Use the Web to Close the Mathematics Gap

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Abstract. In the Netherlands, a severe gap is felt between secondary and higher education when it comes to mathematics. For several years, a dispute is raging about causes and remedies. The gap in the mathematics transition was even a central topic in a parliamentary investigation into the problematic outcomes of educational innovations. In the meantime, a country-wide initiative was deployed to close the gap, especially focusing on the shortcomings in algebraic skills (http://www.nkbv.nl). It brings together a broad range of mathematics materials in a web-based repository. Good practices of remedial courses are shared. Teams of teachers from secondary and higher education develop algebraic skills tests, that are positioned as a benchmark for algebraic skills. Interactive versions of the tests of publicly are available for practicing and for communicating the expectations about content and level.

1 The Mathematics Problem in the Netherlands

Around 2000, in the Lisbon Agenda, the European Community has set a goal of 50% participation in higher education. The number of laureates counts, so apart from an increase in the influx, the study success is important, including the reduction of dropout rates and of study delay. Tartly enough, at this time a gap developed between secondary and higher education concerning mathematics. The success rates were under pressure. For instance, in 2004 at the chemistry department of the University of Amsterdam, the success rate of Calculus 1 dropped from 80% to 45%. In that year, the decline for the mathematics and physics departments was less pronounced, but still about 13%. Study delay increased. While in 2003 for Calculus 1 a single reexamination was sufficient, in 2006 five reexaminations were organized to give the students ample opportunity to pass.

The problem is not limited to the exact sciences, also the technical and economics disciplines suffer from the decrease in algebraic skills. Meanwhile, not only the transition from secondary to higher education deserves attention, the influx from vocational education to higher education, and also the step from professional higher education to an academic master turn out to be problematic.

Where do these problems come from? At the end of the previous century, large scale innovations have changed secondary education in the Netherlands. These educational innovations turned out to have a considerable negative side-effect on the level of algebraic skills.


Fig. 1. Success rates at first mathematics course

<table>
<thead>
<tr>
<th>Study program</th>
<th>cohort</th>
<th># of students</th>
<th>Success rate 1st Math Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groningen, sciences</td>
<td>2007</td>
<td>159</td>
<td>25%</td>
</tr>
<tr>
<td>Utrecht, chem</td>
<td>2006</td>
<td>83</td>
<td>25%</td>
</tr>
<tr>
<td>Maastricht, business</td>
<td>2006</td>
<td>1030</td>
<td>47%</td>
</tr>
<tr>
<td>Delft, electr</td>
<td>2007</td>
<td>354</td>
<td>37%</td>
</tr>
<tr>
<td>Fontys, polytechnics</td>
<td>2007</td>
<td>48</td>
<td>40%</td>
</tr>
<tr>
<td>Utrecht, econ</td>
<td>2007</td>
<td>262</td>
<td>38%</td>
</tr>
</tbody>
</table>

1.1 Educational Innovations

In 2007/2008 the Dutch Parliament organized an investigation into educational innovations [1]. The reason to organize the investigation was a serious concern in society about the results of education. Such a parliamentary investigation is an important political instrument in the Netherlands, for which the parliament may opt independently of the government. Members of parliament form the committee, hearings are held with responsible politicians and experts that take an oath. The main conclusion was that the Dutch government seriously neglected the main task of ensuring proper education.

In the investigation four educational innovations were addressed, here we discuss three of them in more detail: (1) the so-called “profiling” of the curriculum, the (2) the non-differentiated first three year of secondary education, the so called “basis formation” (in Dutch “basisvorming”), and (3) a pedagogic approach, called ”new learning”.

Up to 1999, each secondary school student from age 15 to 18 had freedom to choose subjects, within certain boundaries. To ameliorate the transition to higher education, four ”profiles” were developed that consist of coherent packages of subjects that should prepare for higher education. These profiles are Culture & Society, Culture & Economy, Nature & Health and Nature & Technology. Representatives from secondary and higher education participated in the development of the profiles and the new subject contents.

The “basisvorming”, literally the “basis formation”, refers to the first three years of secondary education. In the old situation, children had to choose at the age of 12 the school type, which led to an early selection. To fully understand the concept, it is good to know that for decades the social-democratic party in the Netherlands promoted the idea of a ”mid school” (“middenschool”) to stimulate equality and to postpone the moment of selection. This idea was stuck in the political arena. However, an advice of the Scientific Council led to a political consensus in which the existing formal school structure was preserved. A distinction of two levels was proposed and concrete attainment targets were replaced by broader primary goals.

The idea of ”new learning” was developed in the time frame of the nineties with an almost limitless belief in the opportunities that Internet would create. The characteristics of new learning are
– An activating learning environment with attention paid to independent learning;
– Meaningful and authentic contexts;
– Cooperation between learners;
– Different role for the teacher (less knowledge transfer, more coaching).

This innovation was different from the other innovations by the government. It was not installed by law like the others. Government started a project that in a pro-active role stimulated new learning at the same time as the introduction of the profiles.

1.2 Findings of the parliamentary investigation

The investigation committee was quite critical in their final report [1]. The effects of the ”basis formation”, the approach of first three years of the secondary education were found to be limited. There was no direct evidence that the moment of choosing by students was at a later age. The committee found a lack of scientific evidence of the ”new learning” approach. The opinion about this semi-official innovation was that it was quite risky. In addition the base conditions like support of teachers and coaching of students were not met and the differences in content and learning style were not sufficiently taken into account. The effects of the profiling system were disturbing. The main goal was the improvement of the transition to higher education. But the number of laureates diminished because switching between the school levels became more difficult. Fewer students opted for scientific and technical disciplines, and this effect was especially noteworthy among female students.

In the analysis of these effects, the committee notes that the main reasons for changing secondary education, i.e. more equality in society and lowering dropout rates in higher education were lying outside of secondary education itself. Although it may be legitimate, there is a clear danger that the innovation will not reach its goals because of a lack of support within secondary education. Moreover, during the innovations, the responsibilities of government and the schools became confused. Government interfered with pedagogy, and quality insurance was too much left over to the schools.

1.3 The impact on mathematics education, especially algebraic skills

All three educational innovations had a negative impact on the level of algebraic skills of the students starting with higher education. The introduction of the ”basis formation” led to a less pronounced learning results. Especially for the better students preparing for higher education, the mathematical fundament became weaker. The just installed committee for a new mathematics curriculum, criticized the ”basis formation” in this way [2].

The new learning concept had a strong influence on the teaching practice. Typically, mathematics lessons consisted of say 30% explanation, and 70% doing exercises with the teacher assisting. With the ”new learning” approach, the
number of contact hours diminished and students were expected to do more self-study. In the case of mathematics, typically exercises would be done in the self-study hours, without a mathematics teacher to support.

Regarding the choice for one of the profiles, only a small number of students chose the profile Nature & Technology. Higher education in science and technology felt threatened and started to allow also students with profile Nature & Health. So, one of the possible merits, a thorough preparation for technology disciplines, evaporated at the very beginning of this innovation. Moreover, the students and schools complained about an overburdened program. Indeed, motivated by the idea of writing for the right selection of students, the developers had broadened the scope and the depth of the curriculum in all disciplines. Unfortunately, time constraints prevented to find a balance between the disciplines that formed a profile. So this resulted in an study overload for the students.

The complaints reached the political platform soon. In 2006, an amendment was proposed by the minister that yielded less hours available for many disciplines, among which mathematics. Now many scientists and teachers complained about these proposed measures. Even larger impact had a student movement called “Lieve Maria” (Dear Maria). This name refers to the opening of a letter of a made-up student to the Dutch minister of Education, Maria van der Hoeven. In this letter [3], students mention the problems that they encounter with algebraic skills when arriving at the university. As a result, algebraic skills were on the political agenda. For mathematics the reduction of hours was somewhat diminished. Moreover, a Resonance group with established mathematics lecturers in higher education as members was installed by the Dutch Ministry of Education to follow closely the plans of the new curriculum committee for mathematics in the secondary school, especially with regard to algebraic skills.

The resonance group recommended three aspects [4]. (1) A continuous development of mathematics ability needs to be reestablished through all levels of the mathematics education. Mathematics education has become fragmented. A continuous line of development of mathematical ability is missing. (2) Reconsideration of the role of the context in the mathematics education. Since two decades, following the ideas of Hans Freudenthal, mathematics education was reformed by introducing contexts for all topics. These contexts helped to motivate students and to connect mathematics to its surroundings. However, the resonance group pointed out that in higher education the context to do mathematics was the discipline itself, like economics, and not a per exercise constructed situation. Moreover, abstract mathematics was missing to a large extent. (3) Reduction of the use of tools, in mathematics teaching and during the final central examination. Another mathematics education innovation of the nineties that the resonance group mentioned, is the introduction of the graphical calculator. In the spirit of bringing more ICT to the classroom, the graphical calculator replaced the standard calculator and brought quite some functionality to the student, such as graphing and tabulating functions, finding zeroes, etc. In practice, the students used this tool to a much higher extent than expected. Both the strong
focus on contexts and the use of the graphical calculator bore a negative impact on the level of algebraic skills.

In summary, we see that Dutch mathematics education faced five educational innovations, three generic innovations and two specific for mathematics education. All these innovations had specific goals that were met in most cases, but had a negative overall effect on algebraic skills. It is hard to discern which effect is due to which innovation, as the effects were all in the same time frame.

Also the Dutch Council of Education (Onderwijsraad), has looked into the matters of transition from secondary to higher education [6]. They find that especially the disciplines of Dutch, English and Mathematics suffer from problems. Their report contains the advice to let secondary and higher education together develop arrangements about the entrance level. This arrangement should yield a series of tests that students may access via Internet to check their level.

After the recommendations of the resonance group, the debate went on. In particular, in a petition *Stop Deforestation Mathematics Education* [5], it was pointed out that the balance was now too much in favor of the algebraic skills, which would damage the image of mathematics and also the transition to higher education. Finally, the Ministry of Education reached agreement with the new mathematics curriculum committee for mathematics about a clear presence of the development of algebraic skills. However, after acceptance of the new curriculum it will take six more years before students will enter higher education that have followed this curriculum.

### 2 A country-wide initiative

In the Netherlands, the SURF Foundation represents the higher educational institutions regarding ICT matters. In particular, it coordinates the distribution of government funding of ICT related projects in higher education. In 2006, in view of the Lisbon agenda, SURF started a National Action Program E-learning to stimulate projects that contribute to the goal of 50% participation in higher education.

Thirteen higher educational institutions that were struggling with the mathematics skills of the new students, were gathered in a special interest group SIGMA (www.sigma.nl). From there, they started a project *Nationale Kennisbank Basisvaardigheden Wiskunde* (National Knowledge Bank Basic Skills Mathematics) in this framework of SURF to share experiences and materials. The first projects were allowed only a limited life time of one year, but a successor project NKBW2 was started in 2008 that runs into 2010. The consortium was reinforced with participants from secondary education.

The idea was to meet the gap between secondary and higher education with

- Remedial education to bridge the gap for the student;
- Activities to close the gap.
2.1 Repository

Remedial education is characterized by a large heterogeneity among the new students. It would certainly benefit from a small teacher to student ratio, but typically there is no structural money to cope with transitional problems. Therefore, the use of ICT can worthwhile since it gives students 24h access to the materials, and possibilities for customization, for automatic feedback. Especially for mathematics, possibilities arise such as generating tests, programming feedback, adaptive tests, etc. A good solution is to be found in the development of a repository for learning materials for algebraic skills. In the project NKBW a start has been made with the repository Wizmo (www.wizmo.nl) that brings together many of the materials for the previous projects. It offers open access to teachers on the basis of the creative commons license. To every learning object, metadata are attached according to the LOM-standard and an extension of the Living Math taxonomy.

Among other objects, Wizmo contains learning objects from

- the MathMatch-project containing Maple TA question banks for algebraic skills;
- the Digital Mathematics Environment, developed by the Freudenthal Institute of Utrecht University;
- The project Wortel TU/e of the Technical University of Eindhoven;
- A selection of FAQ-questions from the site WisFaq, developed by Willem van Ravenstein.

2.2 Algebraic skills tests as benchmark

To help to close the gap, it is important that at this moment there is a distinction between what secondary education sees as a reasonable endpoint of the algebraic skills, and what higher education sees as a reasonable starting point. This distance becomes especially clear when the various entrance tests of higher education is compared with the recently published exit test secondary education [7]. Part of the distance can be explained by use of unknown mathematical language or by uncommon use of variables, but there remains a difference in contents and complexity. In the project NKBW a team of teachers from secondary and higher education develop algebraic skills tests, that are positioned as a kind of calibration point for the transition. An example of such a test can be found at [9].

These algebraic skills tests are tried out at secondary education schools and at the higher education institutes to collect student results and reactions of teachers at both sides of the transition. By means of the repository, interactive versions of the tests are made publicly available for practicing and for communicating the expectations about content and level. Once well-balanced tests are found, these are put forward to gain support from organizations like the association of mathematics teachers, the Dutch mathematics society, the mathematics examination committee, the committee for the new mathematics curriculum, etc.
These tests are not a replacement of the final examination for mathematics of secondary education. The tests are developed from the perspective of transition, so for instance "mathematics A" to economics, and "mathematics B" to sciences. Moreover, it concerns only a part of mathematics, i.e. the algebraic skills, for which it turned out that a fine-grained agreement is mandatory and that needs example tests to really express contents and complexity.

2.3 Transitional Remedial Education

From the participating higher education institutes, eighteen Bachelor programs participate in the NKBW project with their transitional remedial education courses. Disciplines vary from chemistry to polytechnics to economics.

The experiences in the first NKBW project indicate that investments in the transitional remedial education help to raise the study success of the first year of higher education [8]. Algebraic skills are very important for the first mathematics course. Typically, this course is important for the first year, not only because of its own credit points, but also because it supports disciplinary courses. In the project, a common goal is set to reach over two years a 10% decrease of study dropout and delay concerning the first mathematics course. So this directly influences the goals of the Lisbon agenda.

In the project,

- plans for these courses are shared and reviewed;
- materials are shared via the repository Wizmo;
- the algebraic skills tests are tried out;
- data are gathered for a baseline and effect measurement about student results and student and staff satisfaction;
- results are compared and evaluated.

The outcome will be several good practices of education for the transition in mathematics. Monitoring of the data is set-up to follow the trends and to search for effects of the various approaches. When the approach is successful, we will see a raise of the level of algebraic skills and a decline of dropout rates and study delay.

References