THE RECRUITMENT TO SCIENCE AND ENGINEERING COURSES IN THE NETHERLANDS

P.C. van der Kruit
Faculty of Mathematics and Natural Sciences
University of Groningen
Nijenborgh 4
9747 AG Groningen
the Netherlands
e-mail: vdkruit@fwn.rug.nl

Paris, May 9, 1996

Paper presented at the sixth annual meeting of the European Association of Deans of Science: "The declining interest of the youth in Europe to study mathematics, physics and chemistry: meeting the challenge".

In 1994 the number of first-year students enrolling in mathematics at the University of Groningen dropped from around 40 in the late eighties and early nineties to below 20. The Rector Magnificus of our university called a few persons, among which the chairman of the Department of Mathematics and Computer Science and myself as Dean of the Faculty of Mathematics and Natural Sciences, to his office to explain what measures were taken to reverse this disastrous development. We reviewed all the measures that were taken, such as information and promotion campaigns at secondary schools, joint projects with such school as inviting students and their teachers from these schools for exploratory study weeks, connection via Internet to the campus computer network, and many others. We concluded that there seemed little to be gained from further initiatives (we couldn't think of any) or intensifying the existing ones. In 1995 the influx of first-year students in mathematics remained at the same dismally low level.

In the following I will address three questions:

1. What actually is the development in student enrollment in the various disciplines at universities in the Netherlands?

2. Are there still bright students left at the secondary, pre-university schools, that we could try and interest in mathematics, physics and chemistry? Or will we just get large numbers of students that only marginally qualify for such studies?

3. What lessons can we learn from history?

There is an underlying issue that I will not treat in detail and that is whether there is indeed a need in society for a larger number of mathematicians, physicists and chemists than appears to become available around the year 2000 based on the current enrollment in universities. Various committees have warned that this will be a serious problem. For example, the visiting review committee for the academic curricula in mathematics of the Association of Universities in the Netherlands (V.S.N.U.) has this year written that "not too long from now this [the decline in student numbers] will lead to deplorable consequences for the conduct of science and for commerce and industry in the country" (my translation).

1 Student numbers at universities in the Netherlands.

The Netherlands has thirteen universities: six general ones at Amsterdam, Groningen, Leiden, Maastricht, Rotterdam and Utrecht; two special ones at Amsterdam (the Free University, which is Protestant) and Nijmegen and Tilburg (both Catholic); three technical universities at Delft, Eindhoven and Enschede; and one agricultutal university at Wageningen. Natural science can be studied at Amsterdam, Groningen, Leiden, Utrecht, the Free University and Nijmegen, while technical science can be studied at Delft, Eindhoven, Enschede and Groningen.

The academic educational system in the Netherlands has two "phases". The first, which leads to the Doctorandus (Drs.) degree for the general sciences, roughly equivalent to the "Masters", lasts nominally for four years, while for the technical sciences, leading to the Ingenieur (Ir.) degree, this is five years. The second phase can take various forms, such as further courses to obtain a full teacher qualification for secondary, pre-university schools, further professional training for pharmacists or medical students or preparation for the Ph.D. degree. The latter is in the form of an appointment for four years, which is mostly devoted to research. In the natural sciences about one-third of those finishing the first phase continue with Ph.D. thesis research.

The total number of students enrolling for the first time at all universities reached a peak of 35,645 in 1991 (an expected demographic result), but subsequently declined to 30,944 in 1995. This is an average decrease of 3.3 % per year. The expected decrease from demographics on the other hand is no more than about 1.5%. This also is reflected in the following numbers. Traditionally, from those eligible to enroll at the universities (that successfully completed the final exam of the pre-university secondary schools) 66 to 67% went to university. In 1995 this percentage had dropped to about 62%.

Undoubtedly, there is a complex of reasons why this change is occuring. Government support to university students in the form of a stipend or grant has been eroded to the level that it barely suffices to pay the tuition and the rent of a room to live in, but for study materials, subsistence and other necessities or pleasantries the student has to rely on his or her parents, on supplementary income or simply to get a loan. Although some years ago the grant could be received for up to six years (seven for the technical sciences) to complete the first phase, this has in 1995 been reduced to at most five years. In addition, stricter conditions on the grant have been put related to the progress of the study, in the form of turning the grant into a loan (with interest) for those that do not finish courses sufficiently quickly. Starting with the academic year 1996/97 the financial support is given initially as a loan and then only for the nominal four years the first phase should take, but this is for all but the brightest students an unrealistically short period. In addition, continuation of the loan is dependent upon sufficient progress. Only if students actually complete the first phase successfully within six years (where they have to find themselves a way to obtain their income beyond four years anyway) is this loan turned into a grant. For most natural sciences the universities have extended the grant for the newly enrolling students in 1996 with a fifth year out of their own budget. So, students have to live on a rather minimal budget and in addition may end up with a substantial debt. This is of course not unprecedented in history; in fact it has been the actual case for many generations.

Now let us have a look at the shares the various disciplines have in attracting first-year students. To this end I first clustered the various disciplines in larger area's of scientific inquiry and turned these then into percentages. I have grouped technical variants of mathematics, computer science, physics and chemistry under natural sciences. Engineering here is only those disciplines that have to do with construction of things, such as buildings, bridges, ships, airplanes, equipment, instruments, electronic devices, etc. The following table results.

	1989	1990	1991	1992	1993	1994	1995
Theol./Philos.	1.0	1.0	1.1	1.0	1.1	1.0	1.0
Law	14.7	14.4	13.4	13.3	13.8	14.5	14.2
Humanities/Arts	15.4	15.3	15.8	14.6	13.5	12.8	12.5
Medical/Health	7.0	7.0	6.6	7.1	7.6	8.1	8.7
Natural Sciences	13.0	12.6	12.5	12.6	13.0	12.9	12.9
Engineering	11.1	11.1	10.9	10.8	10.9	11.2	11.3
Agricultural	3.6	3.7	3.0	2.9	2.9	2.9	2.9
Social Sciences	16.8	18.4	20.6	22.4	21.7	20.7	20.4
Econ./Managem.	17.2	16.5	16.0	15.3	15.4	15.8	16.2
Total	34295	34463	35645	33671	32684	31712	30944

The trends are well-known. The share for humanities/arts is decreasing significantly, while there is also a decrease for economics and management science (business school). The latter have been on the decline already for some years before the period covered here. The largest increase is for the social sciences (going through a peak in 1992, also in absolute numbers, but since then there is actually a decrease), while the share of medical and health sciences is also growing. The latter, by the way, is mainly due to the fact that there is a ceiling to the number of students in medical school (leading to the medical profession), which is always oversubscribed, and the total absolute number therefore remains more or less constant (actually shows a slight increase as a result of new health-related curricula). Other area's, including natural sciences, remain fairly constant, although of course the absolute numbers are declining.

My personal opinion is, that the major factors contributing to this change in the relative shares are the following. In the first place prospective students tend to give more weight in their choice of field of study and subsequent professional life to a feeling of doing something useful for society in a *social* rather than in an *academic* sense. Secondly, the poor job opportunities after completion of academic education certainly also play an important role.

Now let us concentrate on the natural sciences. To this end I further divided this area up in the following clusters:

- *Physical Sciences*: mathematics, computer science, astronomy, physics, chemistry.
- *Technical Sciences*: technical variants of mathematics, computer science, physics and chemistry.
- *Natural Life Sciences*: biology and pharmacy.
- *Geosciences*: geology, geophysics and physical geography.

The developments in the percentages of the same total number of students enrolling at universities is given in the next table.

	1989	1990	1991	1992	1993	1994	1995
Physical sciences	4.7	4.5	4.0	4.2	4.4	4.0	3.9
Technical sciences	5.1	4.7	4.5	4.4	4.2	3.7	3.7
Natural life sciences	2.4	2.5	2.8	3.1	3.5	4.1	4.2
Geosciences	0.8	0.8	1.2	1.0	1.0	1.0	1.0

Now we see a substantial shift away from physical and technical sciences towards natural life sciences. This poses severe financial and manpower problems for a faculty as mine, which encompasses physical, technical *and* natural life sciences. The funding depends to a significant extent on student numbers and although consequently the total budget remains reasonably constant, there is little room to quickly respond to such changes by reallocating funds and manpower, while at the same time the research effort also has to be funded and, where of good or excellent quality, protected.

Again a number of factors contribute, but I suspect that to a large extent these are the same as the ones noted above for the less mathematically inclined. A further factor, that applies to those contemplating the natural (and more specifically the physical) sciences as their field of study, is that such studies are perceived as difficult (we will see below that the average or fair student at secondary schools indeed has only a fifty/fifty or so chance to get through the four-year first phase), after which they have to enter a very competitive job market with minimal chances for an attractive career.

A major cause is also the public perception of science and scientists. I was distressed by the outcome of a poll that I read some years ago. It was conducted in 1989 in many countries in the European Community (now European Union) and had among other things to do with the public appraisal of science and scientists. Note the following questions and replies (the latter are indicated by percentages).

		E.C.	NL
The benefits of science are greater than the harmfull effects	agree	47	28
	disagree	20	**47**
	don't know	33	25
Scientists can be trusted to make the right decisions	agree	34	23
	disagree	34	**54**
	don't know	32	23

Especially for the Netherlands the numbers are worrysome. The Netherlands repondents have definite opinions (only one-quarter doesn't give a clear answer, against about one-third in the E.C.), but about half of those interviewed have a rather sceptical and distrustfull view of science and scientists.

Another thing that bothers me (especially since I am myself an astronomer) is the outcome of the following poll conducted a few years ago on behalf of the European Commission. To the question whether the earth moves around the sun or the other way around, 76% of Netherlands respondents gave the right answer and 19% still believes that the sun goes around the earth (for the whole E.U. the percentages are 81 and 12). Those giving the right answer were subsequently asked how long it takes the earth to move around the sun. Only 55% in the Netherlands gave the correct answer of one year, while 29% thought the period is one day! (for the E.U. this was respectively 63 and 20%). So only about half the population knows the correct answer to both questions.

And consider this: In the early seventies there was in the Netherlands a discussion on the possibility to introduce daylight saving time. A television reporter interviewed random pedestrians in a shopping area. One person interviewed acknowledged not knowing what it was all about. The reporter explained it as meaning that the sun would rise one hour later. Upon which the person interviewed was astonished and even somewhat insulted, and replied that of course that is not in our hands[1]. This vividly illustrates the uninformed way in which the media often treat science and the basic public ignorance of very fundamental concepts in science (and as far as our clocks are concerned basic societal conventions).

Indeed, there is a general interest in science among the public (and certainly in astronomy), but we still have a long way to go in translating that into a knowledge of very basic facts and an appreciation of the real fascination of science as a tool towards a fundamental understanding of the physical world, the coherent workings of Nature and at least an important part of the answers to the questions relating to the purpose of it all.

Returning to student numbers, it is also instructive to look at absolute values. Nationwide the changes between 1989 and 1994 are the following, where I first give the absolute number of first-year students in the two years and then their ratio.

mathematics	338	–	256	0.76
computer science	888	–	706	0.80
astronomy	44	–	57	1.30
physics	814	–	653	0.80
chemistry	1275	–	793	0.62
biology	688	–	953	1.39
pharmacy	166	–	401	2.42

This shows that the change is far from trivial. Interesting is my own field astronomy, where there is an increase (in 1995 there were even 69 first-year students), while the study itself is similar (in the first years at the university essentially identical) to physics. Maybe we should also follow the fashionable habit of referring to the field as astrophysics. In earlier decades astronomy suffered from the misconception that it was an "easier" study than physics, but intensive information campaigns at secondary schools have mostly corrected this perception. Colleagues have informed me that the number of first-year astronomy students in Leiden university now is comparable to that in physics, while at my university it now approaches that in mathematics.

2 What prospective students should physical sciences aim for?

In recent years there have been a number of studies and discussions on the possibilities to use various measures to select students entering universities. The average grade at the final exam in the pre-university secondary schools was a prominent example. Cohorts that entered universities in the late eighties have been used to study the predictive power of this average grade in hindsight by correlating it with the actual performance and success rate. In the Netherlands grades are given on a scale from 1 to 10 with 10 the highest ("excellent").

[1]There is an amusing story that when the same issue was considered in the US early this century, it was seriously suggested that one might just as well change thermometers too to make winters warmer and summers cooler.

Results of such a study, performed at the University of Groningen shows the following characteristics.

- For almost all fields the distribution of this average grade among the students enrolling has a rather sharp peak at 6.5. In general less than 10% of the students have an average grade of 8 or higher.
- The distribution for physics is very different; it peaks at 7.5 and about 35% have 8 or higher. For chemistry the distribution is distinctly wider with a broad peak around 7.0; almost 20% have 8 or higher.
- The chance to finish the first phase of academic study increases with this average grade, but the curves show very different values for this chance at a given grade. To mention a few (very rough) trends, I quote the increase of this chance from average grade 6.0 to 8.5: medicin from 0.5 to 0.9, pharmacy from 0.4 to 0.9, economics from 0.2 to 0.9, psychology from 0.4 to 0.6, chemistry from 0.4 to 0.8 and physics from 0.1 to 0.8.
  It should be remembered that this not only is a reflection of qualification (although it is probably the major factor), but may also be influenced by a loss of interest, which would reflect on the universities themselves. I suspect that the latter is a good part of the explanation why for the pedagogical sciences the chance actually *decreases* for the range of grades given from 0.5 to 0.4.

Using these numbers we can then try to answer the following question. If we were successful in increasing the number of students in physical sciences, would we only be getting more average or mediocre students or are there still significant numbers of bright students at secondary school left that we could hope to interest in physical science? In other words, would it help to try and attract more students?

In order to address this question I looked at all those students that according to their choice of field of study must have had mathematics in their secondary school curricula. Many would also have had physics and/or chemistry. In any case these appear to form the pool of prospective students that physical science recruits from. In the following table I show for each range of average grades for students in this sample (enrolling for the first time in 1987 and/or 1988) the percentage of students at the left-hand part of the table and on the right-hand side the fraction that successfully completed the university first phase. I should stress that these are very rough numbers and only are indicative.

	percentage			chance		
	< 7	7–7.5	≥ 8	< 7	7–7.5	≥ 8
physical sciences	10	25	30	0.2	0.5	0.7
natural life sciences	15	10	10	0.4	0.7	0.8
medical science	10	10	15	0.7	0.8	0.9
economic/business	65	55	45	0.4	0.7	0.9
total per year	780	720	190			

So we see that of the highest scoring pre-university school students that elected to enroll for university education, only about one-third choose physical science. These bright students can probably complete any study of their choice with a high chance (0.7 to 0.9). Almost half of these choose economical or management sciences. Of the middle group (the good students) only one-quarter choose physical science, where they have a roughly 50% chance to complete the first phase. Most choose for the other possibilities, where indeed their chances for successfully completing the first phase is significantly higher. The lowest group (the average students at secondary school) has few students choosing for the physical sciences and their chances are rather low. In general we do see that students indeed select those fields where their chances are best. The number for medical sciences is limited by a maximum the universities can accept (a *numerus fixus*).

The conclusion is then that there are indeed significant numbers of prospective students left that we could interest in physical sciences and for which this would be a good choice in the sense of chances to complete university education. The question is of course if indeed we can hope to lure these into studying mathematics, physics or chemistry. Many may have a genuine interest in fields as economical sciences or business school, while others may be attracted there because of the expectation of a quick career with a high income.

To those genuinely interested in economical sciences I would point out the following. The Netherlands has had two Nobel Prize winners in economics (at least of Netherlands nationality and training), namely Tinbergen in 1969 and Koopmans in 1975. Both started out with an academic study in theoretical physics. So one apparently optimizes his/her chances for a successful career in economical research (and maybe winning a Nobel Prize) by starting out in physics.

The question remains how we can interest bright students at our secondary schools to enroll in physical sciences. I believe that it must be done through improving the public perception of the importance of science in general and physical science in particular and through their teachers. After all, by the time students are ready to enter university they have already restricted their possibilities through choices in their curricula in secondary schools, often made at ages 15 or so. And it is an often heard statement by those going into physical (or whatever) science, that they do so (and had earlier chosen their secondary school curricula) on the basis of the inspiring manner in which their secondary school teachers taught their subjects. To illustrate this point I will next have a look at what lessons history can teach us.

3 Lessons from history.

The following is based on a Ph.D. thesis by *B. Willink: Burgerlijk Sciëntisme en Wetenschappelijk Toponderzoek* (in my translation "Middle-Class Scientism and Scientific Top Research"), from the University of Amsterdam in 1988. As it is written in Dutch and since as far as I know it has not been translated in English, I will give a short summary of the thesis first.

Willink started out by defining (per decade) in the nineteenth century "National Golden Ages" in natural science research when the following three things occured at the same time compared to the preceeding decade:

- Growth in the number of scientists with at least one column in *Poggendorff's Bibliographisch-Literarisch Handwörterbuch zur Geschichte der Exacten Wissenschaften*;
- Growth in the relative number (a nation's share) of the same;
- Growth in the number of scientists with at least two pages in the *Dictionary of Scientific Biographies.*

I take it as an assumption that when such a Golden Age occurs it not just means that there are prominent scientists, but that this is in the first place a reflection of a high interest and excellent training in natural sciences at secondary schools and at the universities. To give an indication of the number of scientists involved I note that for the Netherlands Willink lists

48 top scientists. These include the following well-known persons as the most prominent ones according to the criteria used:

C.H. Buys Ballot	Physics
J.D. van der Waals	Physics
J.H. van 't Hoff	Chemistry
J.C. Kapteyn	Astronomy
H.A. Lorentz	Physics
T.J. Stieltjes	Mathematics
W. Eindhoven	Biology
P. Zeeman	Physics

Using his definition, Willink then comes to the following Golden Ages in the countries that he studied:

1800 – 1809	France
1810 – 1819	France
1820 – 1829	Germany, Great Brittain
1830 – 1839	Great Brittain
1840 – 1849	Germany
1850 – 1859	Germany
1860 – 1869	Austria, Netherlands
1870 – 1879	Germany
1880 – 1889	Netherlands
1890 – 1899	–

Here Austria of course means the Austria-Hungary or Danube Monarchy. Next Willink showed that these periods and their distributions over the century and countries correlate well with social factors, such as the rise of the Liberal Middle Class, Bourgeousie or Bildungs- and Besitzbürgertum; and the occurence of international challenges as wars (in particular defeats) and responses to reforms in other countries. Finally he concludes that there are seven factors that he can identify. Five of these are relevant here, as these are related to policies (although not necessarily deliberate policies to achieve the goals of a scientific Golden Age) and social circumstances. These are:

- Growth in employment in higher education;
- Reduction in student/staff ratio;
- Growth in investment in university buildings and equipment;
- Improvement in science curricula in secondary schools and universities;
- Growth in social motivation to achieve scientific success and through that social prestige.

Note that most trends are currently the opposite. I will now focus on Willink's discussion of the point about reforms in secondary schools for the Netherlands. Up until 1863 the only secondary school that could lead to university studies was the Gymnasium, which had a curriculum with much time devoted to the study of the classics (Latin and Greek). In that year 1863 the Netherlands government instituted a new type of secondary school: the Hogere Burgerschool (HBS), which means roughly School for the (Upper-) Middle Class. It was instituted with the aim to provide a school that would prepare young men for leading positions in industry and commerce. The HBS had no Latin and Greek in its curriculum, but instead much natural science; in the last two of the five years about half of the time was actually devoted to that. An important thing is that the teachers at the HBS usually were university trained and had Ph.D.'s. They enthousiastically seized upon the opportunity to teach their disciplines and, since they had actually been involved in scientific research, were able to arouse a deep interest in their field among many of their students.

As a result universities opened up to HBS-graduates for studies in natural sciences and the number of students did increase subsequently. In the academic year 1860/61 there were 38 students in mathematics and physics at the universities and this number increased to 182 in 1885/86. This then gave a strong impetus to the scientific research done. It is interesting to note that the Nobel Prize winners that the Netherlands produced in physics and chemistry early this century graduated almost all at the HBS before entering university (van der Waals is the exception). Of course, the Gymnasium continued to produce eminent scientists in the more classical fields, such as the historian Johan Huizinga. So we see, that the reform of secondary education and the fact that young people were taught by teachers who had an univerity training often up to the level of a Ph.D., gave rise to a growing interest in natural science and attracted the brightest students to become mathematicians, astronomers, physicists, chemists and biologists. Note, however that this was not the original aim of instituting this new type of secondary school.

How is the situation nowadays? Teachers in the final years of the pre-university schools (now called Atheneum and Gymnasium) have to have a so-called "first-degree" qualification. This means that they have to complete first-phase studies at the universities, after which they follow additional courses to obtain that qualification. The number of university students choosing that path is not large. The highest salary such teachers can obtain is the same as that for the lowest rank of permanent scientific staff at the universities. There is a growing shortage of well-qualified teachers in secondary schools and the problem is likely to become more acute rapidly. There is a movement to open ways to obtain this first-degree qualification also for teachers that have second-degree qualification; these teach in the lower classes of secondary schools or in those parts that do not prepare for university studies. These teachers never have been in universities and have had no actual experience with the conduct of research.

Even those that have obtained first-degree qualification now are getting less and less experience in a research environment, as a result of the pressure to complete university studies in a shorter and shorter period. I believe this to be a disastrous development. As we have seen above the experience last century was that teachers that have had extensive university training and have conducted research themselves were able to stimulate young people to go into physical science. I remember from my own days at secondary school (indeed the HBS) that a significant fraction of the science teachers actually had a Ph.D.; nowadays there are very few such teachers left.

4 Conclusions.

- There is a substantial shift for students that enroll in universities from a choice for physical science towards natural life sciences or other disciplines.

- The public perception of natural science and scientists in general is rather negative.

- There are still many young prospective students that could successfully study mathematics, physics or chemistry, but rather choose other fields.
- Major causes for this are the perceptions that such studies are difficult and the career prospects poor.
- More university trained persons, especially ones that have obtained Ph. D.'s, should be encouraged to become teachers in secondary schools.
- These then should motivate and stimulate an interest in natural sciences to in particular encourage these bright young people to choose for a study in physical science.