was spread out over many cities and schools. The course saw an increased number of new students throughout the whole of the 1970s and a significant increase in the proportion of female students (see Table 10.1).

T4 was also considered to be well functioning in relation to the labour market (Utbildningsdepartementet 1986, p. 115); few graduates were left without a job after graduating from the programme. In short, it was popular with both students and employers. However, as we will see later, according to several stakeholders there was a need for modernisation and quality improvement, in particular a need for adaptation to international conditions and standards.

10.3 Theoretical Framework

With the proposed reform of transferring upper secondary school engineering education to the higher education level, technical universities (and of course, to some extent, the university colleges) faced external pressure to change. Our theoretical framework therefore has as its starting point the different ways in which organisations in general can act when they experience such external pressures to change. The two extremes – *perfect flexibility* and *perfect inertia* – are less useful (Gornitzka 1999), even for analytical purposes. Oliver (1991, pp. 151-159) identifies five different strategies that an organisation can choose:

- Acquiescence
- The strategy/response is to comply and to follow non-questioned norms and institutional models, as well as to adapt, imitate and obey to new rules, norms and standards. This can be the case when organisational models and standards are very popular and spread rapidly within one area or when the changes are in accordance with institutional norms.
- Compromise
- Organisations may choose to compromise with the external requirements by attempting to balance conflicting and/or inconsistent demands. This can be done by negotiating with different stakeholders, both internal and external.

- Avoidance
- Organisations can try to protect their current operation by seemingly accepting the new institutional rules and expectations while continuing to follow their own standards and values. Organisations can also make their own interpretations of new institutional plans and demands in order to conceal the absence of any intention to implement them. A third option is for the organisation to change its goals, activities or even areas of activity so that the new external rules or standards cannot be applied to it.
- Defiance
- Another strategy is not just to try avoiding new external demands but to simply ignore them altogether or, even more actively, to attack or challenge the content of the institutional processes and the actors behind them. If the expected impact of the new external requirements is very small, it may be worth taking the risk of adopting this strategy.
- Manipulation

- Finally, an organisation can use the strategy of participating and thereby having an influence on new values and norms, or controlling institutional processes. This strategy is proactive since the organisation attempts to influence the norms and values which it later will be judged upon. By being a part of the settings of new rules and norms, an organisation can also complicate the entry of new players.

In her seminal article, Oliver also discusses the "external" conditions: *why* pressure is being exerted, *who* is exerting pressure, *what* the pressure consists of, *how* and *by what means* pressure is exerted, and *where* it occurs. While this typology for response strategies might be suitable for organisations in general, adaptation may be required for higher education institutions (Gornitzka 1999; Reale and Seeber 2011). Geschwind (2010) has adapted these strategies into a somewhat easier-to-use analytical tool by categorising the strategies in two dimensions: type of behaviour and type of attitude. Four out of five aforementioned strategies (Oliver 1991) are found in the quadrants shown in Fig. 10.1, while the fifth, compromise, is positioned in the middle, that is, at the intersection of the axis.

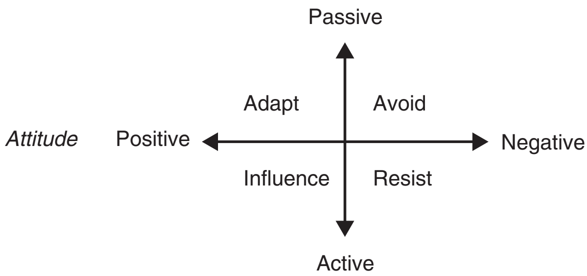

Fig. 10.1 Higher Education Institutions' responses to proposed policy changes (Geschwind 2010)

However, for an organisation to act and respond to external (or internal) pressure for change, it must have a goal or ambition that can be located in relation to the call for change. This goal or ambition may be explicit or unspoken but the response strategy the organisation chooses can be said to reflect the identity that the organisation has or wants to have. By studying an organisation's identity, we are better able to understand why a certain response strategy has been chosen. Modern theories and models of organisational identity have their origin in Albert and Whetten (1985), who, with their background in business administration research, saw how their own university (the University of Illinois) reacted and acted in response to financial cutbacks. Fairly modest budget cuts caused heated internal discussions about their consequences for the university's legitimacy and whether the university would be able to maintain its research profile. Theories about organisational identity have since developed at several levels (see Gioia et al. 2000; He and Brown 2013). Stensaker (2015) has developed a conceptual model of organisational identity related to changes in universities and colleges. This model is based on the challenge of explaining and understanding the relationship between continuity and change in higher education research, and Stensaker identifies four different ways in which organisational identity can play a role in relation to different types of change activity:

- Organisational Identity as Interpretation
- Organisational identity can be seen as an interpretative scheme to help members of the organisation make sense of internal or external changes.
- Organisational Identity as Image
- Even though there have been arguments that organisational identity and organisational image should be kept apart as different concepts (cf. Brown et al. 2006), Gioia et al. (2000) have shown that there are linkages between organisational identity and organisational image, that is, how organisations want to portray themselves externally.
- Organisational Identity as Innovation
- It may be suggested that organisational identity as a model mainly fosters organisational stability and consistency, and thus impedes creativity and innovation. However, Stensaker (2015) claims that studies 'suggest that the potential for using organisational identity for driving university innovation should not be underestimated…' (pp.109–110).
- Organisational Identity as Integration
- Internal discussions about organisational identity in relation to proposed changes can foster engagement and shared ideas of a distinct, collective identity.

We will use these theories in combination and thus take on the challenge made by Stensaker (2015) to further examine intangible aspects of higher education institutions in order to gain a better understanding of factors, such as the somewhat contradictory phenomena of simultaneous inertia and change in higher education institutions.

10.4 Method

This historical study is primarily set in the time before the governmental decision of 1989 to carry out an educational reform. The study applies an oral history approach combined with documentary studies. The primary documents are governmental reports, investigations and bills, together with different stakeholders' reactions to these documents and/or reports of their own. In addition, six interviews were conducted with persons who had key roles in the preparation work and transformation. The interviews were intended to add some 'flesh and blood' to the analysis of the documents, rather than to try to find 'correct' answers (see Appendix 10.1 for a list of the primary documents used in the study). As for materials from technical universities, KTH stands out as the only one where we have found both comments in other reports (UHÄ 1986) and primary documents (KTH 1988, 1989). Thus, KTH is mentioned several times in the following sections, while other technical universities are relatively invisible.

The written sources that were identified and used must, in many ways, be evaluated from a methodological perspective; they cannot simply stand alone (McCulloch 2011). To give one example: the written materials in this study, without exception, reflect a top-down perspective because they were written and published by organisations, authorities and the like that were not directly involved in the education at hand. We have been unable to track down documents that might balance this top-down perspective, such as postings in discussions by teachers, students, or organisations representing them.

The use of oral sources in the form of interviews raises issues of both credibility and ethics. All interviewees had key positions in their respective organisations, such as the program manager at an upper secondary school who then moved to a technical university with the mission of organising and managing the new engineering course. Others were civil servants, political and non-political, who were involved in the investigations and reports that eventually led to the reform. However, we have promised the interviewees anonymity and therefore are unable to go deeper into their background or identity. We thereby potentially solved a number of ethical issues (Kvale and Brinkmann 2009), but at the same time the interviewees' versions have largely been left untouched; the chances of finding a plethora of suitable persons to interview were very limited given that it is approximately 30 years since the events occurred. However, to reiterate, the main purpose of the interviews was to supplement and to some extent help us to 'sort' the analysis of the written material.

Assessing the validity and reliability of the written sources, that is, the primary documents, was a delicate task, and some of the written sources must clearly have had more significance for the decision-making process than others. This led us to a discussion about how to classify the material (Dahlgren and Florén 1996, p. 185). To some extent, the process can be determined by the type of written material involved. For example, a government investigation has a different status than a report from a business organisation. Because the interviewees had various key positions during the process, we have asked them about the importance of the written material for the process, thus asking them to contribute to our assessment of the written material. Overall, we must respect the fact that it has been about 30 years since the actual events. For example, we received some contradictory versions of events, but all in all, the interviewees' versions match. Besides, as stated above, the aim of the study was not to find the absolute 'truth'. Consequently, we are confident about the overall picture and the answers given in response to our research questions, even though both the assessments of the written material and some contradictions in the interviews can give a somewhat uncertain picture of some parts of the process. At the same time, we acknowledge the possibility that another approach could give other versions of the image we paint.

10.5 Results and Discussion

This story begins in 1974, when the governmental authority for higher education, UKÄ, proposed to the Swedish government that new shorter engineering programmes should be introduced at the universities. The proposal had emerged after an external analysis had concluded that this would be a good development for Sweden. The response from the government was negative, however. This was motivated by the argument that such a development would probably have a negative impact on technical upper secondary education (T4); consequently, government would not investigate further (Interview #3).

A few years later, when T4 was examined and discussed more actively in reports from, for example, the Swedish Employers' Association (SAF) in 1982 and the Association of Engineers (CF) in 1984, it was primarily not about a move from the upper secondary school level to higher education level, but rather about ways to extend T4 within upper secondary schools. Thus, the technical universities initially did not have a response strategy to the first proposals on changes to T4 because the proposed changes did not affect them other than minimally.

At the end of 1984, the Royal Swedish Academy of Engineering Sciences (IVA) was assigned by the Swedish government to investigate and address whether the growing demand for engineers and technicians was dependent on the economic situation and thus intermittent, or structural and thus persistent. The investigation also considered demands for technical skills for the period of 10–15 years ahead. IVA presented its report in autumn/winter 1985 (IVA 1985). As mentioned earlier, it has been assumed in our study that IVA, as a stakeholder, had a close relationship with the technical universities, thus making it relevant for this study, especially since there are no other primary documents from technical universities regarding T4 from the period before 1988. This assumption has also been confirmed in our interviews (Interview #1, Interview #3, Interview #4). It is not unusual for non-governmental organisations like IVA to receive such an assignment from the government. It had happened previously and has happened since; subsequent and similar assignments have been assigned to other countries' engineering academies by their governments (cf. The Royal Academy of Engineering 2010).

IVA started its investigation by interpreting and defining the assignment to analyse the demand for 'qualified technicians' to mean only master's students and postgraduates, hence (initially) avoiding the question about T4. In the long run, however, it was impossible to avoid touching upon the demand for T4 and other technicians by the industry, not least because the demand for 'qualified technicians', regardless of definition, could not be covered only by the supply of master's graduates. Therefore, T4 and other shorter technical programmes became a part of the report's discussion, where it became even clearer than in the reports from SAF and CF that the quality of T4 was inadequate. Without referring to any survey or investigation, reference was made to the fact that the span between the 'best' and 'worst' students from T4 was very large, meaning that the subsequent job opportunities varied greatly and that only a few obtained qualified engineering positions. One (very concise) proposal in IVA's report was therefore to establish engineering schools and that the length of education in these schools should be 5 years, that is, an extension of T4 by 1 year. However, it was not suggested that the technical universities should have a direct role in this development, and thus the technical universities could be regarded as non-stakeholders. Is it possible that the report by IVA was the first expression of a more active resistance from the technical universities to the external pressure for a change that pointed in their direction? It is impossible to answer this with certainty, but some factors point in that direction, such as the limitations of the original assignment, the somewhat reluctant widening of the assignment during the investigation and the fact that several new investigative assignments involving higher education institutions were initiated shortly after this report (and after other reports, we might add).

From the perspective of the model of different response strategies to an external pressure outlined by Geschwind (2010), we claim that the technical universities at first were passive and somewhat avoiding stakeholders, or even passive *non-stakeholders*. With the report from IVA in 1985, they shifted position and became more active and pronouncedly negative about the idea that T4 should be transformed to the university level. Hence, they shift quadrant in the model (see Fig. 10.2).

An indication that the years 1984–1986 were very intensive with regard to these issues is the fact that an expert group (created by the government) launched a report

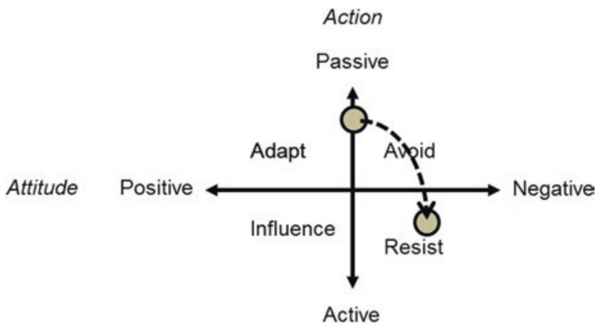

Fig. 10.2 Technical universities' change in response strategy 1985

about ‘shorter technical education’ during the autumn of 1985, that is, roughly at the same time as IVA presented its report (Utbildningsdepartementet 1985). Another major governmental educational investigation was also under way, responsible for reviewing the structure of the entire upper secondary school level system. This investigation presented its final report at the beginning of 1986 (Utbildningsdepartementet 1986) and, of course, also included education in the field of technology. In addition, reports from external stakeholders, such as CF (CF 1984, previously mentioned), TCO (TCO 1985) and an additional report from SAF (SAF 1985) can be added to the list. In short, a lot of investigations and external pressure was ongoing at the same time with regard to technical and engineering education in one way or another. (For an explanation of the abbreviations and a list of primary documents, see Appendix 10.1).

It is difficult to see a clear path for the future of T4 just by reading the many reports and investigations, but the criticism of the quality of T4 becomes increasingly pronounced. Eventually, a new governmental investigation was assigned with the mission of developing forms of cooperation between upper secondary schools and higher education within the field of technical education (UHÄ 1986). Within this mission, 11 different cities reported how they planned for this cooperation between upper secondary school and higher education. In particular, each city had to comment on the ‘Engineering Schools’, a work-in-progress name and trademark/organisation, and for the first time it was declared that the universities in one way or another should have a role in strengthening the quality of T4. For many of the 11 cities, which had young university colleges offering little or almost no technical/engineering education, this was a window of opportunity. It was not only attractive to the local university colleges, which, like all other higher education institutions in Sweden, were, and still are, governmental authorities, but also for the local/regional politicians who saw the emergence of university colleges as a way to strengthen the region (Interview #2, Interview #3, Interview #4). The university colleges and the local/regional politicians thus tried to influence the process, even though, compared to the technical universities, such as KTH and Chalmers, they had less power and legitimacy.

Even in the capital region of Stockholm, the issue had a local/regional political touch. There were political forces that wanted to spread technical education outside central Stockholm, where KTH was located. The southern part of the county of Stockholm was identified as being suitable for an engineering school, with KTH as one party and local T4 programmes as the other (UHÄ 1986, p. 41). SAF also suggested something similar in a 1985 report (SAF 1985). The proposal in the UHÄ report was that KTH should move its shorter technical education programmes to an engineering school, which in the texts still had no declared principal and was used as a collective term referring to places where technical education at the upper secondary school level, university level and adult educational level could be gathered under a united umbrella organisation.

While the entire report (UHÄ 1986) used the term ‘engineering school’ as a collective name referring to an umbrella organisation and something that may or may not eventually be a reality, KTH was already out of the blocks to separate all shorter technical/engineering education from the master's programmes and to create an engineering school. The School of Engineering at KTH was established in July 1986, with its own administrative board, directly under the board of the technical university. All engineering and technical programmes at KTH were collected within the School of Engineering except for the master's programmes. The education activities within the School of Engineering were mainly run off the KTH central campus (KTH 1988).

If the technical universities' response strategies from the outset were to try to avoid the expansion of shorter engineering programmes, that is, a passive and negative approach under the Geschwind (2010) model described earlier, and the report by IVA in 1985 indicated a shift towards a more active but still negative approach, then KTH's initiative in 1986 to create an engineering school showed another approach that was significantly more active and positive (see Fig. 10.3). However, it is relevant to ask if this strategy was at the same time a way to protect the perceived core business and thus to preserve organisational identity.

In the spring of 1987, a new investigation was initiated by the Swedish government with the main aim of starting a try-out operation in some cities where T4 was to be transferred to the university level in order to pave the way for a permanent transition. The question was therefore no longer *if* the T4 would be transferred to the university (and extended) but *how* this would be done. In March 1988, this investigation presented its report (Utbildningsdepartementet 1988), but it was really subordinate to the actual and practical work conducted within the investigation to find organisational and financial ways to transfer T4 to the university level and extend the courses by 1 year (Interview #3, Interview #4). At the beginning of 1989, a Swedish government bill was presented with the goal of gradually increasing the try-out activities at the university level and, correspondingly, to reduce T4. It was planned that the whole reform would be completed and T4 dissolved entirely by 1993–94 (Utbildningsdepartementet 1989). The Swedish parliament voted accordingly on the bill in the spring of 1989. The description of the course of events covered by this study is thus complete and we can now examine how these developments challenged the technical universities' organisational identities and boundaries.

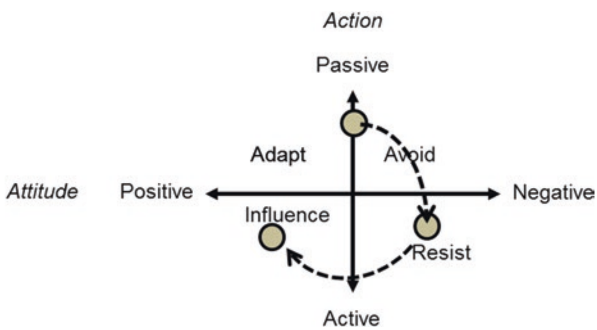

Fig. 10.3 Technical universities' changes in response strategy 1986

In the spring of 1988, a 'Policy for the Development of the School of Engineering at KTH' was presented (KTH 1988) and roughly a year later, a new development plan for KTH was presented (KTH 1989). The development plan was the first to include both research and education. Previous development plans (the most recent had been in 1985) had only addressed research and postgraduate education. Both of the new papers were primarily internal documents that pointed out a direction for the near future for KTH's own staff. Now, the previously somewhat blurry plans for the future for T4 were clearer and KTH saw a considerably larger future educational role for the 2-year engineering programmes, anticipating that they would have the same student numbers as the master's programmes in the long run. However, much of the text in the development plan was about preserving its self-image as a technical university, with research and master's education as its primary tasks, even when the mission was broadened by the introduction of other engineering programmes. One example:

> The addition of the two-year engineering programmes makes it possible to have higher ambitions for master programmes and architectural programmes in terms of the scientific level and to give them a greater content of basic knowledge. (KTH 1989, p. 3)

There is also a clear statement:

> KTH's main task in undergraduate education is Architecture and Master of Science in Engineering. (KTH 1989, p. 13)

This shows that KTH tried to use the challenge from the new engineering programmes as a way to strengthen and retain its image as a research-intensive technical university. Alternatively, as Stensaker's (2015) conceptual model suggests, with their internally and strategically designed decision to create the School of Engineering, they used the organisation's identity as a way of integrating the new engineering programmes, without the intention of altering either the original organisation model or its identity, we might add.

The new programmes' geographical location, at KTH and other existing technical universities, is another area where the relationship and tension between a shorter engineering education and their 'core business' (master's programmes) came to the fore. In Stockholm, the new engineering programmes were placed in a number of rather small educational centres (campuses) outside KTH's main campus in central Stockholm. There were short-term practical explanations for this; the main campus was already crowded and, initially, buildings and equipment were to be provided by the municipalities as part of the financing of the construction of the 2-year engineering programmes (Utbildningsdepartementet 1988; Interview #1, Interview #4, Interview #5). However, while other cities in Sweden integrated the new engineering programmes into their university college campuses relatively quickly after this initial period, KTH retained its multi-campus model of engineering education off the central campus (Interview #1, Interview #5). This organisational model endures at KTH to this day, except for one engineering programme available at KTH's central campus and the fact that the organisational entity and name School of Engineering disappeared at the start of the 2000s, at the same time as a major organisational overhaul at KTH. Moreover, it was suggested in both the policy documents from 1988 and 1989 that the relocation, in fact a sort of outsourcing, was a good solution in that it would not ‘disturb’ the existing research and educational organisation at the ‘main’ KTH campus. This, of course, reinforces our view that KTH did not want the expansion of short engineering programmes to change the identity of the organisation, at least not the core of it.

Interestingly, three of the four leading technical universities at the time in Sweden arranged their new engineering courses in the same way. In Gothenburg, Chalmers University of Technology placed its new engineering programme some 10 km away from the main campus, on the other side of a river. Lund University, with a strong and fairly independent technical faculty located in Lund, located its new engineering programme even farther away, at a new campus in the city of Helsingborg, 55 km from the city of Lund. Lund University still practices this model, while the shorter engineering programmes in Gothenburg have moved back and forth over the river a couple of times (Interview #1, Interview #5).

When the shorter engineering courses in Sweden were evaluated nationally in 2002 (HSV 2003), that is, just over 10 years after the introduction of the new engineering programme, the evaluators reiterated the weak link between up-to-date research and education. This link was particularly weak at the large, ‘old’ universities with strong research traditions. Surprisingly, teaching–research links were stronger at the small/new university colleges, although the volume of the research was very small in comparison with that in the large universities. One exception is highlighted in the evaluation report, namely the fourth of the major technical faculties described earlier, at Linköping University, which made an attempt to integrate long and short engineering courses, both organisationally and geographically, from the beginning. This all gives us good reason to claim that at the traditional technical universities in Sweden, a dual engineering system was built within the framework of a seemingly uniform one. Thus, the core of the organisation’s identity, the research and master’s programmes, was retained despite the challenges of the new engineering programme.

As mentioned earlier, the cities with newer university colleges were quicker to integrate the new engineering programme into their other educational activities. In fact, local politicians, who had a direct role for financing vital parts of the reform, embraced this opportunity to increase the volume of technical education at ‘their’ university colleges. The reason for this behaviour was rational; a wider range of educational programmes would hopefully attract young people (and investors) to the region and thus enhance the development of the region. In these cases, the new engineering education system was an integrated part of the university colleges’ emerging identities.

10.6 Conclusion

This study has addressed the question of how universities, and especially technical universities, act and respond to external pressures for change and how this stretches the limits of their operations and their organisational identity. Our case illustrates how a profound change challenges the self-image of a technical university. As in most historical studies, there is some uncertainty with regard to whether the sources available are telling the whole story, but even with these limitations we have shown similarities and differences between technical universities and other higher education institutions, as well as a development over time. While we have focused on the time before the actual implementation of the new engineering programme, further studies could examine how the implementation was handled and what effects it really had on the organisational identity of the technical universities. From another perspective, it would also be interesting to tell the upper secondary schools' side of the story. They were clearly on the losing side of this in terms of a lost technical education with a long and quite honourable history. On the other hand, and as we have seen in a plethora of reports, there were external stakeholders with, it would appear, great interest in the new development, namely, the industry. It remains to be seen if the industry was on the push or pull side of the development, or whether they, like the technical universities, changed position during the period of investigations and reports.

What does this historical case tell us about contemporary higher education? The climate of the Swedish higher education community of today can in several respects be characterized by New Public Management (Pollitt and Bouckaert 2011), autonomy (Nokkala and Bladh 2014), triple helix (Etzkowitz 2008), marketisation (Teixeira et al. 2004), managerialism (Deem et al. 2010), rankings (Hazelkorn 2015) and so on. Technical universities in particular may often be influenced by ideas about entrepreneurial universities (Clark 1998). If the issue that our study deals with were to be relevant today, these aspects would certainly be factors to take into account. In addition, media and students (and to some extent their parents) would surely be counted as stakeholders, with some kind of pronounced take on the matter. Almost paradoxically, the interest from students in T4 increased every year during the 1980s, even while these investigations were ongoing. The fact that there were investigations that increasingly pointed to a lack of quality in engineering programmes at upper secondary schools appears not to have been communicated beyond the political domain. In fact, we were advised by all interviewees not to search for articles in the press and media about this, for the simple reason that there is probably nothing to be found. Again, this shows how much things have changed. Similar investigations would most likely not be able to fly under the radar in the same way today.

As we mentioned earlier, the governance of universities and colleges was considerably more bureaucratic and less independent than it is now. What kind of wiggle room was there really for a university college or technical university to act on and/or react to the proposals? From the analysis of the primary documents, we have assumed – and the interviews have confirmed – that the technical universities had a stronger position than the university colleges, but apparently this was not enough for the technical universities to preserve their initial passive/negative stance as a response strategy. While the pressure for change was externally triggered, KTH took initiatives for internal organisational change even before the external process, with its formal legal decisions, was brought to a close. Thus, this can be seen as an externally triggered, but internally designed, process with strategic characteristics in which the organisations' existing identity was used as a way of implementing the new engineering education system. In fact, in the cases of the leading technical universities, at KTH, Chalmers and Lund (but not Linköping), they used the change process as a way to preserve or even strengthen their existing identity, without adding or removing anything, as we have seen in the policy documents from KTH and from the reports of how they all organised their new engineering programmes geographically. However, the identities of these technical universities must have been altered eventually; by how much, when and why are subjects for another study. This is another example of the seemingly everlasting challenge to understand the relationship between continuity and change in higher education institutions better.

Appendix 10.1

Primary Documents

Reference (short)	Type of source	Short description/Title
Utbildningsdepartementet 1978	Government report	Inför 2000-talet: samhällets behov av naturvetare och tekniker
SAF 1982	Policy report	Den stora skolreformen
CF 1984	Policy report	Sveriges civilingenjörsförbunds syn på utbildningsfrågor
Utbildningsdepartementet 1985	Government report	Ds U 1985:11 Kortare teknisk utbildning: rapport från Expertgruppen för kortare teknisk utbildning
IVA 1985	Policy report	IVA-meddelande 249: Ingenjörer för framtiden
TCO 1985	Policy report	Tekniker: arbete och utbildning i framtiden
SAF 1985	Policy report	En svensk collegeskola
Utbildningsdepartementet 1986	Government report	SOU 1986:3 En treårig yrkesutbildning
UHÄ 1986	Official report	UHÄ-rapport 1986:18 Stockholm – Uppsala: 14 högskolor i samverkan
UHÄ och SÖ 1986	Official report	UHÄ-rapport 1986:16 Ingenjörs- och teknikerutbildningar i samverkan

(continued)

Reference (short)	Type of source	Short description/Title
Utbildningsdepartementet 1987	Government report	Ds U 1987:12 Försök med samordnad ingenjörsutbildning på mellannivå: delrapport från Arbetsgruppen för samordnad ingenjörsutbildning på mellannivå (SIM-gruppen)
Utbildningsdepartementet 1988	Government report	Ds U 1988:20 Samordnad ingenjörsutbildning på mellannivå
UHÄ 1988a	Official report	UHÄ-rapport 1988:4 Teknikerutbildning i högskolan
KTH 1988	Policy report	Policy för utbyggnad av Ingenjörsskolan vid KTH
UHÄ 1988b	Official report	UHÄ-rapport 1988:15 Ny ingenjörsutbildning UHÄ:s yttrande över rapporten DS 1988:20 “Samordnad ingenjörsutbildning på mellannivå”
UHÄ 1988c	Official report	UHÄ-rapport 1988:8 Från ingenjör till civilingenjör
KTH 1989	Policy report	Utvecklingsplan för 90-talet
UHÄ 1989a	Official report	UHÄ-rapport 1989:19 Ingenjörslinjerna i högskolan. Förslag till utbildningsstruktur
Utbildningsdepartementet 1989	Government bill	Proposition 1988/89:90 inkl Utbildningsutskottets betänkande och 3 motioner
UHÄ 1989b	Official report	UHÄ-rapport 1989:20 Första året med ny ingenjörsutbildning
UHÄ 1991	Official report	UHÄ-rapport 1991:24 Utvärdering av försöksverksamheten med ingenjörsutbildning
UHÄ 1992	Official report	UHÄ-rapport 1992:12 Utvärdering av försöksverksamheten med ingenjörsutbildning
IVA 1992	Policy report	Ingenjörer för 2000-talet

Abbreviations

CF	Civilingenjörsförbundet (now Sveriges Ingenjörer)	Trade union
IVA	Kungl. Ingenjörsvetenskapsakademin	The Royal Swedish Academy of engineering sciences
HSV	Högskoleverket (ex UKÄ, ex UHÄ, now UKÄ)	Government agency
SAF	Svenska Arbetsgivareföreningen(now Svenskt Näringsliv)	Employers’ organisation
SÖ	Skolöverstyrelsen (now Skolverket)	Government agency
TCO	Tjänstemännens Centralorganisation	Trade union
UHÄ	Universitets- och högskoleämbetet (now UKÄ)	Government agency
UKÄ	Universitetskanslersämbetet	Government agency

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

Mikael Cronhjort and Lars Geschwind

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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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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Chapter 12
Concluding Discussion: The Past, Present, and Future of Technical Universities

Anders Broström, Lars Geschwind, and Katarina Larsen

In the introductory chapters of this volume, a few points of departure were outlined for the research efforts reported in this book. One was the lack of studies of this particular segment of the higher education landscape: technical universities *as organisations*. Further, this book offers a response to the call by organisational scholars for better understanding how organisational narratives affect identity formation, inertia, and actions in academic organisations (Gabriel 2004). It does so by addressing fundamental questions about the nature and identity of technical universities (Gioia et al. 2013; Stensaker 2015).

In the context of this volume, two broader questions were addressed in chapters on identity formation and boundary negotiations. First, how do organisations actively work with legitimacy-creating rhetorical strategies, which argue for change within the organisational field? Second, how do universities (specifically university leaders and other academics) think about categories such as ‘technical university’, ‘research university’, and ‘vocational training institution’, and what do these categories mean in relation to the organisational identity of a technical university in comparison with other higher education institutions?

The volume comprises contributions, which shed light on these issues, drawing on experiences from contemporary university landscapes. In some chapters, organisational identity—and particularly the identity category ‘technical university’—is

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the focus, whereas in others change as a consequence of external pressure and/or strategic action is foregrounded. In this concluding chapter, we discuss the findings from the empirical chapters in relation to the framework laid out at the beginning of the volume. Taking stock of lessons learned from the studies presented in this volume, we also discuss the potential futures of the technical university.

12.1 Negotiating Boundaries and Relating to Identity Categories

A first observation arising from the various examinations reported in previous chapters is that the organisational identity boundaries of contemporary HEIs are floating, and constantly challenged, tested, and negotiated within nested organisational fields (Wooten and Hoffman 2017; Hüther and Krücken 2016). This is discussed in the contributions by Schneijderberg, Carvalho and Diogo, Vellamo et al., and Antonowicz with examples from the German, Finnish, Portuguese, and Polish higher education sectors, respectively. Antonowicz provides an overview of technical universities in Poland and shows how status differences can play out at the national level. Despite constituting a large proportion of the sector, technical universities have not been recognised and highlighted as much as the multi-faculty, comprehensive universities. Carvalho and Diogo show that even in binary systems with formal division into two tiers, the boundaries between technically oriented universities and polytechnics are hard to define. An eye-catching example is the merger in Tampere, Finland between a technical university, a comprehensive university, and a polytechnic (a professionally oriented form of HEI in the Finnish two-tier system). Vellamo et al. discuss how the merger process offers interesting insights into the organisational identity of the technical university by triggering reflections on what unites and separates the technical university from the two other HEIs.

Boundary negotiations also take place *within* existing technical universities. The chapters of this volume give several accounts of boundary negotiations concerning the demarcation of a technical university from other advanced universities, in terms of curricula and subject areas. Antonowicz demonstrates how technical universities in Poland were tempted to abandon their focus on engineering subjects to participate in an expansion of education, focused on social science and humanities training, but how instead a path of preserving an existing disciplinary focus was chosen. Cronhjort and Geschwind demonstrate how teacher training was introduced at the two leading Swedish technical universities based on a mix of rationales.

Other important boundary negotiations take place between technical universities and institutions offering professional engineering education. Fagrell and Geschwind highlight a specific change initiative challenging such a boundary. The chapter describes how the Swedish government decided to incorporate the lower engineering education into higher education—until then at post-secondary school *(gymnasium)* level—and how this external 'shock' urged the technical universities to respond.

The chapter by Edström also discusses the relationship between practical skills and theoretical knowledge, which is so important for the idea of a technical university. In contrast to Fagrell and Geschwind, however, the chapter describes an internal initiative to re-shape how these two aspects are integrated into teaching curricula. The chapter illustrates how engineering education is characterised by inherent tensions between identities and institutional logics from engineering practice and engineering science. This tension may play out differently in different organisations, depending on differences in organisational identity. For example, an HEI organisation strongly oriented towards engineering practice (such as a university of applied science/polytechnic) would tend to generate other compromises than a HEI strongly oriented towards academic values (cf Augier and March 2011). Under the premise that organisational identities of a technical university would tend to have somewhat different connotations than that of a technical faculty within a comprehensive university, we may expect technical universities to generate different compromises and solutions—possibly contributing to greater diversity within higher education systems.

12.2 Strategic Responses to High Expectations

The contributions in this volume also shed light on the complex interplay between internal and external stakeholders in contemporary higher education, and the expectations expressed from various perspectives (Geschwind 2019). It can be argued that such expectations, for example, expressed in terms of contributions to local economies, may play out differently in different HEIs. In particular, we see how the recognition of differences between HEIs (in terms of orientation towards different institutional ideals and differences in historical roots) helps to recognise and interpret institutional differences in the way that HEIs relate to contemporary debates on managerial tendencies in higher education (Deem et al. 2010), and on university organisations as strategic actors (Krücken and Meyer 2006). Associations to a tradition of application-oriented activities and close industrial relationships shape the idea of what it means to be a technical university. That identity and tradition also incorporate acceptance and (some) understanding of managerialist tendencies, derived from new public management sweeping over HEIs. The prevalent responsiveness to external actors, and willingness to adjust operations and organisational structures in relation to the technological development show that many universities identifying with the notion 'technical university' arguably are closer to being strategic actors, entrepreneurial, and enterprising HEIs than the average HEI—in particular in comparison with the ideal of the classic, comprehensive, European university (Etzkowitz 1988; Clark 1998).

So, how is the governance of technical universities evolving in a context of increased external expectations and demands for its services (Amaral and Magalhães 2002; Benneworth and Jongbloed 2010)? With more roles added to HEIs' core objectives affecting the day-to-day work of academic staff (such as time devoted to teaching, third mission, or commercialisation activities), the associated competing logics (Greenwood et al. 2011) warrant further analysis to understand conflicting goals within the organisation of relevance for career paths and policy for excellence and performance. The contribution by Benner focuses on the preconditions for three technical universities with seemingly similar contexts, in Sweden, Denmark, and Switzerland. The analysis shows that differences in management structures, funding arrangements, and recruitment patterns seem to have a significant impact on the research performance of the universities. Antonowicz shows how a strong organisational identity has helped technical universities in Poland to sustain in turbulent times, but also hampering renewal, innovation, and higher aspirations.

12.3 A Position of Strength

From the various analyses presented in this volume, it is clear that the category 'technical university' is associated with significant status. While some universities who think of themselves as technical universities are operating in the shadow of more brightly shining peer HEIs, being a technical university is nonetheless in many instances a source of a considerable degree of pride and confidence. Such status is both a function of a proud institutional history, and consistent support from important stakeholder groups. Qualified engineering and technical knowledge remains high in demand by students and industrialists alike, and is shaped by perceptions of what type of engineering knowledge fits the traditional mind-set for constructing physical infrastructures, software engineering, mathematic modelling biotechnology, and career paths in physics, chemistry and engineering. The traditional notion of engineering skills and 'hard' science and technology knowledge of engineering education continues to be perceived as a useful filtering mechanism for employers recruiting students with an engineering background, and as something of a 'rite of passage' for ambitious students. Networks of successful alumni consolidate the status of many leading technical universities, and in countries where the legal status so allows, provide an important source for funding raised from charity donation or similar activities.

Engineering education and technology research—and therefore HEIs championing these activities—have also enjoyed prioritisation from policy. This is clearly reflected in the chapter by Vabø and Langfeldt on NTNU in Norway, and in Schneijderberg's chapter on technical universities in Germany and how they have benefitted from the Excellence Initiative, for example. In some settings, a position of strength has also allowed technical universities to defend their position against the consequences of declining national budgets for higher education and research, as addressed in Antonowicz's chapter in this volume.

A position of strength (a strong identity and self-image) also implies a strong position that is considered worth preserving. This theme emerges clearly from the chapter by Fagrell and Geschwind, who describe how technical universities manoeuvred a situation of unwanted new responsibilities for what was previously vocational engineering education. It also surfaces clearly in Antonowicz's chapter, where he shows how Polish technical universities resisted a wave of diluting expansion affecting the sector in its entirety. Furthermore, the construction of Universities of Technology e. V. (TU9) in Germany, discussed in Schneijderberg's chapter, illustrates how networks and subfields are actively formed.

12.4 Technical Universities: A Negotiated Ideal in Decline

Having argued for the category 'technical university' being strongly embedded in many higher education systems, it might seem logical to predict that the focused technical university is a viable institutional template. Somewhat paradoxically, this prediction is not entirely congruent with empirical observations. As highlighted already in Chap. 2, many previously more focused technical universities have developed into more diversified HEIs. While some disappear through merger initiatives, others are transformed through a more slow-paced change, in the form of scientific bifurcation into other fields. Chapters in this book engage with universities such as NTNU in Norway, which has gone through a series of mergers with other types of HEIs, and TUT in Finland which at the time of writing is about to move away from a previous strong focus on engineering science and education through a merger. In the case of TUT this is also leading to an abandonment of the name 'technical university'.

A way to understand this development, in the context of the overarching analytical framework of the book, is that competing identity categories offer greater appeal. Specifically, it can be suggested that the category 'research university' is being perceived as an attractive alternative—as conveying a higher status in relevant stakeholder contexts—than the category 'technical university', drawing on previous studies about what these categories entails (Beerkens 2010; Martin 2012; Mohrman et al. 2008). The strategic direction for many universities seems to be geared towards accommodating further attributes associated with the research university, even at the expense of attributes associated with the technical university.

However, comparisons of experiences reported in the volume's different chapters also suggest the occurrence of interesting differences between national settings. In Chap. 8, Schneijderberg shows how a group of universities in Germany through their name and their membership in joint 'clubs' identify themselves as 'technical university', and how this category is associated with high status in the national context. Among the group of German TUs, we find some of the most prestigious research universities in the country. Meanwhile, Antonowicz, in Chap. 6, documents how in the neighbouring country of Poland, the group of HEIs referred to as technical universities have at least as much in common with the category that in certain countries is known as 'universities of applied science' (UAS) as they have with the idea of internationally active research universities. In Chap. 7, Carvalho and Diogo show that in one setting (Finland), policy makers were encouraged to maintain a binary system separating institutions for professional technical training from research-oriented technical universities. In another setting (Portugal), a group of international experts representing the same international body (the OECD) advised for the abolishment of such a binary system. Fagrell and Geschwind, finally, demonstrate that for two HEIs in Sweden identifying themselves as technical universities, the introduction of elements of professionally-oriented training into their curricula has given rise to some controversy.

It is possible to understand these findings as reflecting important differences between countries in how the relationship between the identity categories technical university and university of applied science are perceived. In contexts such as the German, Finnish or Swedish, the identity category technical university is associated with research-based teaching and world-class science. In Poland, Portugal and in other contexts, the same category is perceived as largely overlapping with the category 'professional training institutions'. It may be suggested that the presence of national champions in some countries (except for the above mentioned three, Chap. 2 identifies Denmark, the Netherlands and India as such countries) has charged the term 'technical university' with academic status. In the absence of such national champions, it has been possible for professionally oriented institutions to adopt the term in other settings, thereby generating national-level differences in the interpretation of a global script.

12.5 So Who Is Responsible for the Demise of the Technical University?

The aforementioned conditions for strength, together with the discussion about how the ideal of the technical university is changing, trigger questions about the reasons for this development and reactions either for or against change, while also acknowledging that technical universities have many things going for them. How can we understand this development? The student of the paradoxical disappearance of the technical university finds several clues to consider in the analyses contained in this volume. A number of 'suspects' may be identified, as follows:

1. ***The students (and their employers) are to blame.*** For decades, engineering education has included important elements of knowledge from non-engineering disciplines, such as economics, medicine, law, and management. In universities organised around such programmes, those with such broad scope are often amongst the most popular, and in universities where education is more modularised, the ability to include high-quality, non-engineering modules is often seen as increasing institutional attractiveness for students. This taste for variety in education among students is at least partially based on a favourable assessment of a mixed-skill education amongst employers. Furthermore, it has not been uncommon for policy-makers to encourage novel educational combinations of engineering education actively with other types of education. In Chap. 11 of this volume, Cronhjort and Geschwind analyse one such development, where new

curricula integrating engineering and teacher education modules were introduced in response to national-level concerns about unsatisfactory recruitment into science and technology specialisations of existing teacher education programmes. In response to demand for a broad-based educational offering, it makes sense for universities, strongly dominated by science and engineering, to broaden their disciplinary scope. This pressure has most probably been particularly strong for universities based in non-metropolitan locations, where diversification through collaboration with local universities is not possible, and where regional expectations and ambitions are centred on one or very few universities. The recent history of the Norwegian University of Science and Technology (NTNU)—described in Chap. 4 of this volume—offers an illustrative example of such processes (see also Brandt and Nordal 2010).

2. ***The American universities, and the success of their institutional templates, are to blame.*** While technical universities—built on the foundations of nineteenth century polytechnic schools—still play a prominent role in the European university landscape, the leading institutional role models of the twentieth and twenty first century are found on the other side of the Atlantic. And while (for example) the Massachusetts Institute of Technology (MIT) and the California Institute of Technology (Caltech) are technical universities in name, they have developed from traditions and institutional models different from others such as Delft University of Technology and the Swiss Federal Technical University (ETH) in Zürich. As outlined in Chap. 2 of this volume, American universities were historically modelled on the British college, and the North-American higher education system has long been characterised by a strong tradition of 'liberal arts' education. Celebrated American universities with a strong focus on technology and its commercial and societal consequences (such as Stanford and MIT) also take pride in hosting world-class scholarship in the arts (humanities) and in social sciences. As leading role models for ambitious university leaders and politicians across the world, these institutions exercise significant mimetic influence on strategies for (present and previous) single-faculty technical universities across the world. Bearing in mind that European models of the technical university and national idiosyncratic understanding of engineering education are inspired by a model with strong emphasis on elements of liberal arts, the single-faculty technical universities are experiencing something of a transformation, creating debates and discussion of core identity and values for technical universities. Other processes, such as mergers of universities, are further amplifying this debate internally.
3. ***University leaders are to blame*.** Students of mergers, acquisitions, and diversification in private industry have long suspected that a substantial share of such activity is driven by the potential benefits of current managers, rather than those of owners and other stakeholders. University leaders are subject to similar temptations. Being a rector of a large university is more prestigious than a similar job at a smaller institution. Leading a growing organisation can often be more stimulating than the job of managing a stagnated or even contracting organisation. A leader of a specialised technical university, who perceives that the only road to

budget and activity increases goes through a merger with another HEI—or through diversifying the existing portfolio of activities—will think twice before foregoing such opportunities. Not least because the budget of a broader, more diversified university is less sensitive to future changes in funders' priorities, student tastes, and scientific trends. Further, it may be markedly less fun to be a rector of a university, which is forced to navigate a budgetary decrease, than to run an organisation, which can use its weight and breadth to sail safely through stormy waters. For these reasons, university leaders may find it in their interest to leave a focused profile behind and develop their institution towards a more full-breadth type of university.

4. ***The producers of university rankings are to blame*.** The practice of collecting, weighting, and aggregating data into more or less comprehensive ranking lists of universities has flourished during the last two decades (Shin et al. 2011). Through their conceived importance for the prestige of ambitious mid-level universities in the eyes of students, faculty, politicians, and the international academic community, rankings have moved into focus for university leaders worldwide. Moreover, what means does a rector have to act on the university board's strategic directive to ensure positions gained in some of the most important rankings? What policy can the aspiring political reformer push forward to have local universities rise to more prominent ranking positions? A quick analysis of how these rankings are constructed will convince the decision-maker that gaining size is the most viable option. And how does a focused technical university achieve this purpose? Most often, the answer will be to merge with the local comprehensive university (like in Lisbon 2013), the local research institute (like in Karlsruhe 2009), the other local specialised universities (like in Helsinki 2010), or a combination of these. A university leader, seeking to defend the continued existence of an independent technically focused university, must argue why this option is worth the risk of being surpassed by several competitor institutions in the status-laden international benchmarking tools into which ranking lists have developed.
5. ***The bureaucrats are to blame*.** Defenders of ivory-tower ideals, faculty unions, and countless professors do not hesitate to point to the efficiency-oriented bureaucrats of governments and university administrations as the sources of many evils befalling universities. In pursuit of scale economies and increased budgetary efficiency, some universities have been subjected to considerable reform. From an efficiency-maximisation perspective, mergers and diversification often make perfect (theoretical) sense. Under a joint organisational umbrella, different types of education may achieve more optimal resource utilisation, for example, by sharing facilities or service functions. Although perhaps not outright decisive, such considerations may add weight to arguments for diversifying university mergers or a major diversification initiative.

12.6 Does Disciplinary Focus Build Strong Brands?

In seeking suspects behind the trend of widespread disappearance of disciplinary-focused technical universities, the alert reader may have noticed that there is one important stakeholder group not yet mentioned. Analyses presented in the book have provided no clear indications as to how engineering faculties perceive the pros and cons of engineering science and education being performed in a focused technical university—as opposed to a university with a more multi-disciplinary character.

In Chaps. 1 and 2, we have already argued that science and engineering, (while conceived as different academic disciplines) have a great degree of overlap, and that only very few universities are able to excel in engineering research without also being strong in the natural sciences. However, what is to gain (or lose) for a university by broadening the scope beyond these two subject areas? In particular, does the co-location of science, technology, and engineering research with other academic disciplines under the same virtual roof affects the status and prestige of research and education, compared to constituting a stand-alone technical university?

For the sake of argument, let us consider an academically strong faculty of engineering. How would the reputation of this faculty be affected within the confines of a comprehensive university with equally strong faculties representing other disciplines, as compared to a faculty operating within a focused technical university? It could be reasonable to expect that comprehensive universities enjoy positive prestige spill over effects between strong faculties. Academic peers and other stakeholders, according to this view, would assign a status premium to an engineering faculty, due to the existence of positive associations. However, it could also be that focus is rewarded with positive prestige effects. This would be the case if peers and stakeholders more clearly associate a university with excellence in science and technology if the university is dedicated to activities within these domains.

To assess this question, let us visit a list of universities ranked as the most prestigious in engineering and technology (E&T). Table 12.1 is based on the QS ranking (specifically, the 'QS World University Rankings by Subject'). It is possible to exploit the underlying data of this ranking to investigate to what extent the prestige of each university (in each subject area) is inflated or depreciated, relative to objectively observable metrics, such as the volume of scientific output and the level of

Table 12.1 Reputational effects in the area engineering & technology, for universities top-ranked in that area

	All universities top-ranked in E&T	Universities top-ranked across subject areas	Focused technical universities
Research reputational effects			
Positive	28%	22%	43%
Negative	20%	17%	29%
Education reputational effects			
Positive	24%	22%	28%
Negative	48%	39%	71%

citations to works authored at each university. It thereby becomes possible to assess whether focused technical universities are more or less likely than broad universities with world-class activities in several areas to be subject to positive and negative reputation effects, respectively. For example, if positive reputation spill over benefits between scientific areas exist, we would expect universities with top-ranked positions in many disciplines to have their reputation and prestige in engineering inflated beyond what would seem to be motivated from the point of view of their scientific output only. If, on the other hand, a narrower profiling helps a university nurture its brand among peer scientists and other stakeholders, we should expect to find positive reputational effects to be more common among the focused technical universities in the ranking list.

We construct two reputation effect measures based on the underlying data of the QS ranking. This ranking draws on two surveys, which assess the reputation of a university. The first survey is directed towards university faculty, and asks about research prestige. The second targets employers, and asks from which universities employers are most happy to recruit. Based on the two surveys, each university is assigned a score (ranging from 0–100) for each focused subject and (broader) subject area. Publication and citation data from the Scopus database are used to produce a third score with the same range.

Based on this data, we construct measures of reputational effect by comparing reputation scores with the score based on publications and citations. We consider a university to enjoy a positive *reputation effect* within a subject area if it scores decisively higher for reputation than is scores for publications and citations within that area. Specifically, we refer to a positive *research reputation effect* when the score (based on peer assessments in the faculty survey) is >5% higher than the score based on publication and citations. A positive *education reputation effect* correspondingly occurs when the score based on the employer survey is >5% higher than the university's publication and citations.

Table 12.1 presents the share of the 25 universities that are top-ranked in the engineering and technology subject area, for which we find such reputation effects. While column 1 shows results for all 25 universities, columns 2 and 3 show results for two sub-groups of universities. The first of these are the 18 universities that are top-ranked in E&T, but also in both natural sciences and social sciences. The rightmost column lists results for the seven universities that (while identified as excellent in engineering and technology) were not also identified as such in both the natural sciences and in the social sciences. These are EPFL, Tokyo Institute of Technology, Politechnico di Milano, TU Delft, Universiti Malaya, Georgia Tech, and TU Munich—all traditionally profiled technical universities.

The first row of column 1 shows that 28% (7 out of 25 universities) score higher for research reputation than for publication output. Such positive research reputational effects are, as shown by comparing columns 2 and 3 of the same row, more common among the focused universities. Overall, the focused universities are found to be more eligible to reputational effects in both directions. The most striking result, however, is that we find negative reputational effects for 71% of the focused universities. Together, these results would seem to suggest that while a focused

Table 12.2 Reputational effects in the area social sciences, for universities top-ranked in the area engineering & technology

	All universities top-ranked in E&T	Universities top-ranked across subject areas	Focused universities
Research reputational effects			
Positive	44%	50%	33%
Negative	28%	17%	67%
Education reputational effects			
Positive	64%	72%	50%
Negative	16%	6%	50%

profile may help a prominent technically oriented university build credibility in the eyes of its academic peers, it does not generally increase the status of their engineering students in the eyes of employers.

A similar exercise regarding the activities in the social sciences by the same group of universities (presented in Table 12.2) reveals a rather striking pattern. For the group of broader universities, positive reputational effects dominate. This suggests the presence of positive reputational spill over effects between subject areas in a strong, broad university, such as MIT or the University of Cambridge. However, social scientists active at the focused technical universities tend to enjoy lower credibility from their social science peers than what would seem to be motivated by their actual scientific production. This finding suggests a strategic challenge for focused technical universities such as DTU, the Technical University of Denmark, or TU Delft, in the form of a reputation barrier that may inhibit them from being recognised for excellence outside their traditional science and engineering areas.

In conclusion, data from two global reputation surveys suggest that being a focused technical university helps maintaining a strong brand among the global community of engineering faculties. However, focused technical universities also seem to be subject to reputational lock-in effects, in that the quality of social science performed at focused technical universities is underestimated by social science peers. These tendencies may be understood as reflecting prevailing ideas about the identity category technical university, and what types of qualities such a university is known for. If seen in that light, it is interesting to note that a branding strategy based on maintaining focused excellence does not seem to appeal to wider groups of the universities' stakeholders (here represented by potential employers of engineering graduates).

12.7 Strategic Responses to Changing Ideals

In this volume, we have devoted ourselves to the study of past and present events, which we suggest each have something to say about the organisational identity category 'technical university'. When working their way through this volume, the readers have probably asked themselves what can be learnt about the future of the technical university as an ideal, and about the future of contemporary higher education institutions relating to this ideal. Do the lessons we think we have learnt, as summarised earlier, allow us to also glimpse into the future of this category? More specifically, in what ways will it remain a useful point of reference for an ambitious HEI to think of itself, and communicate itself, as belonging to a category of organisations known as technical universities? Should leaders of more focused technical universities seek to stand up against the numerous trends through which so many focused technical universities have been transformed? Should champions of engineering education fight for the preservation and possible re-invigoration of the focused technical university? Should new technical universities be created in a future wave of foundation, institutional upgrading, and organisation of universities?

In reflecting on questions such as these, the theoretical perspectives developed in this volume offer useful guidance. In particular, adopting a perspective based on categories of organisational identity allows us to work around discussions of whether a particular university is to be understood as belonging to an organisational sub-field referred to as 'technical university'. Thinking about the same notion as a category of organisational identity allows for a more nuanced discussion, because it follows natural from this perspective to think of organisations as relating to several, possibly nested categories of organisational identity. It also becomes natural to aggregate empirical observations from several organisations, such as we do in this chapter, to consider the category as such. For example: What *gestalt* must such a category take to be attractive?

This question gives rise to some final reflections about what types of strategies technical universities apply to address both immediate 'threats' of change (discussed previously) and what attributes a category like technical universities need in order to stay relevant and agile to address contemporary challenges and expectations from both industry and society. The chapters in this volume contribute with some examples of such strategies, drawing on studies of strategies of higher education institutions to adapt, influence, avoid, and resist (Gornitzka 1999; Geschwind 2010), but also some strategies including:

– Redefining the boundaries for their activities as a technical university by using the historical legacy of the university (or its ancestors) or arguing for renewal by organisational change through mergers or restructuring.
– Identity agility strategies, including deliberate use of different identities and categories of logics to enable a more flexible way to cope with change introduced externally, through national reforms or introduction of international templates (assessment indicators etc.).
– Further developing and enforcing industrial relations to stay relevant to societal expectations.

Alternative strategies, for example, would be increased independence and autonomy towards industry; however, given the historical ties to industry, such a development is not something we see on the horizon or can detect in the chapters contributing to this volume. Rather, the organisational identities we can detect draw on the creation of counter-narratives about the other (non-technical) universities as an active way of constructing the own identity. Discussing future paths for the technical university as an institutional template and organisational identity category brings us to discuss some broader questions about their position in relation to comprehensive universities and the expansion of the HEI sector, as well as how new identities can evolve during processes of organisational change. This is discussed in the chapter by Vellamo et al. in terms of identity as a collective social concept, where group membership is important; hence, emphasising the category of technical university as important. Conversely, standing out within a field of technical universities and creating a strong identity narrative that is easily communicated is of importance to most HEIs to maintain a distinct profile and argue their relevance to society. Drawing on analysis of sameness and difference, another strategy is to form alliances with similar HEIs in the same category or institutional field of technical universities. Being included in a similar context reaps benefits of belonging to a field (or herd) of technical universities, but nevertheless cultivates a distinct profile and identity to stand out. Another contribution to this debate is made in the chapter by Antonowicz, discussing the tensions between growing popularity of global university rankings and their influence on HE policy and technical universities preserving their unique identity.

Outlining some avenues of further research, there are several areas that seem promising, based on the findings and analysis in this volume. One area concerns how technical universities work internally with strategies, which argues for change within the organisational field. In the light of processes of mimicking existing models of technical universities, and for engineering education (including of liberal arts components in the US and other models based on single-faculty technical universities) we recognise that there are several ideals existing at one point in time. This provides ample opportunity for further studies of both national empirical contexts and in-depth analysis of mechanisms for transformation and resistance to change. A related question concerns 'field membership' and how counter narratives voiced by technical universities (contrasting their activities, status and ideals to other HEIs) will be orchestrated in the future. On the one hand, merger processes challenging existing ideals of technical universities can be expressed as diluting an ideal of the single-faculty technical university and bring about strategies for resisting change. On the other hand, the alternative is that this very same process can lead to debates about enriching existing models to cope with future challenges of technical universities.

12.8 A Roadmap for Developing the Idea of a Technical University

We (the editors of this volume) are all currently active as researchers and teachers at a university which calls itself an 'institute of technology'; a term that we see as largely synonymous with 'technical university'. It is, therefore, natural to us at the end of the volume and the journey that was the writing of it, to also offer slightly more personal reflections on the lessons learned. We, and hopefully our readers, are most interested in trying to take stock of what roads lie ahead that seem the most attractive for the technical universities of today.

As we have argued, many technically oriented universities approach their future with confidence, with the pride that is derived from a strong historical legacy, and from strong support from large parts of society. Technology, the domain of expertise claimed by these institutions, is more pervasive than ever. This situation offers highly interesting opportunities. However, the tremendous penetration of technological artefacts into modern lives and industries does not guarantee the relevance of existing technical universities for the educational and scientific needs of tomorrow. Neither can we conclude that the key importance of technology in itself motivates an organisation of engineering education and technical research in the form of the 'classical' technical university, as envisaged in Europe. We may even feel compelled to argue that the observation that technology has moved into the very centre of society leads to the conclusion that organisational templates dating from previous industrial and technical revolutions need to be updated.

It is our impression that European universities have for a long time been relatively loath to think seriously about picking up some of the key traits of the successful American variant of the technical university—a variant that places less emphasis on engineering orthodoxy. This is probably a consequence of institutional inertia derived from the organisational principles of universities as such, but also a consequence of strong embeddedness in national and inter-European contexts.

As we have noted, more recent years have seen increased activity in re-thinking the boundaries and organisation of technically oriented universities. Does that mean that the broad research university is the only viable institutional template for building the leading HEIs of tomorrow? Are both the heritage and tradition of technical universities to be understood as liabilities? We would argue that this is not the case. The identity category 'technical university' is associated with values and ideas, which we are sure have an important role to play for higher education and for academic research. These values can be mobilised in the building and rejuvenation of academic institutions.

In our view, the engineering mind-set constitutes one such value. Higher education institutions, whose organisational identities are soaked in the problem-oriented approach of engineering practice, are likely to play important roles in the academic landscape of tomorrow, developing novel, innovative solutions in research and education. The focus on, and the genuine fascination for, the opportunities and risks of new technology also constitute an organisational principle that we believe many HEIs currently or historically referring to themselves as 'technical universities' will be able to refine and build successful strategies from. This also entails strategies for actively recognising societal expectations for new technological solutions to acknowledge users' impact on shaping novel technology—not only technology change influencing the daily life of users, industrial sectors, and society broadly. In shaping such strategies, university leaders are, we would argue, well-advised to define what it means to them to be the leader of a technical university. In this exercise of key relevance are questions such as what humanity needs and wants (and, in a slightly more mundane spirit, the objectives of present and future industry, government, and other stakeholders) to know and do to harness the potential of continued technological development. Defining the technical university as an institution dedicated to the existing subjects that constitute engineering science, without recognising future demands of responding to even more complex challenges, means we will risk missing valuable opportunities to grow the next generation of technical universities. Another concern pertains to a how a more fluid notion of technical university organisations influences the understanding of future needs of key engineering skills, as they are being negotiated within and between organisational boundaries of what we today call a technical university.

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