

ENGINEERING IN DUTCH SCHOOLS: DOES IT EFFECT STUDY CHOICE?

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ABSTRACT

Increasing visibility of STEM fields in schools is one way to increase the percentage of students opting for a STEM study. In the Netherlands there are two ways this has been implemented. Firstly, students can choose the course 'Onderzoek en Ontwerpen' (O&O; Dutch for Research and Design) which is offered in lower as well as upper level classes. Alternatively, they can choose the course Nature, Life & Technology which is only offered in upper level. O&O contains mostly engineering related subjects and NLT is a combination of science and engineering topics.

Our study shows a quantitative analysis of the study choice after school over a ten-year period of students with O&O (n=4.936) or NLT (n=27.397) comparing with the full cohort (n=331.602). We find that O&O effects study choice substantially, while the effect is less strong for NLT. Zooming in on female students, their participation in O&O (34%) and NLT (44%) at school are high compared to what we find in typical scientific engineering programs. In the 2010-2013 period we see many female O&O students opting to study Medicine, whereas the 2014-2019 period shows a substantial increase in female O&O students entering science and engineering programs.

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1 INTRODUCTION

Stimulating students to opt for a study path within the STEM fields (Science, Technology, Engineering, Mathematics) is still necessary in order to, finally, increase their participation on the labour market in these fields. STEM related programs at secondary schools is one of the steps we can take [1]. Within this framework, up to now 95 Dutch schools (15% of all schools with A-level examinations) have implemented engineering in their schools by an extra course called Onderzoek en Ontwerpen (O&O; Dutch for Research and Design). The number of these so-called Technasia is still growing. A rerun of our analysis in 2015 [2] over a ten year period instead of five years has been conducted. It shows a consistent pattern when zooming in on the study choice at our university, with a five times higher number of O&O students in our dataset. O&O students enrol more often in Design and Construction Engineering Programs compared to regular students. This result triggered us to look at Nature Life & Technology (NLT) as well. NLT is a similar STEM related program at Dutch secondary schools. This interdisciplinary NLT subject [3] is given in addition to the regular courses in physics, mathematics, chemistry and biology at 246 (46%) schools.

Looking at our own bachelor influx, it only shows a limited picture of the study choice of both student groups. Therefore, to gain insight into whether these educational innovations really contribute to increasing the intake into technical programmes in the Netherlands, we have looked at examination cohorts over the period 2010 to 2019 across the country.

1.1 Background O&O and NLT programs

In 2004 the Technasium Foundation started a new type of school profile called Technasium. Technasium schools offer O&O from Grade 7 to 12 (age 12-18). The foundation was initiated by two parents who had more challenging STEM education in mind for their children. NLT exists from 2007 at schools and is only taught in upper secondary education, Grade 10 to 12 (age 15-18). This subject was developed as a national initiative in order to create more coherence between the individual STEM courses. Both interdisciplinary initiatives at secondary school level are a response to the need for more integrated and interdisciplinary STEM approaches. Even though they are not compulsory, a majority of the secondary schools engage in either of these two initiatives [4]. It has required large efforts at the schools in developing the new subjects, selecting or writing course materials, teacher training and communication with the world of science and technology outside the schools [2]. The quality of both subjects is supported by audits that zoom in on both the course materials and the implementation. Because these innovations have been embedded in Dutch education for (almost) 15 years, we are now able to provide a realistic picture of the effects on the STEM related study choice of students with either an O&O or NLT background.

1.2 Features of the O&O and NLT programs

Both subjects pursue similar goals and have a set-up in which different course contents and skills are combined in projects (O&O) or modules (NLT). The main goals of O&O are (1) to prepare students for studies and employment in STEM fields and (2) to encourage students to develop into competent designers or researchers. O&O is an additional subject which is scheduled 4 hours per week from grade 7 to 12. Throughout their school career students work as a team on real assignments of companies or other organisations. The O&O teacher searches for assignments at companies in the neighbourhood. The student teams then work independently using a prestructured project format and dedicated workplace facilities. Many parts of their teamwork have to be structured by the teams themselves. Their teacher has a coaching role. The final assignment, mostly in pairs, connects with a university research theme with access to some university facilities and a consultant that they can contact. The main goals of NLT are to (1) increase the attractiveness of STEM study programs and (2) to show the connections between the individual science subjects. To achieve this, the examination programme focuses on four characteristics: interdisciplinarity, study and professional context, the interaction between technology and natural science and the relationship between mathematics and natural science. NLT is scheduled 2 hours per week from grade 10 to 12, being one of the STEM options students can select in their upper secondary school profile. As with O&O, teamwork is also important in the NLT context. In addition, NLT also has an individual component because students have to do tests as well. Asking the students what they think of the subject, O&O students appreciate the freedom and independence within the subject whereas NLT students appreciate the structure and depth of NLT [5]. The subjects intend to offer attractive interactive STEM education at school and simultaneously intent to increase the students interest in technique. How to explain study choice effects, if any, is complex. In literature we found among others contribution to attitude change and increasing motivation. For example, Vossen et al. [6] found that O&O students had more positive attitude towards doing research and design activities than regular students and appeared to find doing design activities more enjoyable than doing research activities. Kolmos et al. [7] found that intrinsic motivation is one of the most dominant factors to attract more engineering students. Their study concerned personal experiences and feelings in relation to engineering related activities. Furthermore, Dutch (Technical) Universities act as partners in networks with secondary schools, e.g. by supporting O&O students in their final assignments, by developing NLT modules on frontier STEM subjects and via teacher training programs.

1.3 Female students

An additional goal of the innovations at secondary schools is to raise the number of female students choosing science and engineering career paths. In western countries it is well known that girls no longer lag behind boys when it comes to educational achievements [1]. In the Netherlands, girls attain on average a higher educational level

at the end of their school career than boys even in STEM related courses if chosen. However, in general they still do not opt that much for STEM related bachelor programs in higher education. In order to increase the STEM related workforce, we need the female students as well.

The practical experience and hands-on exercises with real-life examples in the O&O and NLT courses is very promising to change the attitude and motivation of female students as is also mentioned in the Microsoft study [8] as second and fourth important driver to sustain girls interest in STEM. Additionally, bringing girls into contact with female role models, preferably from the very young age, has proven to be effective in getting them interested in technique [9].

1.4 Research questions

Considering the promising STEM related aspects of the O&O and NLT subjects for both male and female learners, we expect higher influx numbers for STEM related studies at Dutch universities. We expect higher numbers in engineering studies for O&O students and higher numbers in science related studies for NLT students. Additionally, the courses have been offered for quite a number of years. Over the years they have been improved and adapted where necessary, giving them a permanent place in Dutch education though not at all Dutch schools. This offers us the opportunity to see variations in what studies are chosen by students from the different school types over a ten year period.

The research questions in this study are:

- (1) Do O&O students opt for science and engineering studies more often than regular students? (sub-question: Do more female student select science and engineering studies?)
- (2) Do NLT students opt for science and engineering studies more often than regular students? (sub-question: Do more female students select science and engineering studies?)
- (3) What are the differences (if any) between the study choice in terms of sector of interest of O&O students compared to NLT students?
- (4) Have there been any changes in the study choice in terms of program choice of both O&O and NLT students in the last ten years?

2 METHODOLOGY

2.1 Data source

A large national dataset was obtained as a pivot table in Excel from Platform Talent for Technology². The Platform has built up a knowledge base with anonymous data from DUO

² Dutch National Agency for STEM-education and Labourmarket (former STEM-Platform)

(Dienst Uitvoering Onderwijs). DUO is a Dutch governmental organization that collects data on all publicly funded education in the Netherlands. Privacy considerations are taken into account and outcomes can not be traced back to individuals.

2.2 Data analysis

We consider the full cohorts 2010 to 2019 of pre-university students (VWO). The year designation means that the diploma was obtained in that year. Most students (90%) start immediately after graduating from their secondary school, 9% one year later and 1% two or more years later. In the Dutch schoolsystem O&O and NLT courses are also offered at senior general secondary education (HAVO) that prepares students for universities of applied sciences. The VWO level prepares for academic studies at technical and other research-oriented universities. In this study we only look at the transition from VWO to academic bachelor programs.

At the upper secondary school level students choose a profile. In our study, we zoom in on those students with Nature & Technology (NT) or Nature & Health (NG) profile, discarding students from other (non-STEM linked) profiles. Some Technasium schools also offer NLT. Checking the number of students who had both O&O and NLT (0,4% of all O&O students), we concluded that this will have no influence on the trends.

To distinguish between science and engineering related programs we use the sector classification used by DUO. The sectors of interest (based on highest number of enrolment) are: *Technique, Nature, Healthcare* and *Behaviour & Society*. The remaining sectors are indicated as *Other* (Economics, Agriculture, Education, Law, Language&Culture, Cross-sectoral). Because our dataset is based on population data, we are using Chi Square tests to look at differences in expectations and observations.

3 RESULTS

3.1 Population numerical data

The number of students in our study is shown in table 1. The high percentage of students with an N-profile within the O&O or NLT group is because these courses are developed for the N-profile.

Table 1. General numbers and percentages population (total cohorts 2010-2019)

Group	Students		N-Profiles	
	Number	Percentage	number	% of group total
Full population	331.602		187.898	57% of full population
Female	176.607	53% of full population	92.241	52% of Female
All O&O	4.936	1,5% of full population	4.896	99,2% of all O&O
Female O&O	1.689	34% of all O&O students	1.668	

				98,8% of Female O&O
All NLT Female NLT	27.397 12.184	8% of full population 44% of all NLT students	27.353 12.164	99,8% of all NLT 99,8% of Female NLT

3.2 Transition to university: distribution across program sectors

85% of VWO students opt for a university program. Other students opt for universities of applied sciences or do not enrol at any (funded) educational institution in the succeeding year. In figure 1 the study choice of O&O and NLT students for a university is compared to all students where the programs are categorized into sectors.

Both O&O and NLT students opt significantly ($p < .001$) more often for *Technique* programs compared to all students. The difference is the largest for O&O students. NLT students opt slightly more often for *Nature* oriented programs than all students. The percentage of O&O students that opt for *Nature* programs is less compared to all students. Looking at the female students we see a similar pattern, though the sum of *Technique* and *Nature* is lower than that of the average of the whole O&O group, with big gains for the healthcare sector enrolling large numbers of female students.

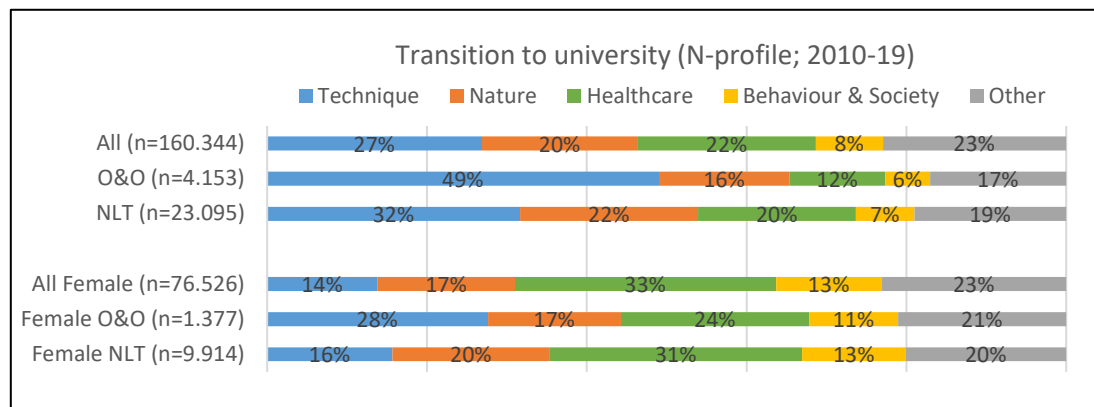


Fig. 1. Transition to university of O&O and NLT students compared to all students per program sector.

Zooming in on both female O&O and NLT students by making a long term overview, we see in figure 2 a jump to a significantly ($p < .001$) higher average percentage of female O&O students opting for *Technique* in the 2014-19 period compared to the beginning years 2010-13. A simultaneous drop can be seen for *Healthcare* programs, see also table 2.

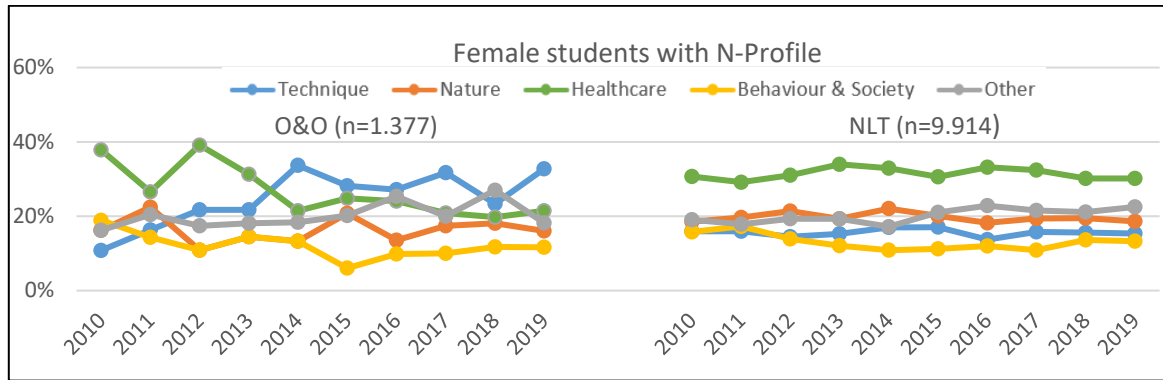


Fig. 2. Transition to university of O&O and NLT students compared to all students per program sector.

Table 2. Sector choice Female O&O students with N-profile: Difference in average percentage periodes 2010-13 and 2014-2019

Sector	Average 2010-13	Average 2014-19	Difference
Technique	18%	29%	+11%
Healthcare	34%	22%	-12%

For the female NLT students, we did not find any change at all over the whole period with a Technique preference at 16% (stdev=1,0%) and Healthcare average at 31% (stdev=1,6%). Healthcare programs are most favourite followed by Nature related programs at 20% (stdev=1,2%). The question is what's going on among the female O&O students, are many of them dropping healthcare in favour of engineering programs? In our previous study [2] we assumed that O&O girls mainly opt for medicine, therefore an interesting question is what happened since 2014?

3.3 Study choice female O&O students

Figure 3 shows the top three studies of female O&O students within the sectors Technique and Healthcare where respectively industrial design and medicine as the most favourite ones. Comparing the enrolment over time with the Technique and Healthcare line in figure 2, we see a similar pattern. The number of female O&O students opting for industrial design increases whereas the number opting for medicine decreases, making a change in preferences as likely explanation.

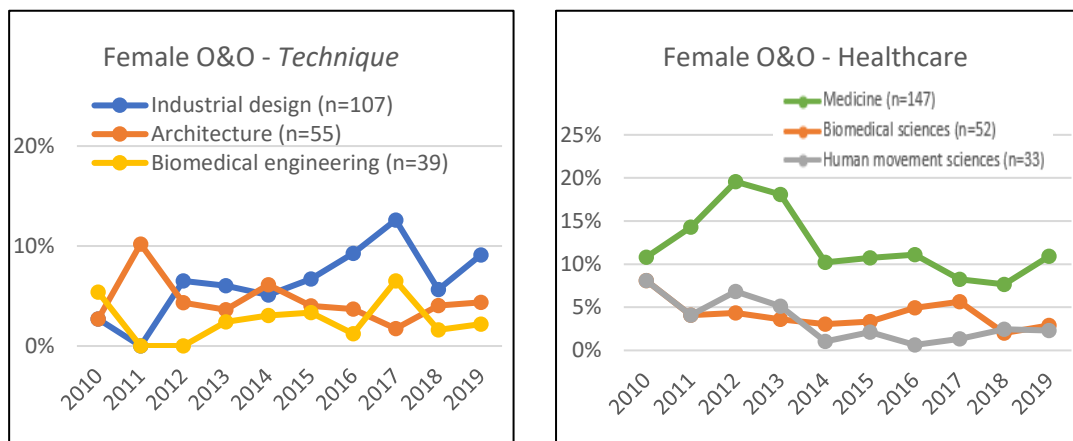


Fig. 3. Top 3 study choice within sector Technique and Healthcare for female O&O with N-profile.

As an underlying explanation we looked into regional variations. Technasium schools and nearby universities collaborate on many aspects including, orientation visits, facilitation of the final assignments of O&O students, parents might work there, and finally many school students, both male and female, will have a first look at the study programs at a nearby university. The variation in female students opting for technique programs turns out to be substantial with the lowest score in the northern part of the Netherlands (17%) with the University of Groningen nearby, as compared to regions near one of the Technical Universities: schools near the University of Twente (28%), near Technical University of Delft (29%) and in the proximity of the Technical University of Eindhoven (41%). This underlying explanation linked to the regional educational ecosystem turns out to be a good candidate to explain the jump in female students we found since 2014, as many schools in high scoring regions (such as near Delft and Eindhoven) started their Technasium profile around 2007-2008, delivering their final year students from 2014 onwards.

4 CONCLUSIONS AND DISCUSSION

Based on full cohort data over a period of ten years we showed in this paper that the STEM related aspects of the O&O and NLT subjects both lead to higher influx in STEM related studies at Dutch universities. O&O students as well as NLT students opt for science and engineering studies more often than regular students, where we see a strong shift to *Scientific Engineering* related programs for O&O students. NLT students choose slightly more often *Nature* oriented programs. Female students show the same pattern, which means that in particular O&O at schools encourages girls to more often opt for scientific engineering programs. Furthermore, O&O starts at an earlier age compared to NLT allowing for a bigger influence on study choice, for example by building self-efficacy and confidence [6].

However, one jump in numbers does not fulfill our aim to have a more balanced gender representation in science and engineering programs in the Netherlands. The 31% female students in the Netherlands choosing such programs is still way behind the 61% of male students doing so. The same pattern can be found for students with NLT as an exam subject, 35% vs 68%, and for O&O with 44% vs 76%. We do however see that introducing STEM subjects properly can help make a difference. A more qualitative analysis of O&O project characteristics and educational practise will help us to improve our understanding of the differences among schools, while highlighting what they can do to further interest, attitude and motivation related to STEM study programs and career opportunities [7], with particular interest into the gender aspects as the growth potential is high among female students [9]. A further study about the higher percentage of female students choosing NLT than O&O (44% vs 34%, see Table 1) is worthwhile. Explanations might be sought in the admissibility and/or in the content offered. If NLT is offered at a school, all regular students with an N-profile can choose it. For O&O you have to do the Technasium stream from the 7th grade with a midterm decision at the end of the 9th grade whether to continue in the upper classes. We might loose some of the girls here. Analysing the content, overall NLT leans more towards science while O&O relates to engineering more than to science. Besides the mainly quantitative approach in this study, limitations in our study are the small numbers of O&O students in the early years, and the fact that there will be some self-selection of technique oriented children and/or parents selecting a Technasium school with O&O on offer. Looking at the future, the regional variations can be analysed in more detail with a combination of quantitative and qualitative methods that jointly will help test more detailed explanations.

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