Engineering Education in Germany

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Introduction

The kind and the intensity of student/teacher interaction influence the way a student learns as well as the teaching style and the teaching load of the professor including the number of students he or she can effectively handle. It should be worthwhile, therefore, to investigate other systems of higher learning and see how they function and how they cope with certain problems that arise in the academic environment from time to time. Of particular interest in this regard are educational systems that are significantly different from our own. The German higher education system has a strongly different structure and approach.

Short descriptions of the educational progress of the German engineering student and of the structure of the German technical university are presented first. Some advantages and disadvantages from the author's point of view are enumerated. Specific courses, laboratories, projects, examinations, etc., that are listed in this paper as examples have been completed by the author at the University of Karlsruhe, Karlsruhe, Germany, for a degree in Mechanical Engineering.

The Curriculum

Table 1 is an attempt to contrast the educational progress of a typical American and a typical German child and adolescent. "Volksschule" is the German grade school which the student leaves if he or she (or rather his or her parents) decides on a future career that requires a university education. The student switches to a "höhere Schule" (higher school), called "Gymnasium", which provides a nine year long general academic education in preparation for studies at a university. Successful completion of the final examination, the "Abitur", at the Gymnasium is <u>the</u> prerequisite for admission to <u>any</u> university for <u>any</u> course of study. This exam is prescribed by the state educational authorities and thus is uniform throughout a state. During times of limited enrollment, a university's admissions office uses the Abitur scores as selection criterium.

Students desiring to enroll in an engineering school are required to complete six months of an "Industrie Praktikum" (industrial practicum) before they are admitted for study at the university. The practicum is prescribed in detail by the university and is to familiarize the future engineer with his or her work environment and its problems. Many students also choose to complete their (mandatory) time with the armed forces between Gymnasium and university. It should be noted at this point that in general the German student is older, more mature and more experienced than his or her American counterpart when joining a university.

At the university, the curriculum leading to an engineering degree takes between 4 years (minimum required) and 7 years (maximum allowed) to complete. The curriculum is divided into two major parts. The first two years are devoted to the study of the basic engineering science subjects. Most courses require two to three exams per semester which determine the passing or failing of a course. Mastery of these subjects is tested at the end of the fourth semester in a set of comprehensive exams, called the "Diplom-Vorprüfung" (pre-diploma examination). A special certificate is issued when these exams have been passed. While being approximately equivalent to the B.S. degree in this country, the pre-diploma exam does not result in a degree and is not considered a completed education. It merely entitles the student to commence with the second part of the curriculum. One repetition of this exam is permitted.

The second part of the curriculum starting with the fifth semester consists of advanced engineering science and technical application courses in the specific engineering disciplines. This part is much less structured than the first two years. Most courses are electives and no further testing is performed. In the Mechanical Engineering curriculum two design projects and a thesis project are also part of this advanced curriculum. Table 2 shows a compilation of courses for a Mechanical Engineering curriculum. The first number behind each course indicates the weekly hours of lectures, the second number those of "Übungen" (exercises, recitations).

Upon completion of all courses, laboratories and project requirements the student applies for a date for examination. In a series of written and oral exams extending over several days he or she provides proof of acceptable knowledge in a number of major and minor subjects of his or her choosing. This set of examinations is the "Diplom-Hauptprüfung" (main diploma examination). Table 3 lists the subjects examined in the pre-diploma and main diploma exams as well as the titles of the design projects and the thesis project completed by the author. After passing the main exams, the degree of "Diplom-Ingenieur" (abbreviated Dipl.-Ing.) is conferred. In scope and time requirements this degree is equivalent to the American M.S. degree. It is the prerequisite for study towards a doctoral degree.

The University

As in other countries, the "Universität" is the highest ranking school for scientific education. Universities having special emphasis on teaching and research in the pure and applied sciences and engineering also carry names like "Technische Universität" or "Technische Hochschule" (technical university). Obviouly, translation of "Hochschule" with the American "high school" would be quite wrong.

The university is headed by the "Rektor", a full professor elected by the academic staff for a limited time, generally three to six years. Since all German universities are state schools, the Rektor's administrative assistant, the "Kanzler" (chancelor), is appointed by the Minister of Education with the consent of the university's academic staff.

The largest subdivisions of the university represent the various branches of science. They are called "Fakultät" (faculty) and include all academic and non-academic personnel and all physical facilities dedicated to the teaching and the research in a specific branch of science. The head of a faculty is the "Dekan", like the Rektor a full professor elected by the academic staff for a limited period of time, generally one to three years. The classical faculties are those of philosophy, natural science, medicine, and law. Today they are, of course, more specialized. Table 4 lists the faculties that presently exist at the author's alma mater.

Within each Fakultät, the units responsible solely for teaching are called "Lehrstuhl" (teaching chair) and those engaged in teaching as well as research are termed "Institut". Table 5 enumerates the chairs and institutes belonging to the faculty of Mechanical Engineering with which the author was associated. A chair or institute is headed by a full professor ("ordentlicher Professor") who has responsibility for and authority over all academic and non-academic staff and all physical facilities necessary for teaching and research in the chair's or institute's area of involvement.

Table 6 shows the organizational chart of an institute of which the author was a member. This unit was typical in most features for all others belonging to the faculty. It was housed in a three story office building adjacent to extensive laboratory and mechanical and electrical shop facilities. The academic staff consisted of the Professor, his right-hand man, the "Oberingenieur" (chief engineer) who was a full time employee possesing a doctorate in engineering, and a number of "wissenschaftliche Assistenten" (scientific assistants), graduated engineers, employed full time on limited contracts, who in their free time worked on their doctorates in the area of the institute's involvement and normally with the head of the institute as their dissertation advisor. Semi-academic staff were the "Hilfsassistenten" (assistant's aids, graduate assistants), upper division students working part time at the institute. The non-academic staff consisted of research support and institute maintenance personnel.

Instruction

Historically the position of the German university professor has always been one of strong authority and independence. He continuously ranks at the very top of the general public's scale of esteem.

From Table 6 it should be obvious that the modern full professor is not as much a teacher as he is the manager of his institute for which he has full budgetary, personnel and program authority and responsibility. His teaching activities are generally limited to lectures and seminars. The lectures are more often than not mass lectures in order to reach all interested students at the same time. The seminars deal with very advanced topics limiting the audience to other professors, scientific assistants and upper division students. By necessity, the full professor has little or no time to interact with students on a one-to-one basis. This interaction is delegated to the scientific assistants (S.A.) who hold the recitation sessions and consult, generally by appointment, with the individual student on specific questions. Laboratories are normally conducted by the graduate assistants under the supervision of an S.A. The graduate assistants also grade the laboratory reports. Written examinations are organized, administered and evaluated by the S.A. with the help of graduate assistants. S.A.'s are also the advisors for design and quite often thesis projects. Oral examinations, particularly those for the two diploma examinations, are generally conducted by the professor himself, but it is not uncommon to find the chief engineer or an S.A. in his place in the examination room.

It should be apparent from this discussion that the notion of a student/teacher ratio has not much meaning at a German university. The limit to the number of students that can be accepted is not dictated by the number of professors but by the available physical resources like lecture halls, laboratory spaces, offices for S.A.'s, etc. The S.A. salaries are and always have been very competitive to those comparable industry positions thus avoiding shortages in the number of S.A.'s at the university. The large authority position of the professor and his dependence on the S.A. have seen to that.

The Student

The German system of higher education places exceedingly strong demands on the student's motivation, initiative and self-discipline. Since there exists no individual academic advising or councelling by the teaching staff, the student is required to assemble his or her own program based on posted course and curriculum requirements. By paying the fee for a course the student only acquires the right to attend the lectures and to be examined in that course. There is practically no mechanism in place to provide him or her with continuous feed-back on his or her mastery of the course material. Home work on a regular basis is not assigned, collected and graded. Class attendence is not required. Lectures are normally held from notes and no text is assigned. Mass lectures prohibit any exchange with the lecturer beyond a short question, if the student can muster the courage to ask it. Personal help is not readily available. In short, to a very large extent the student faces an impersonal system of education rather than educators. The responsibility rests almost entirely on the student's shoulders to decipher the system, find a way through it and emerge on the other side with the desired degree.

It goes without saying that such a system has effective, built-in screening mechanisms that do not require much personal involvement by the teaching staff. Without sufficient amounts of the qualities mentioned at the beginning of this section plus plenty of perseverance, a student is forced very soon to consider a change in his or her career plans.

Conclusion

No or only minimal contact with the students removes those factors from the German professor that make teaching the involved, time consuming and satisfying endeaver it is in this country. Particularly during times of high enrollment and/or faculty shortages, the overloaded American professor might be tempted to adopt some of the German ways, such as mass lectures, no exams at all or only few comprehensive exams instead of many quizzes, in order to ease the load and to find time for research and other necessary academic pursuits besides teaching. Of course, many of the large "research" universities already operate with these methods to be able to accomplish their research objectives without large numbers of faculty. From the author's observations this is done often at the expense of the average undergraduate student who expects and needs much direct and personal interaction with his or her teachers. Merely making knowledge available is not sufficient. Considerable effort on the part of the teacher is required to assure that the knowledge he or she offers is being picked up and properly assimilated by the students. The German system does not provide for this. To give a specific example: Large enrollment may require the adoption of impersonal mass lectures instead of the more personal small section lectures. Unless simultaneously carefully planned and supervised small group recitation sections are instituted, the quality of eduction has been lowered significantly.

From a selfish point of view, satisfaction in teaching is derived from dealing with students as individuals, providing and facilitating learning experiences for the individual and observing the individual respond and grow as a result of the efforts expended. In the author's opinion, the American system of engineering education, when handled as intended, can provide this satisfaction for the teacher. The German system was not designed for this purpose.

age	USA		Germany	
1				
2				
3				
4				
5	Kindergarten		Kindergarten	
6	Grade School	1. gr.	Volksschule	1. gr.
7		2. gr.		2. gr.
8		3. gr.		3. gr.
9		4. gr.		4. gr.
10		5. gr.	Gymnasium	5. gr.
11		6. gr.		6. gr.
12	Junior High	7. gr.		7. gr.
13		8. gr.		8. gr.
14		9. gr.		9. gr.
15	Senior High	10. gr.		10. gr.
16		11. gr.		11. gr.
17		12. gr.		12. gr.
18	College	1. yr.		13. gr.
19		2. yr.	Industrie Praktikum	
20		3. yr.	Militär Dienst	
21		4. yr.	Universität	1. yr.
22	Graduate School	5. yr.		2. yr.
23		6. yr.		3. yr.
24				4. yr.

Table 1

1. Semester

Mathematics I	5,2
Mechanics I	4,2
Physics I	4
Chemistry	4
Drafting I	3
Intro. Mech. Engg.	1
Non-techn. Electives	4

2. Semester

Mathematics II	5,2
Mechanics II	4,2
Physics II	4
Drafting II	3
Descript. Geometry	3,2
Non-techn. Electives	4

3. Semester

Mathematics III	4,2
Mechanics III	2,2
Physics Lab	3
Machine Design I	4,3
Mat. Technology I	4
Non-techn. Electives	4

4. Semester

Mechanics IV	2,2
Thermodynamics I	4,1
Machine Design II	4,3
Mat. Technology II	4,1
Intro. Chem. Engg.	1
Electr. Circuits	3,1
Non-techn. Electives	2

5. Semester

Thermodynamics II	2,1
Engg. Measurements	2
Piston Machinery	5
Materials Handlg. I	4
Fluid Mechanics	4,2
Mech. Engg. Lab. I	3
Adv. Strength of Mat.	2
Mech. Design Seminar	1
First Design Project	3
Non-techn. Electives	2

6. Semester

Thermodynamics III	2,1
Turbo Machinery	4
Combustion Theory	4
Shop Theory I	2
Kinematics of Mach.	3
Piston Engines II	3
Materials Handlg. II	4
Machine Tools	4
Mech. Engg. Lab II	3
First Design Project	4
Non-techn. Electives	2

7. Semester

Materials Science	3
Intro. Ind. Engg.	4
Electr. Power Engg.	3,3
Control Theory	3
Heating, Air Condg.	2
Turbo Machinery II	2
Welding Design I	2
Shop Theory II	2
Non-techn. Electives	2

8. Semester

Welding Design II	2
Vibrations I	2
Refrigeration	2
Plate Theory	2
Second Design Project	6

9. Semester

Vibrations II	2
Power Generation	2
Farm Machinery I	2
Control Equipment	2
Second Design Project	4

10. Semester

Adv. Control Theory	2
Farm Machinery	2
Gas Dynamics	2
Industrial Planning	2
Energy Economics	2
Welding Lab	2
Thesis Project	

Table 2

Subjects examined in Pre-Diploma Examinations:

Mathematics I-IV	Physics I-II
Descriptive Geometry	Thermodynamics I
Mechanics I-IV	Materials Technology I-II
Chemistry	Machine Design I-II

Subjects examined in Main Diploma Examination:

Theoretical Subjects:	Fluid Mechanics
	Thermodynamics
	Mechanical Vibrations
	Control Theory
	Electrical Circuit Theory
	Kinematics of Machinery
Design Subjects:	Piston Machinery
	Turbo Machinery
	Materials Handling
	Furnaces and Boilers
	Farm Machinery
	Electrical Machinery
	Heating, Air Conditioning
Manufacturing Subjects:	Engineering Measurements
	Materials Technology
	Manufacturing Methods
	Energy Economics
	Industrial Planning
	Industrial Administration

Design Projects:

1. Design of a hoist for construction sites.
2. Design and construction of an internal combustion engine test stand. Performance tests on a VW engine.

Thesis Project:

Kinematic investigation on a high density hay bailer.

Table 3

Faculties at the University of Karlsruhe (1975)

1. Mathematics
2. Physics
3. Chemistry
4. Biological and Geological Sciences
5. Social Sciences
6. Architecture
7. Civil Engineering
8. Mechanical Engineering
9. Chemical Engineering
10. Electrical Engineering
11. Information Sciences
12. Industrial Engineering

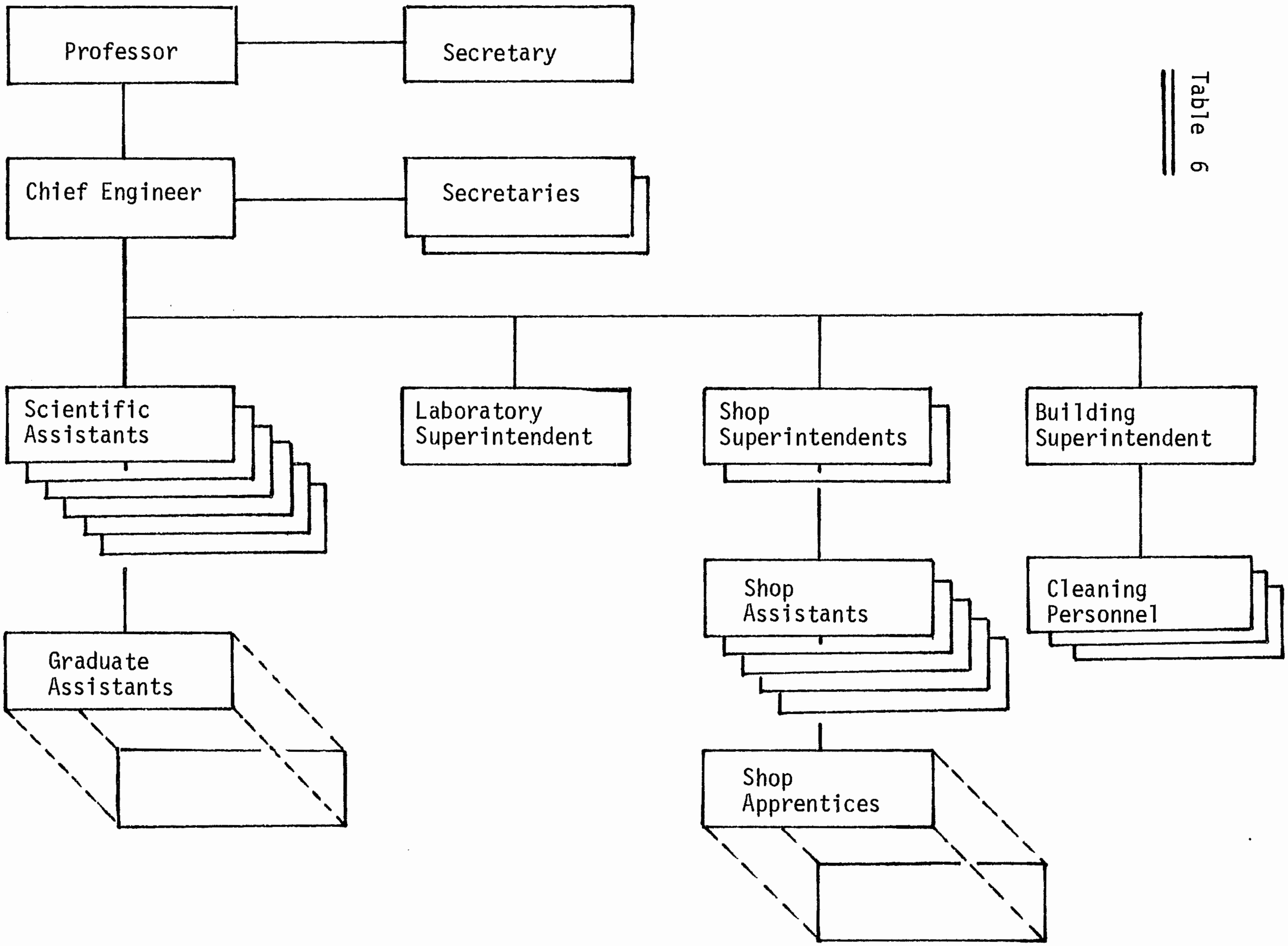
Table 4

Chairs and Institutes within the Faculty of Mechanical Engineering
University of Karlsruhe (1975)

1. General Machine Design
2. Automobile Design
3. Turbo Machinery
4. Thermal Turbo Machinery
5. Reciprocating Machinery
6. Machine Tools
7. Materials Handling
8. Thermodynamics
9. Mechanics
10. Measurements and Controls
11. Fluid Mechanics
12. Materials Science
13. Nuclear Reactor Physics
14. Nuclear Reactor Technology

Table 5

Table 6


Professor
Secretary
Chief Engineer
Secretaries
Scientific Assistants
Laboratory Superintendent
Shop Superintendents
Building Superintendent
Graduate Assistants
Shop Assistants
Cleaning Personnel
Shop Apprentices