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# A distinguished scientific field? Pursuing resources and building institutions for engineering research in Sweden, 1890–1945

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**ABSTRACT**
The perennial issue of the relations between science and technology and society is a backdrop to this study of material, symbolic and economic foundations of engineering science in Sweden. It analyzes three cases of institutional reform from the first half of the twentieth century that were essential to the formation of engineering research as a distinct and respected scientific field. Taking the intersection of institutional and linguistic analysis as a starting point, two intertwined processes are followed: the drawing of boundaries by different actors that delineated the new kind of research, and the struggle over resources for the institutions that could enable this research. The institutional reforms are placed in context, relating arguments by the proponents of engineering research to the politicians and university academics who were in control of various resources. It is suggested that an institutionalist perspective enunciated in terms of form and content is a productive interpretive possibility.

**KEYWORDS**
Engineering research and education; politics for research; twentieth century Sweden; historical institutionalism; conceptual history

## Introduction

When and how were engineers distinguished as scientific researchers in Sweden? A simple question calls for a simple answer: in the first half of the twentieth century, through a series of institutional reforms that established engineering research as a distinct and acknowledged scientific field and brought resources to it. Even if this phrasing of my basic thesis is straightforward, the processes that led to this institution building were complex rather than simple. In this introduction, I will spell out points of departure for my way of framing questions and articulating answers when analyzing this complexity.

One starting point is the broad tradition of institutional theory, or new institutionalism, with its key claim that institutions matter.[1] They pattern actions and behaviour, and are at the same time products of human activities. They are a mediating link between social structure and individual actor. Central to an institutionalist perspective is the notion of path dependence, i.e. the tendency of an institution to be sustained once it has been established, perhaps as a solution to a perceived problem at a formative moment in the past.[2] The idea is reminiscent of the systems approach in the history of technology: a system once

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established tends to be reproduced. Central to another strand of institutionalism is the notion of institutional isomorphism, i.e. the tendency of an organization to mimic others in the same field as a means of gaining legitimacy and maintaining credibility.[3] The idea can be rephrased: as a part of a larger system, an organization adapts to its environment so as to be acknowledged by adjacent forces that it is dependent on. The notions of path dependence and isomorphism create a dynamic tension between the diachronic and synchronic aspects that they highlight.

In this article, organizational models as the university and the institute of technology, with associated elements as the laboratory and the doctoral degree, are viewed in terms of institutions. They are significant objects of study because they affect behaviour – the production of scientific knowledge, for example, typically takes place in institutions established to promote research. But as they are forms for rather than the substance or content of education and research, I will make use of the distinction between form and content.[4] Thus, this article deals not with the practices of producing a new kind of techno-scientific knowledge, but with the forming of institutions on which production of technical knowledge deemed to be scientific was predicated. As we will see, there was a continuous traffic between three aspects of this process: *articulation* of a perceived problem, *mobilization* of resources for a proposed solution, *formation* of an institution. Either a new institution could be formed or an existing one could be reformed, say by incorporating elements from others in the organizational field. In the case of higher technical education, taking over institutional forms from the universities was a vehicle of academic drift.[5]

As language was the means of verbalization and persuasion in these processes, my analysis of the discussions and controversies that paved the way for institutional formation takes its starting point in the tradition of conceptual history, with its focus on language usage.[6] More specifically, the notion of essentially contested concepts has guided my inquiry.[7] Interminable disputes about the correct understanding of concepts such as art and democracy indicate that something valued is at stake when delineating the rules for their applicability. In our case, we will see that actors engaged in a similar tug-of-war due to differing views about the appropriate use of concepts such as science and technology – which, in turn, had connections to scientist and engineer, research and higher education, institute of technology and so on. Attempts to spell out the meaning of a concept by clarifying it in terms of something else tend to entangle it in a web of related concepts.

And as language is permeated by this kind of metaphorical reasoning, i.e. viewing something in terms of something else, I have also analyzed uses of figurative language in the accounts that actors gave of a situation they perceived to be a problem and sought support to solve. But problems that politicians in control of resources can address are not fixed and given. They are represented by means of problem-setting stories in which a particular perception of an uncertain issue is formed in a complementary process of naming and framing.[8] Tacit but generative metaphors underlie accounts that, when framing the problems, also imply appropriate solutions. We will see, for example, that some actors described expenditures on higher technical education in terms of a national investment rather than a government cost, even if the metaphorics in this description of the state of things were not spelled out. I will also scrutinize a more complex case of metaphorical reasoning underlying the argument that such investment was needed to prevent Sweden from 'lagging behind' other industrial nations.

But institutions and words do not acquire meanings unless humans make use of them, and I have, guided by the interpretive framework sketched above, followed actors with different backgrounds and points of view. Engineers had interests in the processes and promoted them, but the profession was no singular entity and did not speak with a unified voice.[9] Many of the two thousand Swedish men who had received a higher technical education by the turn of the century had worked for the government, constructing railways and canals, for example, others could become municipal engineers, working on the infrastructures of the growing cities. With their focus on technical expertise and legality, they could seem old-fashioned and bureaucratic to the swelling ranks of new or 'modern' engineers, working in the expanding private industry and with more focus on the commercial aspects of technology. But viewpoints varied within the private sector as well. An engineer in the aged mining industry might not see things the same way as one in the novel electro-technical industry, based on science rather than tradition. There was also a more vertical than horizontal aspect to the dispersion of engineers in Swedish society. Not least in public agencies, the majority of those in the upper echelons had a higher technical education, whereas many working in industry had a lower, more practical education. The spatial analogies implied that 'higher' was superior and more worth.

The concept of science was a decisive criterion for distinguishing between the kinds of education. 'Research' as an emerging task in the context of higher technical education related to forms of professional training by which students acquired skills to handle 'science'. This was a prerogative for higher education institutions, where teachers generally had a background in the university or in engineering. But the outlook and interests of a professor of physics could differ from those of his colleague in mining mechanics, and these actors might embrace different aspects of their institution's mission. Institutions for professional education that aspired to be higher were caught in a bind. They had to be practice-relevant but not unscientific, academic but not impractical. Academic drift was a possible outcome of this status-dilemma, but not the self-evident or only possible one.[10]

Beyond these institutions there were other, such as the universities, where professors could act as guardians of science. Institutions in the educational system were dependent on the approval of current and potential peers for legitimacy. In Sweden, these institutions also depended on public support in the form of policy decisions on funding. Politicians had to be persuaded to assign resources for institutional maintenance and reform. If actors perceived the situation as a zero sum game, with a potential for relative redistribution of scarce resources, the claims of others loomed as threats.

Varying points of view were also present in Parliament, whose mix of actors in its way reflected power structures in Swedish society. At the beginning of our period, agrarian interests strongly influenced policy; at the end of it, the labour movement dominated. One aspect of this transformation is what I call the *political industrialization* of Sweden, viz. the articulation of the interests of industry in order to reform legal and other institutions that made up the framework for industrial activities.[11] Engineers, whose power in terms of influential positions grew rapidly during our period, were crucial to articulating and promoting industrial interests. A case in point is the issue in focus here, the organization of education and research in technology, by virtue of its importance to the managing of knowledge in industrial society. But the relationship between technology and industry was not self-evident, nor were the connections between industry and industrialism and visions of a better future society. The machine, for example, could from a socialist perspective be perceived as a potential liberator of the working class, but also as the practical means of industrial capitalism for exploiting actual workers.

In sum, distinguishing engineers as scientific researchers in Sweden was a complex process. This study of material, symbolic and economic foundations of engineering research deals with relationships between science and technology and society, a perennial issue that I will approach from an institutionalist perspective. Two themes are intertwined: the boundary work that created the notion of a new kind of research, respected as scientific but distinct from science, and the struggle for resources that forged institutions enabling the kind of research that was being distinguished.[12] Since building institutions of this kind is resource-intensive, actors in control of resources – the notion of resource will here understood in a broad sense – had to acknowledge the validity of the claims. Given that the processes were political, building institutions for research was a political matter. And because language is crucial to setting agendas, I will examine the naming and framing of the issues. Setting the terms of how a problem is perceived and discussed affects which solutions can be proposed and, eventually, acquire political appeal.

## The institutional landscape

Before turning to promises and commitments made by engineers when pursuing resources for reform, I will sketch norms and institutions in the organizational field that set the stage for the actors in my account.

The notion of research as an essential task for the university won acceptance in nineteenth century Sweden, where state universities had existed in Uppsala and Lund since 1477 and 1666, respectively. Ideals and organizational guidelines were taken over from Germany.[13] The German research university that emerged from reform processes starting in the late seventeenth century became very influential. With its notions of academic freedom this model is symbolized, in retrospect, by the new university in Berlin that opened in 1810 under the auspices of Wilhelm von Humboldt, the philosopher and scholar who as a short-lived Prussian government official reformed educational organization. An image of a fundamental, dynamic unity was central to the 'Humboldtian' tradition. Research can not be scientific unless basic education has been, and education can not be scientific if those providing it do not conduct research. When research and education strived 'deeper', the university manifested its position as an institution for 'higher' learning. Freedom under responsibility was seen as the most productive way to organize and promote the pursuit of knowledge by academic teachers and students alike.

In Sweden, admission tests, and thus basic preparation for the kind of self-guided work that became a characteristic feature of academic studies, were in 1862 removed from the universities and instead assigned to upper secondary schools. A high school diploma, the so called student degree of the Swedish *Gymnasium*, became the admission ticket to the university. Given that this diploma was beyond the reach of all but the very few, it also served as a ticket to distinguished positions in society. The *Gymnasium* and the university were coupled as essential elements of an educational system that produced distinction, for example, between men and the women that were not admitted to it (Figure 1).[14]

University studies became more specialized as the number of subjects required for a degree decreased. Freer choice at higher levels allowed in-depth studies in fewer subjects, which could lead to the independent research work that characterized true academic study.

**Figure 1.** In 1895, these young men had won their degree from the *Gymnasium* and wore the white caps that signaled this. They could go on to the university and become pillars of the state (Courtesy of Stockholm City Museum).

The process of granting degrees was also reformed. The Doctor of Philosophy degree, which was institutionalized in 1870, became a requirement for many higher positions. New sites and methods for teaching were introduced with two other institutions: the laboratory and the seminar. Major government funding for new buildings and more professorships confirmed and promoted the notion of research as an essential and, thus, distinguishing activity. The institutionalization of a research imperative was eventually codified in statutes. According to 1908 legislation, a mission of the state universities was to provide 'education based on scientific research'. Eight years later, the mission was simply to promote 'scientific research and education'. Despite all transformations, Swedish universities continued to organize in line with a path taken much earlier, i.e. with the four faculties of philosophy, medicine, law and theology.

Formal education in technical matters had no aged institutions to reform. In accordance with the contemporary European pattern, various schools were established in the early nineteenth century for the mining industry, for agriculture and the military.[15] Of special interest here are two that opened in the 1820s: the Technological Institute in Sweden's east-coast capital Stockholm, financed by the government, and the Chalmers School of Arts and Crafts in the west-coast city of Gothenburg, originally financed by a donation but soon supported by the city and the government. Given that these two schools are significant from the perspective of later developments, it should be noted that they were initially related to crafts and industry rather than the higher education system. According to the first statute, the training provided at the Technological Institute should be 'more popular and practical than scientific'. Eventually, influential actors made a different evaluation of the significance of science. After fierce debate about the curriculum, mid-century reforms introduced more theory. Meanwhile, the government established technical upper secondary schools in various parts of the country.

The 1870s, when industrialization gained momentum, mark a turning point at which professional engineering associations began to stabilize, such as the Swedish Association of Engineers and Architects. Under the influence of German models for technical education, and adapting to the new ideals of higher learning, the Technological Institute was reorganized to be a *Technische Hochschule*.[16] It was renamed the Royal Institute of Technology, in 1876, and more closely linked to the hierarchical higher education system. Admission generally required a *Gymnasium* education. The curriculum aspired to academic recognition, although studies were strictly regulated by the institute, in contrast to the free and self-guided ideal of the university. Already in the labeling of subjects, a distinction was made between 'basic' and 'applied', suggesting that some subjects were primary in relation to others. Providing education continued to be the overriding purpose. Research was dependent on interested individuals, not an institutionalized undertaking that characterized the Royal Institute of Technology.

The technological education system became more stratified. Graduates of the prestigious Royal Institute in Stockholm often became public officials, at utilities or infrastructure agencies, for example, some at high levels. Graduates of the five technical upper secondary schools, at which training was more practical and the admission requirements were more elementary, tended to find work in the expanding industry.

The Chalmers School of Arts and Crafts in Gothenburg evolved into something of an anomaly in this two-tiered system of government-supported technical education. The school had two sections, labelled in spatial terms as 'higher' and 'lower'. The lower section was basic and preparatory in nature, whereas the higher was more theoretically oriented and perhaps sought equal status with the Royal Institute of Technology. In 1882, the institution was renamed Chalmers Technical School.

The name was finally changed to Chalmers Institute of Technology, in 1937, despite resistance from the Royal Institute of Technology, suggesting how much was perceived to be at stake in the naming. The process leading up to this decision in Parliament, along with its wider repercussions in terms of a breakthrough in funding for engineering research, is the subject of the third example of institutional reform presented below. It had distinct parallels and links with the two preceding cases. The theme of the second is the formal recognition of engineering research as scientific, as illustrated by the Royal Institute's pursuit of the right to award a doctoral degree of its own. However, the resulting institutional innovation of 1927 – the DEng degree – was not matched by a breakthrough in research output. To start with, we will follow the process that led up to the 1911 parliamentary decision to grant the Royal Institute funding for new buildings, equipped with modern laboratories that were depicted as essential to the production of new knowledge. This example will also make us acquainted with a special feature of Swedish political culture – the importance of government commissions, in this case appointed by the Ministry of Ecclesiastical Affairs, which handled educational matters.

## Building resources

After a recession in the 1880s, the Swedish economy prospered. The number of applicants to the Royal Institute of Technology started to exceed the capacity of the buildings and their facilities. Applicants were turned down. This novel situation entailed problems, but also possibilities. Resourceful parents argued that it was unjust of a publicly financed institution to reject formally qualified candidates, and accused the institute of disregarding the rights of citizens. Growing demand for the education that the Royal Institute offered became an argument for its expansion and reform. The old buildings had to be renovated and enlarged in order to accommodate more students, the institute's management argued. But the rise of industry required not only a larger *number* of engineers, other observers argued, but also another *kind* of engineer, less scientifically lofty and more cost-conscious than the kind hitherto trained.[17]

The findings of a smaller government commission in the early 1890s led to minor reforms. As the number of applicants did not fall, problems persisted. Committees at the Royal Institute proposed various solutions. The proposals caused conflicts within the faculty, whose members came from different backgrounds. Some professors came from the university, whereas others had acquired their competence as practicing engineers. Tensions can be understood in terms of the opposing perspectives of a school culture and a shop culture.[18] Differing priorities complicated the issue even before it spread beyond the walls of the institute.

In 1906, the government finally appointed a major commission with the task of investigating 'the organization of higher state-supported technical education'. The commission was one of several assigned to rejuvenate Sweden after the national ordeal of having lost its control of Norway in 1905. The presidents of the Royal Institute and Chalmers, Anders Lindstedt and August Wijkander, wrote most of the commission's report. Both of them had a university background with a PhD in physics and were professors in 'basic' subjects. Formally, both institutions were under consideration – a fact that we will return to in our third case – but in practice the 'Royal Institute issue' took center stage.

The commission collaborated closely with the faculty of the institute. It also had strong links to the prestigious Swedish Association of Engineers and Architects, based in Stockholm but hoping to represent engineers on the national stage. The commission also requested the opinions of several smaller, local engineering associations based outside the capital and its bureaucracies but more directly related to industry. The opinions of these later actors tended to differ from those of the commission, which was more inspired by German ideals of a dynamic union between scientific research and education. Despite the academic inclinations of the dominant investigators, invocations of 'industry' were a recurring theme in the argumentation of the commission. But trying to mobilize industry for support could, as we will see, be double-edged. Compromise and tension marked the commission's final report in 1908.[19]

Notwithstanding the drawn out preparations, the proposals remained open to dispute. Wider concerns were at stake when deciding on what could appear as formalities, such as altering some wording in the statutes. Three issues had been controversial throughout the discussions: admissions, organization of the curriculum, degree of specialization.

Decisions concerning admission requirements affected what kinds of people could become engineers. The commission in practice proposed the equivalent of a high school

**Figure 2.** At a ceremony in 1903, the student union was bestowed a standard. The president interpreted its motto 'For peaceful feats'. Singers sang patriotic student songs. (Courtesy of The Royal Swedish Academy of Sciences, Anders Lindstedt's archive).

diploma, something that the social standing of engineers required. Like university students, they were to possess the broad education provided by the Swedish *Gymnasium*, which would thus serve as a gatekeeper also for the highest technical education. Those of a different opinion argued that it was more important that engineering students possessed technical knowledge and industrial experience than liberal education. They also wanted to open the doors for applicants who had graduated from a technical upper secondary school, where training was more vocational than theoretical.

Concerning the organization of studies, local engineering associations close to industry generally preferred a regulated curriculum and mandatory attendance as a means of encouraging steady progress and discouraging prolongation of theoretical studies. Opponents argued that such an emphasis on compulsion would make the Royal Institute more like a 'primary school', with adverse effects on the status of engineers. Similarly, students formed a union in 1902 to fight the system of assessing a fine for every absence, which they regarded as unworthy of an institution that had almost achieved the status of a university. The commission, for its part, proposed a more flexible organization, in line with the tradition of *Bildung*, or 'liberal education', and its self-guided approach (Figure 2).

In the tension between specialization and breadth, the commission emphasized the former. The purpose of specialization was to permit more scientific studies, depicted as both 'deeper' and 'higher'. Industry-oriented opponents insisted, in more horizontal spatial terms, on 'broader' familiarity with technical applications so as not to turn students into 'narrow' theoreticians. In conjunction with the basic dichotomy between specialization and breadth, some actors also discussed the relevance of non-technical subjects in order to provide a wider outlook. To prevent prolongation of studies, this debate was toned down. Nevertheless, some protested. A course in economics could, one critic argued, serve as a means of making the specialist aware that the world consisted of more than just turbines. Otherwise, the engineer would be reduced to no more than a 'profit-generating working hand of less exclusive specialists', an aspect of social standing of importance to the 'position of engineers as leading or led in society'.[20]

As we can see, viewpoints varied among engineers in different positions. Even if the engineering profession was relatively small in Sweden, it did not speak with one voice. We can also note that there were tendencies within the profession towards a revolt against an order that did not appreciate engineers in proportion to the significance of their work. In the light of technology's importance to society and progress, educated engineers argued that a widened professional responsibility was a base for extended professional autonomy.[21]

The preliminary issues discussed above concerned the activities within the Royal Institute – the content, in terms of our interpretative framework of institutional form and content. This was not resource demanding in an economic sense. The institutional forms, the framework in terms of buildings and personnel, generated the main expenses.

The commission proposed increasing annual admissions from 125 to 300 students. This suggested *quantitative* expansion justified claims that would bring about *qualitative* improvements. Given that new buildings had to be built to accommodate all the new students, the argument went, it was imperative that they at the same be equipped with modern laboratories so that education could be scientific and research carried out. And if students were to be educated properly, the number of professors had to increase from 14 to 31.

Underlying the commission's proposal for resources of a magnitude that had not previously been granted was the presupposition of a national *need* for engineering education, a need that manifested itself in the number of applicants. The Royal Institute could meet this need if given adequate resources. If not, Sweden would risk *lagging behind* other industrial nations. Without scientifically based technical education, the country would also be in danger of *declining* in comparison with other cultured nations. These two yardsticks, along with their spatial analogies, are worth noting: industrial development in horizontal terms and cultural standing in vertical terms, with the corresponding threats of lagging behind and falling down. Furthermore, the public expenditure was described not as a sacrifice for the sake of higher education, a cultural cost, but in terms of a national *investment* that would 'undoubtedly yield interest on the ventured capital'.[22] These ways of articulating problems and solutions are a recurring feature in the three cases that this article presents, and we will return to this mode of argumentation in the concluding discussion.

The government presented the proposals to Parliament in a 1909 bill. Politicians who controlled funding, and were responsible for expenditure, were skeptical. Did the country really need so many engineers, considering heavy emigration of technicians and the fears engineers themselves had expressed that an oversupply could create unemployment and an 'engineering proletariat'? Critics also argued that any need for more engineers was for those with practical training. Why had the commission taken the opposite approach and insisted on students from the *Gymnasium* with its liberal education, making it virtually impossible to go on from a technical upper secondary school to the Royal Institute? At a time of political strife over the entire education system, this was perceived as a form of class prejudice. A Social Democrat member of Parliament, who himself had a practical training in construction technology, contended that young people with genuine technical interest and ability should be admitted, not just those with rich and educated parents. Opening the doors for technical talents was a question of both individual fairness and national efficiency. The Royal Institute was described as an upper-class institution that the commission had tried to expand in disregard of wider, societal interests.[23]

Parliament decided that the proposals had to be reworked. After further deliberations, an amended bill was presented in 1911.[24]

This time industry played an active role in politics – by demanding influence but waiving responsibility, mainly for funding. Backed by leading industrialists, many of whom had a technical education, the 1910 founded Federation of Swedish Industries went on the attack. An independently working committee within the Federation had prepared a statement on the proposals and called to a public meeting. The committee argued that industry had no need of an over-production of theoreticians, technically sophisticated but ignorant of the economic and managerial realities of industrial production. The solution was *not* to spend money on lots of sophisticated laboratories, but to raise salaries in order to attract the right kind of teachers, namely those with experience from industry. In the heated debate at the meeting, the attack won both supporters and critics. Speakers associated with the Royal Institute contested the views of the committee. The president declared that the mission of the institute was not to produce managers for industry, but to be a home for 'technical-scientific research'. In a later public meeting, he followed up his counter-attack and underlined the conceptual distinction between 'technology' and 'industry', maintaining that the former was *not* a means for the latter. On the contrary, industry was a means for scientific technology to spread its benefits to the population at large.[25]

The campaign of the industrialists was a move in a struggle over the understanding of the concept of technology and its relations to industry and science. It attracted a great deal of attention. To the meeting came not just different kinds of engineers, but also the prime minister and the minister of finance, members of Parliament with different views, representatives of the press. The public clash between representatives of technology and industry also had political repercussions. Prime minister Arvid Lindman, the first one with a background as an industrialist rather than as a government official, sent a confidential telegram to one of the Federation's most influential managers, Sigfrid Edström, the Chalmers-educated CEO of the Swedish General Electric Inc. Lindman warned that the entire bill would fail again unless decisive counter-action was taken. Under the next board meeting, Edström emphasized this point even if others thought that much of the committee's criticism was justified. The Federation backed down.[26]

However, there were still skeptics in Parliament. Promoting industrial prosperity was surely not a matter of simply training more engineers? Was it reasonable to place such emphasis on science and theory, as the commission and the bill did, if the goal was to support industrial practice? Despite persistent hesitation, most politicians were persuaded that the Royal Institute needed more professorships and new buildings with well-equipped laboratories, where engineering education and research literally could take place. If Parliament did not acknowledge this need, one politician summed up, the country's engineers would be unable to compete with their counterparts in other nations and Swedish industry would fall behind. Funding for the qualitative changes in terms of buildings and personnel, which had assumed greater prominence as the issue evolved, was granted despite a steady retreat with regard to the quantitative argument that had initiated the debate. Parliament accepted

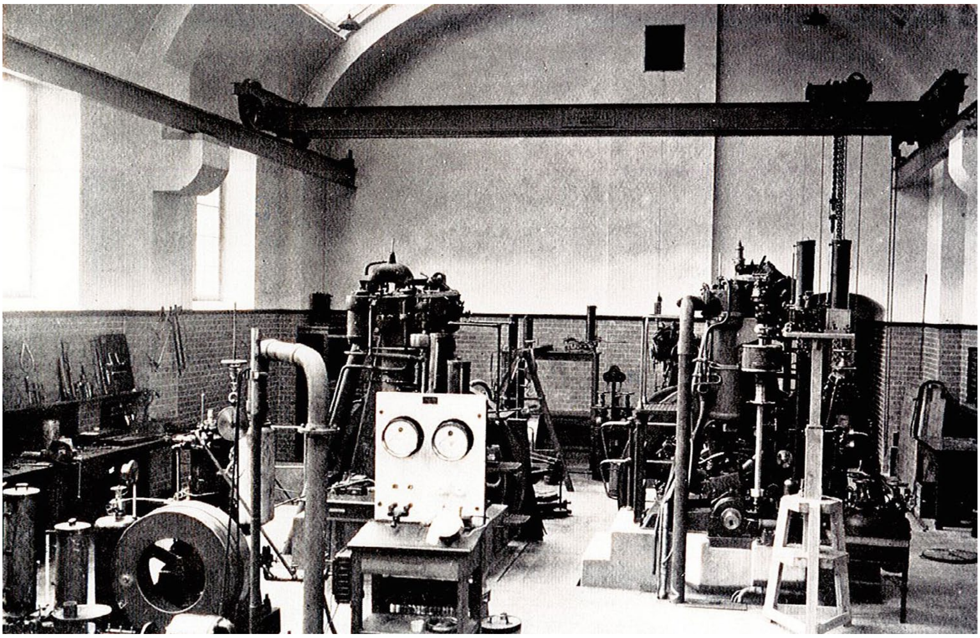

**Figure 3.** The Royal Institute's new laboratories, such as the one for combustion engines, were intended for practical exercises in engineering education, for research, and tests for companies and authorities (Courtesy of *Kungl. Tekniska högskolan: Fyrans album*, Gothenburg, 1925).

the costs for laboratories and professorships, even if annual admissions at the end of the day only increased by 25 students (Figure 3).[27]

The new buildings, which are still in use, opened in 1917. But the acknowledgement of the need for modern laboratories did not lead to flourishing research or to recognition of the scientific proficiency of engineers. Meanwhile, the impact of technology during the war spurred some institutional innovations. However, the Academy of Engineering Sciences, formed in 1919, did not result in automatic recognition by the community of recognized scientists. Nor did the establishment of some independent industrial research institutes, which also encountered insurmountable obstacles during the post-war depression when industry withdrew funding.[28]

In the Swedish case, securing a stable financial base required a public and political acknowledgement of the national need for engineering research. The new buildings and laboratories did not guarantee, however, that the activities carried out within these institutional forms would be conceived in terms of scientific research and education. One way to promote such a recognition was to appropriate a less material kind of institution. We will now turn to that pursuit.

## Academic resources

In connection with the discussions analyzed above, actors at the Royal Institute of Technology proposed the introduction of a doctoral degree in technology. An influential example was the German *Doktor Ingenieur* degree, which was adopted in 1899 despite fierce opposition form university academics. This controversy suggests that something of value was at stake.[29]

As indicated by a debate in the faculty of the Royal Institute, in 1905, the issue could be viewed in different ways in Sweden too. Many faculty members, particularly those responsible for subjects labeled as 'basic', were in favor of the idea of a doctorate in technology. As a rule, they had received their undergraduate training and a PhD at a university. However, not everyone was supportive.

Among the opponents was a university-trained professor in chemistry. He argued that if engineering research was essentially scientific, the Royal Institute should have the same right to grant degrees as the universities. And if an engineer could receive a PhD like any other scientist, there was no reason to establish a *different* degree for the same kind of competence.[30]

Faculty members who taught applied subjects and had received a basic education in engineering could also be opposed, although on other grounds. A professor in the School of Mining, who had practical experience of his industry and its demands, had three main objections to creating a doctorate. First, the title of Engineer would be degraded in the public mind if a 'higher' degree were introduced. Engineers should not depreciate their own basic degree, which was more demanding than its exalted university equivalent. Second, any engineers who wanted to return to the institute after a few years would probably have failed in industrial practice; doctoral students and prospective doctors were likely to be capable mathematicians, but hopeless as engineers. Third, when recruiting teachers for the institute, a doctorate would be rated too high in comparison with practical experience. This would surely harm Swedish industry in the long run, as doctors who were incompetent engineers could not be expected to train proficient engineers.[31]

This 1905 debate made it clear there was no unequivocal support among members of the Royal Institute faculty for a degree that could transform engineers into scientists. Nor was it obvious that the engineering profession as a whole would share an interest in a higher degree. It was even less evident that university academics, the guardians of true science, would have an interest in recognizing engineers as scientists.

Nevertheless, the quest for a doctorate in technology gained momentum in 1918 once the new laboratories had opened. The controversies came to an end in 1927 when the government issued an ordinance concerning the new degree Doctor of Engineering, DEng. The process leading up to the ordinance was a social drama, with a Hegelian twist, consisting of three acts with different casts: first engineers, essentially the faculty of the Royal Institute, then university academics as an antithesis, and finally engineers and academics together in a mutual compromise and synthesis.[32] I will summarize the debates by highlighting three recurring issues and then three lines of argument.

The *subject matter* of this new specialization in the realm of scientific knowledge was a matter of dispute from the very beginning. It was essential to demarcate a subject matter that distinguished research as technological, as well as a methodology that distinguished research as scientific, in order to justify the proposed doctoral degree. Doing this entailed challenging received ways of understanding key concepts as science and technology. The wider implications of the issue are suggested by an answer that the engineers gave to it. A dissertation in a technical subject 'shall deal with a technical subject', a faculty committee proposed in 1919.[33] This circular solution did not solve problems of principle and was criticized. What it meant in practice was that research at the Royal Institute would be limited to subjects in the category called 'applied' or 'technical' or 'engineering'. This drawing of a boundary line was a way of assuring that there would be no competition in the 'basic' or 'scientific' subjects. At the same time, the engineers took over the methodology from the universities. The focus on mathematical processing of empirical observations and experimentation was similar, but the objects of study differed. The form for presenting results, a written dissertation, also came from the universities.

Given our focus on institutional forms and how they tend to confirm and reproduce mindsets, it is interesting to note attitudes toward a potentially productive alternative. Replacing part of the written dissertation by a blueprint or model of some construction was an option in some countries but barely discussed in Sweden. It is as if the notion of science was so dependent on established conventions and paths already taken, that alternative approaches, say forms for presentation that could be more akin to the content of technological research, were ruled out even before their potential could be explored. That this option was inconceivable suggests that there lay a significant message in the academic dissertation as a medium. There was an isomorphic pressure to mimic institutional forms of the universities, as the pursuit for the doctorate was dependent upon recognition of the academics. The form was a norm.

A second issue was how to determine whether prospective students possessed *scientific training* that was satisfactory in the absence of a licentiate degree, which was a requirement for obtaining the prestigious PhD at the universities. The licentiate was essentially preparatory in nature and consisted of higher studies and a thesis in one subject; previously two or three subjects had been required. The doctorate was awarded following public defense of a more thorough thesis. Doctoral candidates wrote this thesis independently and without additional courses, an organization in line with the Humboldtian tradition of 'solitude and freedom'.

During the first act of our social drama, engineers rejected the idea of introducing a preparatory degree. Instead they proposed that applicants, besides the basic engineering degree, be required to have the highest possible grade in their major subject, as well as the third highest grade in three subjects designated as essential by each school. These subjects generally belonged to the 'basic' category. Critics on the faculty argued that making the first years of study in theoretical subjects decisive for eventual graduate study in a technical subject would distort the ordinary engineering program. During the second act, academics rejected the proposals of the engineers. Some academics questioned whether particular grades in the Royal Institute's basic program would guarantee that doctoral candidates had acquired the intellectual independence that was needed. During the third act, a joint committee of engineers and academics replaced the detailed requirements with what in practice was the equivalent of a licentiate degree.

The relationship between theory and practice was at the heart of a third issue. Was *practical experience* necessary to conduct research in technology and, if so, how much? The eventual consensus was that two years should be required, and that working as an assistant at the Royal Institute laboratories would count as practice.

Three main reasons for the introduction of the new doctoral degree were presented. First, proponents argued that research at the Royal Institute would be greatly stimulated and that its scientific standing would be raised to a higher level if the 'applied' subjects were recognized as sciences. But it was also argued that there was a difference in kind between these subjects and traditional academic ones. While pointing out similarity and difference at the same time, the proponents of the degree, primarily professors in basic subjects, reiterated the need to promote research – but had little to say about why research was so important

**Figure 4.** The faculty of the Royal Institute consisted of engineers and scientists who represented different subjects and outlooks. As strong opinions often differed, clashes were frequent. Eight professors are missing in this photo from 1916 (Courtesy of the Royal Institute of Technology Library).

in the first place. Students, engineering professors, practicing engineers and representatives of industry tended to be skeptical, although they did not explicitly oppose the attempt to obtain scientific ranking.

The second argument was that a doctorate in technology promoted progress and competitiveness, the 'entire economic life of a nation'.[34] The relation between cause and effects was assumed rather than proven, and the argument was mainly supported by comparative allusions to other nations that endorsed science and industry. We can here note the parallels to the spatial analogies discussed above, especially the image of 'lagging behind', evoked as a threat and as a problem that had a techno-scientific solution, so to speak.

The third reason was that the new degree would promote recruitment of qualified personnel. This reason probably was as important as the concerns about Science and the Economy, particularly because of interest among professors in recruiting assistants to their laboratories (Figure 4).

Committees dominated by faculty members with a university background initially raised these issues at the Royal Institute. Given the complexity of the matter, the proposals were controversial. Professor of construction statics Carl Forssell was a recurring, often stern, critic who represented one of the 'technical' subjects that constituted the formal center of the controversy. He had a degree in civil engineering but had also studied at the university. His opinions won few adherents, but are of interest as they indirectly illuminate the mainstream views that he criticized.

Forssell launched his attack in 1922 by declaring that the faculty committee had brushed aside the fundamental question of the purpose of higher technical education. Stating that the primary duty of the Royal Institute was to enable students to conduct independent, innovative work that would benefit industrial progress, he accused the committee of implying that not all graduates had acquired the skills to work in this scientific way. Thus, the proposed requirements for special grades before conducting research degraded the basic engineering degree and implied that the Royal Institute was not performing its primary duty. If the foundation was so poor, basic education should be reformed rather than being saddled with a new degree. Moreover, the proposed requirements excluded able practitioners, the absurdity of which was illustrated by the fact that only two engineering professors would have been admitted as doctoral candidates in their own subjects.[35]

Forssell went on to argue that mathematical skills and real-life engineering experience was what counted. Furthermore, teachers should be required to conduct research, since it was their ability, primarily in terms of promoting scientific studies, that was the decisive factor, not the grades of their students. Having these kinds of engineers–professors at the Royal Institute would constitute a step toward introducing a doctoral degree *in technology* without subservient and counterproductive adaptation to university norms.

Nevertheless, we can see that Forssell adhered to fundamental university notions, such as the dynamic unity between teaching and research. He had already identified two kinds of opponents to his program. The first consisted of those who would do almost anything in order to breathe the academic atmosphere, while the second consisted of those who wanted the Royal Institute to produce 'young men ready to serve as cogs in the machines of industry'. Modern engineers were distinguished by more fundamental qualities than aged academic degrees, he believed, and should stand firm between university and industry, between lofty theory and narrow-minded practice.[36]

After endless internal debate, the Royal Institute in 1925 finally managed to submit a formal request to the government. The authorities referred the entire matter to the universities for consideration. Academics said that they were supportive of the goals, in principle, but questioned whether the proposals were the best way to reach them. Faculty members at Lund University argued that technical practice and experience was indispensable for a doctoral degree *in technology*. But were two years enough, and was assisting at the Royal Institute's laboratories practice in the true sense of the word? Furthermore, there was an essential tension between the close industrial contacts that were necessary and the kind of public presentation that science required. 'Thus, the conflict between scientific and corporate interests would place considerable restrictions on the choice of subjects.'[37]

We should here note that the engineers had, in their own deliberations, already touched upon the main objections that came from the universities. For example, the academics criticized the definition of 'technical subject', viz. delineating a subject matter that would be unlikely to entail a conflict of interest with university research, for being ambiguous and caught in a vicious circle. Furthermore, academics argued that the congested nature of the basic engineering program – a string of mandatory courses that were short and thus superficial – did not demand intellectual discrimination or encourage the independence that was a prerequisite for scientific research.

The latter criticism should not be dismissed as mere rhetoric for the purpose of safeguarding university privilege. Engineers had made similar objections. A member of the board of the Royal Institute, and a former teacher there with an engineering background, expressed concerns in 1926 that the amount of scheduled, mandatory course work made individual, self-guided study impossible. He thought that too many too specialized subjects had been introduced. 'Every teacher wants to promote his subject and considers it more important than any other, all at the expense of the students, who simply can not cope with such demands. They turn into cramming machines.'[38] This image of a student stood in stark contrast to Humboldtian ideals.

To complicate matters further, some influential academics at Uppsala and Lund universities supported the Royal Institute's request. However, the academic bodies voted down the proposals, and the authorities referred the issue back to the institute. The matter was then entrusted to a new committee, consisting of two representatives from the universities and eight from the institute. All of these had a university PhD, with the exception of a professor of steam technology, one of the subjects that were at the heart of the issue, and a committee member by virtue of his position as vice president.

The new degree was eventually approved by means of a double compromise. Despite lingering opposition at both the university and the institute, the doctorate was celebrated in connection with the Royal Institute's centennial in 1927. 'Science', 'technology' and 'progress' amalgamated in a linguistic union in the many speeches held in honor of the occasion (Figure 5).[39]

Beneath the surface was a controversy, still largely unresolved, between contending kinds of competences. Who possessed the knowledge to assess the hybrid 'technical-scientific research', as the contemporary term read: engineers or scientists? Engineers maintained that the boundary line signifying non-intervention had two sides, that university academics were not qualified to judge scientific research *in technology*. What was at stake for the engineers was control over their formal knowledge-base, perhaps the main asset of their profession. If external forces, say academics or industrialists, were to start exercising control, the integrity and relative autonomy of the profession would be in danger. Under the struggle *about* words – what is 'technology', 'science', 'technical-scientific research'? – lay a struggle *with* words.

The engineers may have won a somewhat Pyrrhic victory. One price for formal recognition of their scientific status was far-reaching adaptation to the academic forms of the universities. The forms that were introduced and institutionalized would come to affect graduate studies, examinations, research and, eventually, basic education at the institute. For example, a growing number of teachers were to have a DEng degree.[40]

In terms of the effects so passionately debated, however, the new institution changed little. Research, science and the economy did not suddenly prosper after the introduction of the doctorate. The reason was simple. After the first couple of years, very few engineers were interested in the new degree. The same as for the laboratories, sites for science-based production of engineering knowledge, this institutional novelty was probably, given contemporary international developments, a necessary but not sufficient condition for a breakthrough on the scientific field being staked out.

## Economic resources

In the absence of funding, the two institutional reforms discussed above were empty, figuratively speaking, the doctorate almost literally being a formality. On the other hand, they opened the door to the argument that resources should be assigned to promote the 'technical-scientific research' that had obtained infrastructure and recognition. Government

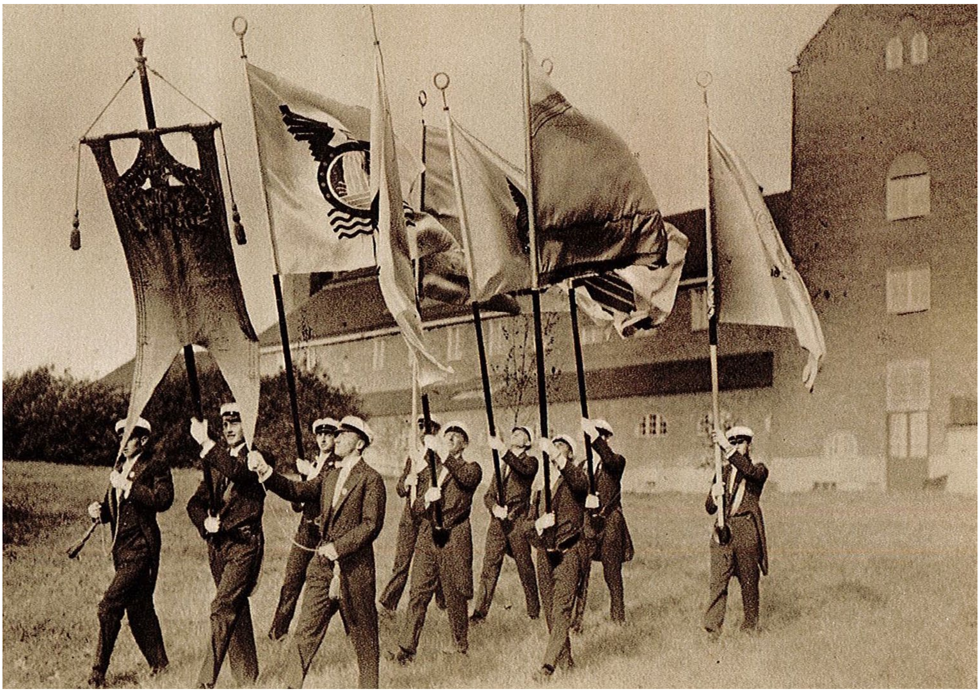

**Figure 5.** At the Royal Institute 1927 centennial, several speakers called for unity under the motto 'For peaceful feats'. The students marched on behind their standard, followed by special flags, representing the Institute's seven schools, which they had received on the occasion (Courtesy of *Kungl. Tekniska högskolans 100-årsjubileum*, Stockholm, 1928).

acknowledged claims and funding started to flow in the early 1940s, after which engineering research gained momentum in Sweden.

But why did the government hesitate for so long? Engineers were themselves to blame in one crucial sense. Controversies had made politicians reluctant. What gave rise to a deadlock was 'the Chalmers issue', a tug-of-war over various resources within the engineering community, which we have seen did not have uniform interests. Even though the Royal Institute occupied a lower rung than the universities in the hierarchy, it was regarded as higher than the Chalmers Technical School – particularly so by the institute itself. We will now examine how this controversy emerged, evolved, and finally reached closure.[41]

As noted above, the government commission appointed in 1906 to investigate the organization of 'higher' technical education had as a task to present proposals concerning Chalmers. Faced by scarce resources, it discussed the option of closing down the higher of Chalmers's two sections. Some members of the commission opposed this idea. One of the critics was Chalmers's forceful president, August Wijkander, who also was a member of Parliament. To avoid splintering the commission and thus rendering the proposals dead on arrival, a compromise was reached. The claims of the Royal Institute were prioritized, but Chalmers was left untouched.[42] The final report from 1908 stated that, despite the large and growing need for engineers, it was not yet advisable to divide scarce resources between *two* institutes of technology. However, some reforms were suggested for Chalmers.

But when Parliament considered the commission's suggestions, in 1909, the minister declared that no decisions regarding Chalmers could be made. What complicated matters was the peculiar two-section organization that had evolved at the institution. As another government commission had been appointed to investigate the organization of 'lower' technical education, in 1907, the minister wanted to assess its conclusions before he could present any proposals for reorganizing Chalmers.[43]

A year later, this commission issued its final report, which made a distinction between 'basic' and 'scientific' technical education. While basic education involved the results of science, scientific education also imparted knowledge of how the results had been arrived at. Familiarity with the workings of research enabled a scientifically educated engineer to perform independent, innovative work to promote technological progress. But just as indispensable was vocational education, focusing on the kind of industrial practice that a theoretician was frequently unfit to deal with. Consequentially, the commission depicted Chalmers, with its 'higher' *and* 'lower' sections, as an example of the difficulties that follow if you try to house two essentially different missions in one institution. The commission refrained from making proposals for Chalmers.[44]

Given the ensuing uncertainty, Chalmers applied for higher grants to cope with the most pressing practical problems that had accumulated. The minister replied in 1913 that decisions on expenditure had to be preceded by an answer to the question of what kind of institution the money would be spent on.[45]

Viewed from the institutionalist perspective adopted here, Chalmers's predicament illustrates how the institution was bound to a path previously taken. Institutional forms of the past affected subsequent developments, creating a deadlock. The organization of Chalmers, with two separate but interconnected sections, was once established to deal with particular difficulties but eventually caused more problems than it resolved. By the early twentieth century, obtaining resources for buildings and personnel depended upon a kind of resource that was relatively new in the Chalmers context: academic recognition, the formal acceptance of the institution as a *Hochschule*. Such recognition was hostage to the assessment of extra-institutional forces: the Royal Institute of Technology, government, Parliament, and other stakeholders in the relationship of technical education to science, industry and society. It would take a quarter of a century and four more government commissions to resolve 'the Chalmers issue', as it eventually was named. It is reminiscent of 'the Royal Institute issue' and reminds us that the three processes presented in this article were more or less contemporary and interconnected.

The minister said in 1913 that only the appointment of a separate commission could rescue Chalmers from its 'dead-end street', as he called it. He appointed a small commission. It proposed the introduction of a one-semester supplementary course in order to ensure that the two sections would not have to adjust to each other, thus making it possible to separate them. The lower section would be a technical upper secondary school – and the higher section should be a *Technische Hochschule*, a real Institute of Technology.[46]

The Royal Institute of Technology strongly opposed this conclusion of the commission, arguing that the congested and forced program of Chalmers's higher section made it qualitatively different from the program offered in Stockholm. Recognizing this section as equivalent to the Royal Institute would be tantamount to accepting two essentially different kinds of institutions under the single concept 'institute of technology'. The minister said that he did not want to get into an argument about the naming. In 1914, Parliament passed a bill in accordance with the proposals, but changing the name to Chalmers Technical Institute.[47]

Meanwhile, the number of applicants rose dramatically and Chalmers began turning down formally qualified applicants in a way that reminded of the situation for the Royal Institute in the 1890s. Chalmers's board eventually applied for funds for new buildings, equipped with modern laboratories for a science-based training of engineers, to be able to meet the growing demand (Figure 6).

After some hesitation, the government appointed a new commission in 1919. It broke down the issue into two separate questions: buildings and formal organization. The first part of the final report in 1920 proposed the construction of new buildings. The second part in 1922 proposed that the higher section be reorganized as Chalmers Institute of Technology and eventually be granted the right to confer doctoral degrees.[48]

Underlying the argument for a second institute of technology was the assumption of a need for science-based technical education in order for Sweden to keep up with other industrial nations. This assumption was corroborated by statistical accounts of the distribution of engineers in various sectors of industry and society. The 1919 Chalmers commission here followed the commission that had investigated 'lower' technical education. The report of this earlier commission described the country's need for technically educated people based on their distribution in relation to production statistics. The even earlier commission that had investigated 'higher' technical education did not underpin its argumentation this way. It simply stated that the number of applicants reflected a need. As discussed above, this assessment became a matter of dispute in Parliament. In our context, a mode of arguing in terms of societal needs, supported by statistics, was conceived and became persuasive during this period.

When the proposals were presented in Parliament, some members maintained that funds should not be granted until it was clear what they were for. Nevertheless, the politicians granted funding for a new building with laboratories for education in physics and chemistry. The organizational issue was, however, put off in light of the post-war depression.[49]

Meanwhile, the Royal Institute got more and more entangled in the process. Its claims for resources could be rejected with reference to developments at Chalmers and its needs. Politicians pursued a similar policy as toward the older universities. Claims by the universities in Uppsala and Lund, which were entangled in interdependence *and* competition, could be postponed until they had settled internal and organizational matters in a satisfactory manner. This was a way of exercising political influence over research long before the phrase 'research policy' had been coined.[50]

In connection with its centennial in 1929, Chalmers again applied for recognition of its status and further funding. The minister hesitated dutifully, but Parliament insisted. Yet another commission was appointed. Not unexpectedly, it wanted to turn Chalmers into a *Hochschule*. But, in order to save money, it also proposed horizontal differentiation of higher technical education by closing down one or two schools at the Royal Institute and Chalmers, respectively. However, the commission requested that it be relieved of its responsibilities before releasing a final report, given that the state of government finances in 1932 would render any proposal meaningless.[51]

Everyday practice at Chalmers and feelings about the Royal Institute at this time are evident in a letter from a new, university-educated professor of chemistry – perhaps the first

**Figure 6.** Chemistry and laboratory lessons were part of the basic education curriculum, not just for students in the School of Chemical Technology. In the 1920s, Chalmers's old buildings could seem outmoded. The laboratories limited the number of students and could be hazardous (Courtesy of the Chalmers Archive).

one to conduct systematic scientific research on a larger scale at Chalmers – to a professor of mineralogy in Stockholm:[52]

> I never have time to do anything but write and guide these young technicians, who rush through the lab to prepare for their subsequent rush through life. It definitely has its drawbacks, and I miss the opportunity to concentrate and conduct *my own* experiments. But I can't deny that it's nice to have all these assistants – if only the damned Royal Institute wouldn't ruin my chances to train doctors of engineering, so that at least one person a year *truly* became engaged in a problem. As things are now, I'm endlessly giving but never getting anything in return.

In 1933, Chalmers requested that a decision about new buildings be made as a deadline was approaching. The City of Gothenburg had already in 1920 decided to donate a site for Chalmers, but on a condition: that the state start construction before 1935. This time even the minister in charge, since 1932 the Social Democrat Arthur Engberg, backed the request. Although political pressure was mounting, the position of the parliamentary committee was unyielding: any decision must await a proper investigation by an expert commission.[53]

In 1934, the government gave a new commission the task of promptly submitting proposals. Meanwhile, Chalmers negotiated with the City of Gothenburg for an extension of its deadline for the site. In a report the following year, the commission suggested that Chalmers be reorganized as an equivalent to the Royal Institute. But it also suggested closing down the Schools of Building and Chemical Technology at Chalmers, and the School of Naval Architecture at the Royal Institute; shipbuilding was a major industry in

**Figure 7.** In 1933–1934, students entering the first grade of the higher section found a Chalmers not yet affected by the policy struggles over educational organization. Of the six different schools, most students entering in this year chose Civil Engineering and Electrical Engineering (Courtesy of the Chalmers Archive).

Gothenburg – with significant impact on Swedish economy – but not in Stockholm. In order to economize with resources, there would be a division of labor between the two state-funded institutes of technology. When these proposals were referred to the concerned parties for consideration, the Royal Institute set so many conditions for accepting that it in practice rejected them (Figure 7).[54]

The skillful politician Engberg separated the pressing question of facilities for naval architects at Chalmers, mainly for shipbuilding experiments, from the more complicated and volatile organizational issue. Pressures were building up as the minister prepared a bill for 1936 year's Parliament.

On the one hand, the state would lose a huge but conditional donation for a shipbuilding experimental tank if Parliament did not reach a positive decision during the year. This donation with its timely condition came from a wealthy ship-owner's widow in Gothenburg. She had been approached by Hugo Hammar, the influential Chalmers-educated CEO of Götaverken, one of the world's largest shipyards at the time, who in relation to politics had his mind set on practical results.[55] Hammar had served on the 1919 and 1934 Chalmers commissions and he was a member of Chalmers's board. – We can here note that this intricate play between state, city and private donors as potential providers of resources was a characteristic of Gothenburg's political culture. A central actor in the local network such as Hammar could mobilize an influence that was decisive, albeit informal and hidden. Conditions were different for the Royal Institute. Its closeness to the authorities and ministry in Stockholm opened up other opportunities than in Gothenburg, but also imposed restrictions on the feasibility of informal manoeuvres.

On the other hand, the Royal Institute was fully capable of mobilizing resistance on different arenas, in Parliament, for example. Carl Forssell, the professor of construction statics whom we met above and a member of Parliament at the time, strongly opposed the proposal. He argued that the bill for new facilities for naval architecture in Gothenburg in practice amounted to a decision about Chalmers's future organization, thus jumping the gun on any inquiry into matters of principle. During the fierce debates, some supporters admitted hesitation on formal grounds but went along with the general political sentiment. A Social Democrat, who had been a member of the 1929 and 1934 Chalmers commissions and was in support, said that the most important aspect of the whole issue was that it blocked development not only for Chalmers but *also* for the Royal Institute.[56]

> As long as this matter is in a state of uncertainty, both of these institutions for higher technical education will suffer. Whichever one applies for increased funding for one need or another will always face the same objection: we do not know how it can be done. – According to me, this is the main reason that higher technical education has had to subsist on too meager fare in recent years.

The bill for new buildings eventually passed. A second bill the following year reorganized Chalmers into an institute of technology. Parliament reached this decision despite strong opposition by Forssell, whose prediction of the year before thus came true. No other opponents appeared this time.[57]

The two institutes of technology were assigned the task of drawing up joint statutes, which were issued in 1939. They included an exemption that is interesting from our perspective: the paragraphs concerning the DEng degree did not apply to Chalmers yet. A year later, Chalmers requested that they take effect. Despite persistent hesitation by the Royal Institute, which maintained that the congested basic program and lack of laboratory resources at Chalmers did not provide a good basis for scientific work, the statutes took effect in 1940.[58] The Royal Institute assumed a position that permitted the criticisms it had once received from the universities to be passed on to Chalmers. The pecking order was preserved.

But other doubts had evaporated by this time. Pent-up interest was freed and new opportunities emerged when 'the Chalmers issue' finally was resolved. Meanwhile, the idea of a national need for higher technical education in general and engineering research in particular became a topic of public debate.

Research in technology was discussed in 1936 when the Swedish Association of Engineers and Architects celebrated its 75th anniversary. The Academy of Engineering Sciences and the Federation of Swedish Industries took action the following year. Committees were appointed, networks mobilized, influence brought to bear. Engberg, who was well acquainted with the issues and forces involved, published a 1938 election manifesto that strongly promoted engineering research. But this move was not so conspicuous, given that the matter was not politically divisive at this time. Even a newspaper like the *Swedish National Socialist* discussed it, albeit in its own terms: 'Technological research – a neglected national task: The profit motive totally dominates Swedish corporate life.'[59]

Two motions on the issue were submitted to Parliament in 1939, one by the Right and one by the Left, and the government appointed a pair of commissions on the same day in 1940. The first commission was to deal with higher technical education, the second with the 'organization of technical-scientific research'. They promptly delivered proposals that generated concrete results.[60]

The commissions submitted a joint proposal in 1941 for the introduction of a Licentiate of Technology degree. Despite opposition from the universities, the authorities approved it the following year. The balance of power between engineers and academics had begun to shift. The commission dealing with research submitted its main report in 1942, leading to the establishment of the Technical Research Council in the same year. The purpose of this new state institution was to fund and promote research. It was the first of a series of research councils for allocating appropriations to researchers outside the traditional channels of block grants for faculties. The Technical Research Council paved a path and historians regard it as instrumental to the eventual formation of research policy in Sweden. The commission dealing with education presented its main report in 1943, centering around the need for more engineers in order to maintain national competitiveness. The proposals, supported by copious statistics, led to major expansion at *both* the Royal Institute and Chalmers.

With this influx of resources, the field of engineering research began to flourish. The system came to please those with interests in it: input of more money, output of more research. Its basic institutional forms are still visible today. But what made the breakthrough of the early 1940s possible? Without downplaying contemporary international developments, some specific Swedish features can be identified.

We have already pointed out the building up of political interest in engineering research that 'the Chalmers issue' produced by standing in the way of various decisions. Furthermore, due to this lengthy issue, preparing reports concerning the state of technical research and education was a well-developed art by the late 1930s. All parties knew what to do and how to do it. Far-reaching continuity and familiarity with the issues are also evident on the actor level. As we have noted above, people often served on a series of different commissions over time. Gösta Malm, the chairman of both 1940 commissions, was a distinguished alumnus of the Royal Institute, former high government official, county governor and cabinet minister. He was a member of the board of the Royal Institute from 1928 to 1945, as well as its chairman starting in 1933. Together with three other members of the 1940 commissions, and alongside the Minister of Ecclesiastical Affairs, Malm was awarded the title Doctor of Engineering *honoris causa* by the Royal Institute in 1944. The awards look like an act of gratitude, a gift in return.

The politicians knew what they wanted when they appointed the esteemed Gösta Malm. As a member of the Royal Institute's board he had handled a number of reports on 'the Chalmers issue', and he knew how deadlocks could delay desired decisions. The commissions he chaired finally brought funding to 'technical-scientific research' in Sweden.

## Discussion

In this article, I have examined three instances of institutional formation that were essential to the making of a field of engineering research in Sweden: the 1911 decisions about new buildings with modern laboratories at the Royal Institute of Technology; the introduction of the DEng degree, in 1927, formally acknowledging the scientific capability of engineers; the upgrade of Chalmers to an Institute of Technology, in 1937, which opened the door to other reforms and funding.

I have interpreted all three cases as controversies over resources of different kinds. As controversy implies more than one interested party, I have related events in a contextualizing mode. We have seen that both the academic community and the government exercised far-reaching influence on the emergence of this new domain of research. Furthermore, opposing views were often held within the engineering community. Men of industry, for example, could oppose the taking over of institutional forms from academia and the ensuing tendency to drift from engineering practice. All three processes date from the 1890s to the mid-1940s and were closely intertwined. However complex the issues appear when viewed in context, they were all resolved by means of institutional transformation, primarily during the inter-war years.

The examined period was thus crucial in terms of institution building. However, the post-war period may seem even more momentous. New institutes of technology were established in many places. But these institutions for science-based technical education have been modeled on the same pattern as the Royal Institute and Chalmers. Viewed from a sufficient distance, higher technical education during the post-war period can be summarized in a somewhat blunt way: more of the same. The qualitative change in terms of institutional forms harks back to the earlier period, which not merely in terms of chronology was a prerequisite for the latter with its quantitative changes. Path dependence characterized the advent of mass education in engineering, as more and more subjects, programs and schools were tacked on to the basic conception. The general process is not unique for Sweden and has been aptly characterized in the United States as 'the expansive disintegration of engineering'.[61]

Exploring the Swedish case is, thus, not primarily of interest because it is a highly original precursor. But, as clashes and tensions in Sweden are more or less typical, this national trajectory casts light on the larger pattern of events of which it is a part. At the same time, an in-depth study of Swedish peculiarities can sharpen the perception of specific traits in trajectories that are more familiar to observers in other countries. Comparing is the mode for sensing similarities and differences, patterns, but here is no place to develop specific comparisons.

The case of higher technical education is interesting in its own right but also, I would argue, because it casts light on more general patterns in the field of higher education. In a sense, the actors from the engineering profession that we have followed struggled with underlying, fundamental questions. What is the primary purpose of the education, the rationale that gives legitimacy to the institution: contributing to industrial productivity or conferring a fundamental understanding of technical processes? This question can be transposed to other cases of higher education for practice-oriented professions.

The Swedish engineers studied in this article faced issues that have parallels in other national settings, fields of activity, time periods.[62] Academic drift is not a self-evident outcome of the negotiations of answers to questions that are essential to the education of professions. But academic recognition can lead to academization, of course, as political recognition can lead to politicization.

In the case explored here, however, the institutions that evolved were patterned on the features of academia. The DEng degree is the most clear-cut example of an institutional form taken over from the university. The formal recognition that the doctorate represented was crucial for the formation of engineering research as a distinguished – discerned and respected – field of scientific research. The controversy-laden process of taking over the doctoral degree is an object of historical study that is relatively discrete, while at the same time reflecting much wider concerns. As an institution, the doctorate is an illuminating part of a larger whole (Figure 8).

**Figure 8.** The forms for public defense of a Royal Institute doctoral dissertation in technology were copied from the universities, as were the rituals for the ensuing conferment ceremony. In this picture from the first group of graduates, in 1929, we can see five doctors with their diplomas, a newly installed professor and the president (Courtesy of *ASEA:s tidning*, 1929).

The degree was not a prerequisite for scientific engineering research from a logical point of view. Nor was the new title in itself sufficient to promote such research. The relationship between institutional form and content is not a simple one-way causality. Historical experience nevertheless suggests that ideals and procedures associated with the doctorate affect the institutions of higher professional education that embrace it. A mindset emerges, an ethos is fostered, as specific conduct is made possible and promoted, while alternative activities are often denigrated. Decisive importance is attached to the experience of research represented by a dissertation when filling teaching positions, which eventually affects the knowledge that is transmitted as part of professional training. Institutions pattern behavior.

But new kinds of research and activities also affect the doctorate as institution. The relationship between content and form is one of intriguing interaction. Even if a main conclusion of this study is that institutional forms and norms originating in academia during the period were adopted in the technological sphere, where they eventually came to influence education and research, this drift had implications not just in one direction. In an interdependent system of higher education, the transfer of institutional forms affects not only the recipient but also the form taken over and, eventually, the originator.

We have seen that the Royal Institute of Technology substantially influenced the process that in the end led to the recognition of Chalmers as a scientific institute of technology. Similarly, the way that 'the Chalmers issue' was handled had significant repercussions on the Royal Institute itself. Influence was reciprocal. Both institutions were also affected by the university community and the government. Influence operated in the opposite direction in this larger setting too, but perhaps in more subtle ways.

An interesting aspect of this dynamic is the emergence of a research policy field in which the interests of researchers could lock horns with those of politicians. This political arena for negotiating about resources – with the potential for both freeing and, by way of commitments made, tying up actors and institutions – has affected the university. Many expressions and notions associated with research policy, profoundly influencing Swedish universities, originated in the sphere of technical education and research.

Sticking to the doctoral institution as an illustrative example, 'research training', the Swedish phrase for formal graduate study, is a case in point. The university-centered view is that this key concept in contemporary research policy emerged during the 1950s and 1960s when the issue became politicized as graduate studies were subject to formal organization and the ideal shifted from 'apprentice' to 'professional'. However, the phrase 'research training' – which might be perceived as a contradiction in terms from the perspective of the Humboldtian way of relating to independent graduate students – was already used in 1941, when one of the commissions chaired by Gösta Malm proposed new approaches to promoting technological research: a licentiate degree, scholarships, equipment and assistants for laboratories. The framing of problems to be dealt with by these means was deceptively simple: if there is a national need for more research, then more researchers are needed, then the training of these needs to be organized more efficiently.[63] The solutions associated with the new concept of 'research training' represented an attempt to cope with the disturbingly slow response that the doctoral institution had encountered when introduced into the realm of technology. It had initially been conceived of in accordance with academic tradition, with emphasis on freedom rather than organization.

This ideal of maximum freedom at the universities was called into question later in the 1950s. Graduate studies were reformed in the 1960s in the wake of political sentiment that society was in need of more research. A clear manifestation of this interest was a government commission that addressed graduate studies in terms of 'research training'. But neither the framing of the problems nor the proposed solutions were new and original. From the Royal Institute to the Pharmaceutical Institute, seven different doctoral degrees were introduced between 1927 and 1954 at institutions of higher education for practice-oriented professions. The doctorate as institution was not unaffected by this dissemination, all this new content, which eventually had repercussions on the originating universities and the way that they organized graduate studies. This kind of interaction and reciprocity is hidden if the history of higher education is viewed solely from the perspective of the university, as if it were always influencing, but never being influenced.[64] Academic drift can breed a counterflow.

More figures of speech associated with research policy that were initially used in the technical sphere became more widespread in the post-war period. The stabilization of a distinction between 'basic' and 'applied' research is an example. It is not self-evident that the world of science should be categorized this way, which tends to make some subjects secondary in relation to others that seem more primary. The distinction has as a premise that research in the applied kind of subjects is recognized as scientific, something that in Sweden first happened in the field of engineering. The categories produced by and producing the dividing-line are frequently employed in the realm of research policy, thus affecting stakeholders in research policy, as well as institutional arrangements on various levels.

Not surprisingly, research that promises to make a fundamental impact on societal conditions when applied seems to attract more political interest than research committed to a search for truth that can yield benefits in the long run, perhaps. The latter line of argument may be in need of politicians with the mindset of researchers when pursuing resources. The former argument may be more persuasive for politicians with minds set on practical results, such as 'interest on the ventured capital', as the 1906 commission for higher technical education phrased it.

The influence of discussions about engineering research and education on the emergence of research policy has not been examined very much, but strikes me as an interesting topic. I will simply hint at possibilities by commenting on the notion of 'lagging behind', a recurring theme in the three cases we have explored. This figurative expression is central to a line of argument that has proven persuasive in political discussions about the allocation of resources for research. As an underlying logic, the phrase presupposes a complex of metaphorical reasoning, the steps of which perhaps owe something of their persuasiveness to being tacit, but which I believe can be spelled out.[65]

During the nineteenth century, Europeans began to consider more and more aspects of life in terms of evolution and progress. Given that evolutionary thinking presupposes a timeline, differences in degree of development could be expressed in terms of a time scale. When socio-cultural differences between peoples separated in space were understood in temporalized terms, some could be said to be 'ahead' while others had come 'after' and were 'behind', albeit contemporaries. As spiritual values became less persuasive criteria for deciding who was ahead of others, material culture gained ascendancy when grading the scale.

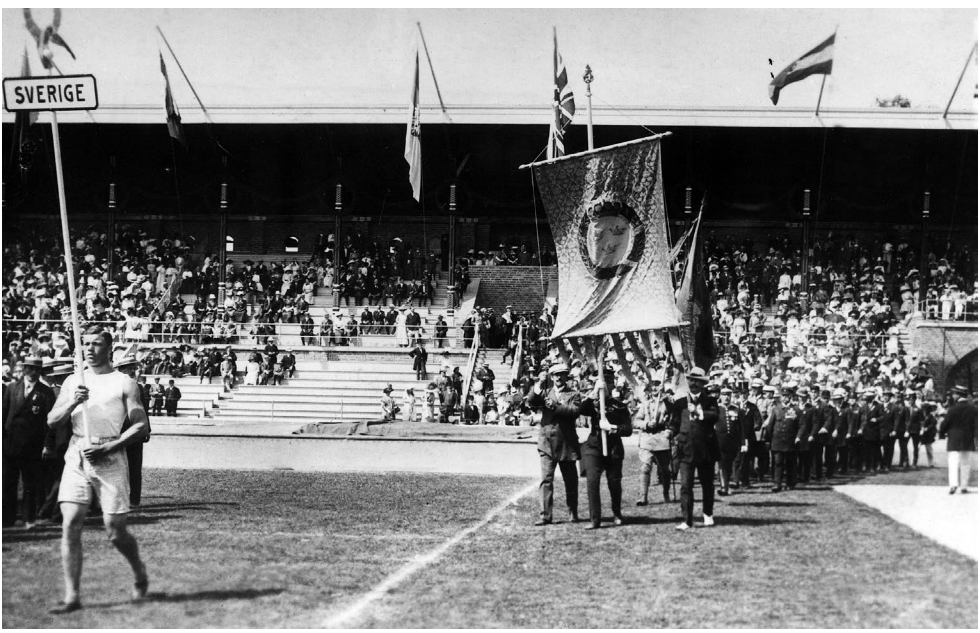


**Figure 9.** The modern Olympic ideal merged competition and friendship, at the national and international levels. Its swift breakthrough indicates that the Olympic movement both reflected and provided an outlet for tensions in fin-de-siècle Europe. In Stockholm 1912, the Swedish team marched for peaceful feats on the field of Olympic competition (Courtesy of Stockholm City Museum).

The capacity to dominate nature by applying scientific findings was perceived as a yardstick of development. By the turn of the century, it also seemed clear that the nation-states were engaged in a struggle and represented a basic unit of comparison. Technological ability became a peaceful means, alongside Olympics, for example, for the nations to settle who was ahead and who lagged behind. Machines were seen as 'the measure of men' (Figure 9).

The conspicuous industrial expositions of the times were a fit field for entering competition and manifesting progress.[66] A characteristic idiom captured the ethos of the expositions. 'Science', 'technology' and 'progress' were invoked in ways that are reminiscent of the public addresses that accompanied the 1927 centennial of the Royal Institute of Technology. This way of speaking also has parallels to a mode of arguing that we have seen engineers began using around the turn of the century when pursuing different kinds of resources to build institutions. To avoid the risk of lagging behind, they claimed, it is vital to invest in technical education and research in order to promote development and national competitiveness. Advocates of engineering research have since reiterated this figure of speech and line of argument, although the bottom line today is more likely to be in terms of GDP statistics rather than prizes won at expositions. The basic phrase with its underlying logic is not unique for engineers nor to Sweden, but is a trope in research policy rhetoric that other professions in other places have resorted to when trying to make a case for better funding.

## Notes

1. There are varieties of institutionalism in different disciplines; an overview with a focus on politics that discusses varieties in terms of old–new and difference–similarity is Peters, *Institutional Theory in Political Science*. The historical aspect is in focus in Fioretos, Falleti and Sheingate, *Oxford Handbook of Historical Institutionalism*.
2. See, for example, Magnusson and Ottosson, *Evolution of Path Dependence*.
3. A starting point in this case is DiMaggio and Powell, "The Iron Cage Revisited"; for an overview, see Greenwood et al., *Sage Handbook of Organizational*.
4. Higher technical education is discussed with reference to a form and content perspective in Lindqvist, "A Cost-Benefit Analysis of Science"; Liedman, *Stenarna i själen* is a grand history of the concepts of form and content (or matter/substance).
5. For a general discussion of research-based technical education, see Harwood, "Understanding Academic Drift", and his nation-by-nation review of the literature in "Engineering Education between Science and Practice". For a comparison in time rather than space, see Kaiserfeld, "Why New Hybrid Organizations Are Formed". For a more theory-driven discussion, see Morphew and Huisman, "Using Institutional Theory."
6. See, for example, Richter, *History of Political and Social Concepts* and, more recent, Ifversen, "About Key Concepts" and the collection of articles in "Roundtable: *Geschichtliche Grundbegriffe* Reloaded?" The relevance of conceptual history in relation to the history of the notion of applied science is discussed in Bud, "Framed in the Public Sphere"; cf. the collection of articles in "Focus: Applied Science", with an introduction by Bud, and the earlier Kline, "Construing 'Technology' as 'Applied Science'". Histories of related concepts are in focus in Schautz, "What is Basic Science?", and Godin, *Innovation Contested*.
7. The discussions of intricacies such as the distinction between term and concept can be somewhat philosophical, and I have found the argument for studying contested concepts as developed in Connolly, *Terms of Political Discourse* to be useful as a historian; the notion of essentially contested concepts has been discussed within the tradition of conceptual history, but with reference to the original 1956 articulation rather than to Connolly's elaboration of it.
8. Metaphors have also been discussed within conceptual history, see for example, Schäfer, "Historicizing Strong Metaphors". The question of how to understand relationships between

ideas, concepts and metaphors is also theoretically intricate. I have found the praxis-oriented approach in Schön, "Generative Metaphor" useful. In this context I can also mention his book *Displacement of Concepts*, which has not been commonly cited in recent discussions, but perhaps a quote (45) can spur curiosity: 'Focusing attention on the metaphors in ordinary language is like focusing on the colour green. We see it everywhere. It has, too, the effect of immediately removing the film of obviousness that covers our way of looking at the world.'

9. Although my focus is on Sweden, the notes will refer, when possible, to literature in English, such as Torstendahl, *Dispersion of Engineers in a Transitional Society*. For comparative perspectives on trajectories in this context, with chapters on Sweden, see Ahlström, *Engineers and Industrial Growth,* Fox and Guagnini, *Education, Technology and Industrial*, and Meiksins and Smith, *Engineering Labour*. Sweden is not in focus in antoher comparative study, Fox and Guagnini, "Laboratories, Workshops, and Sites", but the laboratory institution that is central to the first case presented below is.
10. Cf. Harwood, *Technology's Dilemma*, chapter 1.
11. I discuss the notion of political industrialization in my *Staten, Chalmers och vetenskapen*.
12. For the notion of boundary work, cf. Gieryn, *Cultural Boundaries of Science*. Even if I have different points of departure, my mode of working has features in common with Gieryn's: a focus on contested concepts such as science, a sensitivity to metaphorical reasoning in the arguments, an appreciation of the role of acquiring authority to obtain resources. Like Harwood, "Engineering Education", my use of the spatial analogies of 'boundary' and 'field' is loosely inspired by more elaborate views on their use in (historical) analysis; for a discussion of the terms, cf. Silber, "Space, Fields, Boundaries."
13. On the origins and tradition of the German university ideals, see Clark, *Academic Charisma and the Origins* and Josephson, Karlsohn and Östling, *Humboldtian Tradition*. On German cultural influence on the Scandinavian countries in general, see Henningsen et al., *Skandinavien och Tyskland*, and on education in Sweden, Liedman, "In Search of Isis."
14. Cf. Blomqvist, "State, University and Academic Freedom in Sweden", and, from 1919 to the 1990s, Elzinga, "Universities, Research and the Transformation of the State in Sweden."
15. Torstendahl, *Teknologins nytta*.
16. Runeby, *Teknikerna, vetenskapen och kulturen*. An influence from the USA came early in the technical sphere, cf. Grönberg, *Learning and Returning*.
17. Relevant material has been collected in the National Archives (hereafter NA), Ministry of Ecclesiastical Affairs, Cabinet Act 11/1 1890 no. 17, item 48. I have analyzed the process that follows in my *Staten, Chalmers och vetenskapen*, chapter 3, cf. Sundin, *Ingenjörsvetenskapens tidevarv*, chapter 4, and Berner, *Teknikens värld*, chapter 11.
18. *Underdånigt betänkande och förslag till utvidgning*; subsequent material has been collected in NA, Ministry of Ecclesiastical Affairs, Cabinet Act 13/1 1894 no. 1, item 47, and NA, archive of Younger Commission no. 14. The distinction between different cultures is from Calvert, *Mechanical Engineer in America*.
19. *Underdånigt betänkande och förslag till ordnandet*.
20. Ibid., vol. 2, 74: a protest against the answers submitted by the Swedish Association of Engineers and Architects.
21. Cf. Layton, *Revolt of the Engineers*; with their sensitivity to issues of *Bildung* in relation to social standing, the reactions of Swedish engineers with higher education are somewhat similar to those of their German counterparts, cf. Voskuhl, "Engineering Philosophy."
22. *Underdånigt betänkande och förslag till ordnandet*, vol. 1, 21.
23. The publications of the Swedish Parliament (Riksdag), 1909: Bill 155; Lower House (hereafter LH) minutes 38; LH motions 239, 246, 250; State Committee report 173; LH minutes 65; Upper House (hereafter UH) minutes 44.
24. NA, Ministry of Ecclesiastical Affairs, Cabinet Act 10/3 1911 no. 52; Riksdag 1911: Bill 124.
25. For the committee's statement and the debate at the meeting, see *Meddelanden från Sveriges industriförbund*; cf. the views of the president of the Royal Institute in [Magnell], "Tekniska högkolans omorganisation" and idem, *Inledningsföredrag*.

26. NA, J. Sigfrid Edström's collection, vol. 36, telegram Arvid Lindman to Edström 30/4 1911; Centre for Business History in Stockholm, Federation of Swedish Industries, board meeting 3/5, cf. dossier 7610 and press clipings.
27. Riksdag 1911: LH motion 345; Select Committee no. 2 report 1; UH minutes 30; LH minutes 53.
28. Cf. Sundin, *Ingenjörsvetenskapens tidevarv*.
29. Kändler, *Anpassung und Abgrenzung*, 114–118. I have analyzed the Swedish process in my *Teknikens art och teknikernas grad*, to which I make a general reference.
30. NA, Royal Institute of Technology (hereafter RIT) main archive, faculty meeting 3 & 5/4 1905, protest by Peter Klason.
31. Op. cit., protest by Erik Odelstierna.
32. The drama notion here is from Turner, *Dramas, Fields, and Metaphors*. The primary sources for discussions among engineers have been collected in NA, RIT main archive, FI vol. 3: "Handlingar rörande införande av teknisk doktorsgrad", and *Om införande av teknisk doktorsgrad vid Tekniska högskolan*. Supplementary material from the later 'acts' has been collected in NA, Ministry of Ecclesiastical Affairs, Cabinet Act 7/10 1926 no. 31, and Cabinet Act 9/9 1927 no. 35. In the following summary of the process, I will basically limit the notes to quotations.
33. NA, RIT main archive, faculty meeting 15/1 1919.
34. Proposal of April 1922, reprinted in *Om införande: Betänkande*, 57.
35. RIT main archive, faculty meeting 8/3 1922. Forssell had also published articles in which he debated the issue.
36. NA, Swedish Association of Engineers and Architects main archive, AII: 30 (item 33).
37. NA, Ministry of Ecclesiastical Affairs, Cabinet Act 7/10 1926 no. 31, Lund University, faculty of philosophy 23/4 1926.
38. Axel Wahlberg's comment to the debate in *Blad för bergshandteringens vänner*, 316.
39. Henriques, *Kungl. Tekniska högskolans 100-årsjubileum*.
40. Cf. Larsson, "Physics in a Stronghold of Engineering."
41. Chalmers's history is in focus in my book *Staten, Chalmers och vetenskapen,* to which I make a general reference.
42. Regional State Archives in Gothenburg, August Wijkander's collection, letters from various commission members, especially vol. 32, Axel Wahlberg to Wijkander, 22/4 1908.
43. Riksdag 1909: Bill 1, 8th main title, item 116; Bill 155, 15.
44. *Underdånigt utlåtande och förslag*.
45. Riksdag 1913: Bill 1, 8th main title, item 211.
46. Op. cit. The unpublished report of the commission can be found in the Regional State Archives in Gothenburg, Chalmers archive, EI: 10, no. 219.
47. NA, Ministry of Ecclesiastical Affairs, Cabinet Act 29/5 1914 no. 56; Riksdag 1914: Bill 144.
48. *Betänkande avgivet av 1919 års sakkunnige*.
49. Riksdag 1922: Bill 238; State Committee report 56; UH minutes 30; LH minutes 34.
50. For example, Riksdag 1922: UH minutes 35, 32; LH minutes 41, 17; cf. Blomquist.
51. NA, Ministry of Ecclesiastical Affairs, Cabinet Act 4/11 1932 no. 21.
52. Royal Swedish Academy of Sciences in Stockholm, Gregori Aminoff's papers, letter from Arvid Hedvall to Aminoff 21/11 1932.
53. Riksdag 1934: Bill 1, 8th main title, item 105; State Committee report 8; cf. report 124; UH minutes 17; LH minutes 18.
54. NA, archive of Younger Commission no. 492; material collected in NA, Ministry of Ecclesiastical Affairs, Cabinet Act 5/3 1937 no. 64.
55. Gothenburg Maritime Museum, Hugo Hammar's collection, E3:3, draft letter to Martina Lundgren 27/11 1935; Regional State Archives in Gothenburg, Chalmers archive, FVIII:1 stack no. 6, copies of letters from Chalmers's president Sven Hultin to ministerial secretary Georg Zacharias Topelius 3/2, 10/2 1936.
56. Riksdag 1936: Bill 135; UH motion 333; LH motion 658; State Committee report 83; UH minutes 28 (quote: 18-9); LH minutes 28. On naval architects and their education, cf. Olsson, *Technology Carriers*.

57. Riksdag 1937: Bill 268; State Committee report 191; UH minutes 41; LH minutes 41.
58. NA, Ministry of Ecclesiastical Affairs, Cabinet Act 3/5 1940 no. 29.
59. Cf. the numerous articles and reports in the 1936 volume of *Teknisk tidskrift*; Engberg, *Demokratisk kulturpolitik*; "Teknisk forskning", *Den svenske nationalsocialisten* 9/11 1938.
60. Cf. Nybom, "Socialization of Science". For subsequent changes, cf. Althin, *KTH 1912–62*, Samuelsson and Samuelsson, *Chalmers tekniska högskola*.
61. Williams, *Retooling*.
62. Cf. Harwood, *Technology's Dilemma*, chapter 6, where the discussion is extended to other cases.
63. NA, archive of Younger Commission no. 492, vol. 1, meeting 17/4 1941, proposal dated 24/9 1941; material collected in NA, Ministry of Ecclesiastical Affairs, Cabinet Act 3/1 1942 no. 112.
64. On 'research training', cf. Odén, *Forskarutbildningens förändringar 1890–1975*, a comprehensive historical account, focusing on historical disciplines at the university.
65. I suggest that the basic pattern in the recurring arguments can be understood by way of combining the perspectives of Fabian, *Time and the Other*, and Adas, *Machines as the Measure of Men*. The pattern may, in a sense, be clearer in Swedish, a language in which the temporal and spatial aspects in focus here are mixed in the same prepositions ('före' for both *before* and *ahead*; 'efter' for both *after* and *behind*).
66. Cf. Rydell, *All the World's a Fair*.

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