Engineering Education in The Netherlands

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Abstract

This paper presents an overview of higher engineering education in the Netherlands. The intent is to give the information necessary for a comparison of the Dutch engineering education system to engineering education systems in other countries, especially the United States of America. The discussion includes the following topics: the historical development of engineering education in the Netherlands; secondary education and the preparation of students for higher education; forthcoming changes in engineering curricula; university entrance requirements; student financial aid; student enrollment; and the international exposure of students while studying engineering.

1. Introduction

Engineering education was established before the Dutch industrial revolution (1870-1914) and has been important ever since. Development of various industries, the trading position of the Netherlands due to its fortunate geographic location in the Rhine and Maas delta, its enclosure by the North Sea, Belgium, and Germany (see Figure 1), and the development of the European Union have furthermore helped create a market for graduates of engineering schools.

The Netherlands is geographically about 40% of the size of the US State of Ohio with about 15.8 million inhabitants (compared to Ohio's 11.2 million). Education has always been one of the top priorities for the Dutch which is obvious from the fact that about close to half a million people are enrolled as students in universities. Furthermore, about 24% of the Dutch population has completed a course of higher education [1]. Currently, the Dutch education system is undergoing many changes at both the secondary school level and in higher education. The former reform drastically changes the structure of the upper three classes referred to as the 'tweede fase' or second phase and the latter reform is a migration of the current curriculum system to an Anglo-Saxon system characterized by the presence of both a Bachelor program and a Master program.

Section 2 discusses the general education system in the Netherlands and section 3 gives a short history of engineering schools in the Netherlands. Section 4 describes recent developments in the secondary education system and the impact of these changes on the entrance requirements for engineering universities. Section 5 provides an overview of the engineering schools, their disciplines, enrollments, and curricula.

Fig. 1. The Netherlands

2. Education in The Netherlands

The Dutch educational system for children consists of mandatory education from age 5 through 16 consisting of two stages: primary education and secondary education. Primary schools start teaching children at age 4 until about age 12. These schools focus on teaching reading and writing skills, science, history, and society-related topics [1,2]. For primary education one can choose freely between existing public and private schools. After primary school a child must choose from a variety of secondary school systems. Among other factors, the secondary school choice of children and their parents is heavily influenced by the exam that many of children take at the end of the Primary School.

Unlike the American high-school system, the duration of Dutch secondary school curricula is variable (there are four-, five- and six-year programs). In general, the four-year schools prepare children for vocational training; however, a child may also choose to transfer to the final grade of the five-year school after graduation. An example of a four-year school system is the MAVO (Middelbaar Algemeen Voortgezet Onderwijs). The five-year secondary school or HAVO (Hoger Algemeen Voortgezet Onderwijs) prepares children for a professional training college or university of technical profession (HBO and HTO). Upon graduation the student may opt to transfer to the final grade of the six-year school in preparation for a university. The six-year schools are referred to as the Voorbereidend Wetenschappelijk Onderwijs (VWO) or pre-university schools and prepare students for a career at one of the country's universities. Two types of VWO exist, the Atheneum and the Gymnasium. The primary difference between the Gymnasium and the Atheneum is the presence of mandatory courses in classic Greek and/or

Latin. At the end of the final grade of each one of the secondary schools, all students are required to take a written state exam in order to qualify for graduation.

The Netherlands provides higher education at 14 universities and professional-level higher education at more than 50 'hogescholen' or universities of professional education. This paper will focus on the former form of higher education. Nine out of the fourteen universities cover a broad variety of topics such as law, health, natural sciences, social sciences, humanities, economy, culture, languages, etc. These nine universities are located in Amsterdam (2), Rotterdam, Nijmegen, Tilburg, Maastricht, Utrecht, and Groningen. One university focuses on agriculture and is located in Wageningen. Another specializes in distance education and is referred to as the Open University. And three universities focus on the engineering disciplines: Delft University of technology, Eindhoven University of Technology, and the University of Twente (located in Enschede). Note that various engineering related programs such as Computer Science are also offered at some of the nine non-Technical Universities.

Universities in The Netherlands are more specialized than the typical American university and often lack general classes in social science, humanities, and fine arts. The reason for this is the structured nature of the secondary education system where all students are already introduced to languages, the arts and sciences, the fine arts, and the social sciences in preparation for universities. Their choice of classes is arranged accordingly. Section 4 will give a more detailed description of the preparation in secondary education.

Currently, most university degree programs are four-year programs with the exception of five-year programs in the natural sciences, engineering, and agriculture [3]. Programs in medicine may even exceed five years. Throughout these programs students are in pursuit of the 'doctoraal' degree. This degree must not be confused with the doctorate degree in the US higher education system. The freshman year is referred to as the propadeuse and is the period in which a student and the involved department determine if the student is able to pursue the rest of the program. Upon the fulfillment of all requirements for the 'doctoraal' program a student is allowed to carry the degree of doctorandus or 'drs.'. Exceptions are the engineering and law programs in which case students receive an 'ingenieur' (ir.) or a 'meester' (mr.) title, respectively. The doctorate program is referred to as the 'promotie' and upon graduation one may use the title of doctor or 'dr.' for short. Because graduates of engineering universities are expected to work as professional 'ingenieurs' in society, the title of 'ir.' is protected under law [3]. Note that in The Netherlands most titles ('drs.', 'ir.', 'mr.' and 'dr.') are placed in front of the name instead of after it.

During their study at a Dutch university most full-time students qualify for financial support from the government. The amount of support is based on the student's parents' income and the student's living arrangement. Student support also includes a public transportation pass that allows students to travel 'free-of-cost' on public transportation during certain times of the week.

The quality of higher education is guaranteed through legal regulation and quality control by committees of independent experts appointed by the association of all universities [3]. These committees produce reports that describe the quality of the program and indicate improvements. The Ministry of Education, Culture, and Science prepare education-related legislation and may

take steps in those cases where committee's findings are negative. At the present time the Dutch government and universities are preparing a migration from the current structure to the Anglo-Saxon system with separate Bachelor and Master programs. Under this new structure the first three program years are referred to as the Bachelor program. After the Bachelor's degree one can choose to pursue a two-year Master's program [4].

Within the various disciplines offered at a university, the so-called 'hoogleraren' (full-professors) head up the various research groups. Their responsibilities are research, teaching, and management. The full professors are assisted by 'universitair hoofddocenten' (associate professors or senior lecturers) and 'universitair docenten' (assistant professors or lecturers). The 'docenten' have responsibilities concerning research, teaching, and/or management. In the Dutch university system Ph.D. students ('promovendi') are full-time employees of the university with both teaching and research duties.

3. Historical development of engineering schools

The origin of engineering schools (or technical universities as they are called in The Netherlands) can be traced back to the period between the industrial revolution in England (1770-1830) and the industrial revolution in The Netherlands (1870-1914) [5]. The creation of a central government and the strong hierarchy and organization of government employees, along with the foundation of a government organization to control and monitor the various water bodies (Rijkswaterstaat) raised the need for better education of people in fields such as administration and civil engineering. As a result various educational institutes were founded. In 1842, King Willem II founded the predecessor of Delft University of Technology (TU Delft or TUD), referred to as 'Koninklijke Akademie Burgelijke ingenieur te Delft' or Royal Academy. The goal of this Academy was to educate engineers, trade experts, and also government employees for the Dutch-Indies [6]. A Polytechnische Hogeschool (Polytechnical School) replaced the Royal Academy in 1864. This school no longer trained government employees, but focused on the education of civil, marine, mechanical, and mining engineers.

In 1905 the Polytechnical School attained academic status equivalent to a university and its name was changed to Technische Hogeschool (Technical Higher Education). Along with the rapidly growing field of engineering two more engineering schools were founded that are currently called the Eindhoven University of Technology (TU/e) (1956) and the University of Twente (UT). With the *Law of Scientific Education* in 1985 the name of the engineering schools was changed from 'Technische Hogeschool' to 'Technische Universiteit' (Technical University). The name 'Hogeschool' is reserved for universities of professional education.

4. Preparation of secondary school students for studies in engineering

Universities in The Netherlands can afford to be more specialized during the 'propadeuse' year due to the structured preparation of the students in the VWO. Before 1998 the students in VWO (atheneum and gymnasium) were almost free to choose their program of study for the upper three grades with a minimum amount of requirements that had to be satisfied ('old style' VWO

degree). In the 'old-style' programs it was important to include the right courses to be prepared for the university of choice after graduation. In 1998 the so-called 'tweede fase' (second phase) was introduced to the upper three grades of the VWO. The changes to the upper three grades concerned both changes in course content and teaching-philosophy; with classic in-class lectures replaced by a combination of in-class lectures and group-oriented projects, independent research, computer-based information acquisition, etc. [7]. Reasons for the introduction of the Second Phase were the desire to improve the transition from VWO to the universities, the application of scientific findings in the areas of psychology and education, the desire to produce students with a both broad and specific knowledge who are able to independently acquire knowledge, and the change in the lower three grades that already took place in the early 90s [8].

In the Second Phase, the 'studielast' or course load in the upper three grades of the VWO is distributed among three sections: a common section, a profile, and electives. The coarse load is expressed in terms of credit hours. Each credit hour is defined as an hour spent by the student on lectures, homework, exams, group work, field trips, etc. The total number of credit hours per year is 1600 hours (40 weeks times 40 hours per week) resulting in a total course load equal to 4800 hours for the upper three grades. The common section consists of classes covering more general educational topics such as the Dutch, French, German, and English languages (the student must choose from a particular aspect of the language), general natural sciences, society and history, culture and fine arts, management and organization, introduction to computer science, and sports. In the profile section the student must choose from four different profiles: 1) economy and society, 2) culture and society, 3) science and health, and 4) science and technology. At the end of the profile each student must complete a project and a project report. This project can be performed in cooperation with a university or a university of professional education. Table 1 shows some basic courses in the four profiles. Note that the student's profile choice drives the student's qualifications for admission in certain university programs.

Table 1. The Four VWO profiles

Economy and Society	**Culture and Society**	**Science and Health**	**Science and Technology**
Economy 1,2*	German / French /Philosophy / Greek /Latin	Biology 1,2	Physics 1,2
Mathematics A** 1,2	History	Physics 1	Chemistry 1,2
Geography	Mathematics A** 1	Chemistry 1	Mathematics B*** 1,2
History	Cultural education and Fine Arts	Mathematics B*** 1	

* The numbering 1 and 2 refers to parts of the course.

** Mathematics A focuses on mathematics applied to social sciences such as matrix theory, probability, statistics, linear programming, applications of differentiation, etc..

*** Mathematics B focuses on the more abstract mathematics required for technology-oriented universities such as graphs, equations, goniometry, geometry, differentiation and integration, etc.

The third section encompasses the elective portion of the VWO program. This section forms about 20% of the total program. The student can freely choose from the remainder of all classes. Certain schools may limit the student's choice in particular areas or make certain classes mandatory for the students. Already, changes for this Second Phase are being proposed that concern language and general natural science courses. These changes will be implemented by 2004.

For most engineering programs at the three technical universities the entrance requirements are a VWO degree 'old style' with mathematics B and physics, or a VWO degree 'new (Second Phase) style' with either the Science and Technology profile or the Science and Health profile combined with mathematics B 2 as an elective.

5. Engineering programs at technical universities

Each one of the three technical universities has its own character determined by various factors such as the university's history, its regional location, regional industry, teaching and research philosophy, etc. It must be noted that the regional character of the university is slowly disappearing due to the internationalization of higher education. The geographical spread of the three technical universities results in a large percentage of the student population originating from the surrounding regions. Although technical universities offer programs that are identical in name, their specialization and curricular differences may attract different students. Furthermore, all three universities offer programs unique for that school. Table 2 shows the programs being offered by technical universities. Personal preferences, location, available programs, teaching and research philosophy, present industry, etc. drive the student's choice of technical university.

Table 2. Programs at the three technical universities.

Delft University of Technology	Eindhoven University of Technology	University of Twente
Mechanical Engineering	Mechanical Engineering	Mechanical Engineering
Electrical Engineering	Electrical Engineering	Electrical Engineering
Chemical Technology	Chemical Engineering and Chemistry	Chemical Technology
Applied Physics	Applied Physics	Applied Physics
Applied Mathematics	Biomedical Engineering	Biomedical Technology
Computer Science	Mathematics and Computer Science	Mathematical Sciences
Civil Engineering	Building and Architecture	Computer Science
Aerospace Engineering	Information Technology	Civil Engineering
Marine Engineering	Technology and Social Science	Business Information Technology
Geodetic Engineering	Applied Mathematics	Philosophy and Social Science
Applied Earth Sciences	Installation Technology	Public Administration and Public Policy
Industrial Design Engineering		Educational Science and Technology
Architecture		Communication Studies
Biotechnology		Environmental Technology
Material Science & Technology		Industrial Engineering and Management
Life Science & Technology		Telematics
		Industrial Design

Table 3 shows the total number of students for selected engineering programs at the Technical Universities. The table is limited to various programs the universities have in common. The abbreviations in the column header and their explanation in the footer of the table may not necessarily correspond to the exact name of the program given by its university. The table indicates that the number of students per program has remained fairly constant over the last three academic years.

Table 3. Total number of students per program [9,10,11].

2000/2001

	EE	ME	CE	AR	CT	TM	CS	AP	AM	Other	Total
TUD	614	1047	1640	3229	387	798	845	487	170	3910	13127
TU/e	458	743	0	1547	386	1094	526	384	128	813	6076
UT	456	709	545	0	362	1000	592	395	173	1652	5884

1999/2000

	EE	ME	CE	AR	CT	TM	CS	AP	AM	Other	Total
TUD	670	1100	1680	3081	407	686	803	534	166	3797	12924
TU/e	409	722	0	1366	395	1018	443	386	117	717	5573
UT	477	718	512	0	412	937	591	404	175	1515	5734

1998/1999

	EE	ME	CE	AR	CT	TM	CS	AP	AM	Other	Total
TUD	753	1215	1738	3023	446	654	728	570	161	3714	13002
TU/e	372	728	0	1187	417	957	380	410	125	616	5192
UT	466	709	517	0	443	922	509	403	189	1481	5639

Note on the abbreviations: EE – Electrical Engineering, ME – Mechanical Engineering, CE – Civil Engineering, AR – Architecture, CT – Chemical Technology, TM – Technology Management, CS – Computer Science, AP – Applied Physics, AM – Applied Mathematics.

The total number of female students attending technical universities is in general a relatively small percentage of the total student population. Table 4 shows the percentages for various engineering programs at Delft University of Technology. Certain engineering disciplines have a traditionally lower average of female students such as EE, ME, and CS, whereas other disciplines have a large percentage of women; examples are architecture and chemistry.

Table 4. Percentage of female students at the TUD [9].

Female Students (Delft University of Technology)

	EE	ME	CE	AR	CT	BM	CS	AP	AM	Other	Total
00/01	6.4%*	5.6%	13.2%	33.5%	23.0%	19.7%	6.9%	11.5%	32.9%	22.8%	20.6%
99/00	5.7%	5.7%	13.0%	33.2%	21.1%	19.4%	6.4%	10.1%	32.5%	22.0%	19.8%
98/99	4.9%	5.3%	12.6%	32.6%	21.5%	22.8%	6.2%	9.5%	31.7%	21.4%	19.2%

*Interpretation: 6.4% of all Electrical Engineering students are female.

Table 5 shows the efficiency or graduation percentages of the ‘propadeuse’ and ‘doctoraal’ programs. The cohort year refers to the entry year of that particular group of students. Table 5 indicates the presence of a strong selection process.

Table 5. Graduation percentages per 31 August 2000 at the TUD [9].

Propedeuse (average over cohort years 1994, 1995, 1996)

	EE	ME	CE	AR	CT	BM	CS	AP	AM
TUD	61%	56%	70%	77%	67%	72%	55%	58%	55%

Doctoraal (average over cohort years 1989, 1990, 1991)

	EE	ME	CE	AR	CT	BM	CS	AP	AM
TUD	50%	44%	63%	58%	56%	NA	36%	56%	37%

The Electrical Engineering program at Delft University of Technology is used here as an example engineering curriculum. Note that among the three universities and also among the different programs within the university, variations may exist. The first or propadeuse year consists of two components; in-class lectures and a laboratory. The topics of study are mathematics, electronics, computer and digital systems, and various areas of physics. The second and third year are referred to as the 'Kandidaats' (Candidate doctoraal) program [12]. Again, this program consists of a laboratory component and a class component in the areas of telecommunications, computer systems, electromagnetics, physics, and electronics. The fourth and fifth year are referred to as the 'Eind-doctoraal' or Final doctoraal program. At this stage, the student must make a choice between three directions; 1) research, 2) design, 3) and product-systems (the planning, organization, realization, and management of technical product systems) [13]. Each of these directions has its own set of mandatory classes and electives. Besides a class requirement, the students must complete a thesis project to fulfill their graduation requirements.

'Praktijk stages' or practical training with companies, institutions, or other universities is not a requirement but is recommended. The goals of the practical training may vary from an engineering experience to a social-psychological experience, or the goals may be the application of acquired knowledge or the acquisition of new knowledge. More information on practical training can be found in [14].

Presently, the Dutch government and universities are preparing a migration to the Anglo-Saxon system or Bachelor / Master structure. Under this new structure the first three years of each program are modified such that they lead to a bachelor's degree. This may require the inclusion of an exam or thesis project requirement before the end of the third year. After the completion of the bachelor's program, students may continue and pursue a two-year 'Master of Science' or 'ir' program. Most universities are planning to start offering the Bachelor and Master programs in the academic year 2002. Another expected reform is an internationally oriented accreditation reform to guarantee the quality of Dutch universities nationally and internationally. Other European countries have recently made similar transitions. Similar changes in Poland are described in [15], for example.

6. Summary

This paper presents the educational system of the Netherlands with a special focus on Technical University education and the secondary school education that prepares students for studies at academic levels. The Dutch educational system is currently being reformed. A second phase was introduced in the VWOs starting in 1998 and 1999 to improve the transition between VWO and universities. The first generation of student have graduated from this new program in 2001 and started their careers at one of the universities. Furthermore, the university system is on the verge of migrating to the Anglo-Saxon system, a Bachelor / Master system, and will probably do so in 2002. The effect all these changes have on higher education will become visible in the next several years.

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