The use of Technology in Flemish Mathematics Education: Secondary versus Higher Education

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1 Introduction

In this paper we’ll give an overview of the use of ICT - Information and Communication Technology - in Flemish mathematics education. We’ll compare the results of three different polls; the results of secondary education versus higher education and the results of 2001 versus 2005. But first we will briefly describe our research and the origin of this subject.

The subject of our research is set within the field of mathematics education and the use of computer algebra systems in mathematics education. During the research we wanted to measure the influence of the use of ICT (especially the use of CAS) on the mathematical learning process of last year pupils. What was the reason for this research topic?

In Flemish secondary education pupils can choose between many different disciplines. We have four main options: general secondary education, professional secondary education, art secondary education and technical secondary education. Within those four main options, pupils can choose between different sections. One of the main characteristics of such a section is the number of mathematical lessons a week. In former years the students of the first year bachelor of engineering, bachelor of physics and bachelor of mathematics had followed a section with at least 8 mathematical lessons a week. Since 2001 the population is changing. More students with 6 or even 4 mathematical lessons a week start in the first year bachelor of engineering. As a consequence there is now a large diversity between our students. But there are some other problems as well. A lot of our students are not able to link the different courses of mathematics. They see every course (Mathematical Analysis, Geometry, Linear Algebra, etc.) as a different closed box. Instead they should think of mathematics as one large box! We also notice that the mathematical creativity and the problem solving skills of a large group of our students are decreasing. Of course, as a result of all this the passing rate in the first year bachelor of engineering is going down.

Of course we are looking for solutions and therefore we were wondering if an efficient and carefully considered use of CAS in the last year of general secondary education could
help to give the pupils of the 6 hour sections a better preparation. There was only one way to find out if the use of CAS could positively influence the mathematical learning process of these pupils. We had to organize a teaching experiment. In Montral we presented the results of the first cycle of this teaching experiment. Between September 2004 and June 2005 there was a second cycle that confirmed our positive results of the first cycle.

2 Poll 2001: Secondary education

In this paper we will describe a side branch of this research. In the preliminary phase of the teaching experiment we tried to find out if the Flemish mathematics teachers of secondary education intensively used ICT in their mathematical lessons. We wanted to know if they preferred a graphical calculator or a computer algebra system, if they gave demonstrations or if the pupils were allowed to use the computer algebra system themselves, if the schools had a good infrastructure, if the pupils had to work in pairs, etc. With other words, we wanted to put together a survey of the use of ICT in Flemish mathematics education.

In May 2001 we prepared a questionnaire that contained a dozen open and closed questions. There were questions about the positive and negative experiences of the mathematics teachers, about the infrastructure provided by the schools, about the frequency of the use of ICT and about the influence of the use of ICT on the mathematical learning process of the pupils. We sent this questionnaire with e-mail to 'every' Flemish secondary school. We were able to reach over 600 schools.

254 teachers returned a completed questionnaire. These forms contained the information we were looking for.

Some results:

- In 2001 87% of the Flemish mathematics teachers already used ICT. 4% used a graphic calculator, 49% a computer algebra system on a pc or mathematical software and 34% used both.

- The graphic calculator turned out to be very popular. Almost 38% of the Flemish mathematics teachers used such a calculator during their course and the majority of these teachers obliged their pupils to buy a graphic calculator. Most respondents had Cabri, Derive and/or Excel at theirs disposal.

- 25% of the respondents said that the infrastructure of school was not sufficient. The computer lab is often too small for large groups or occupied for other courses like informatics.

- The mathematics teachers motivated their use of ICT mainly with practical arguments; they preferred the use of a graphic calculator because it’s a small instrument and the pupils can use it everywhere, or they preferred the use of a computer because the school had a large computer lab with fast computers or they didn’t use any ICT because there was no money, no infrastructure or no time.
• The teachers had no idea about the influence of ICT on the learning process of their pupils. They said that they hoped that the influence was positive. Some teachers said that the question came too early. They couldn’t answer yet.

• 83% of the teachers called themselves supporters of well-considered use of ICT. They stressed the word ‘well-considered’.

• There were large differences between our respondents with respect to frequency and method. Some teachers intensively used a computer algebra system during their lessons and other teachers only used it two or three times a year. Some teachers let the pupils work in pairs on a computer and other teachers mainly gave demonstrations.

• These differences were related to the age of the teacher. The ‘older’ generation of teachers (40+) was more enthusiastic about the use of ICT than the ‘younger’ generation. The implementation of ICT in their course was a new challenge. The ‘older’ teachers liked this challenge very much but the younger teachers had no time left for such a new challenge (first job, young children, etc.). The older teachers also complained that the young teachers - who had just completed their training - were not able to use ICT. These beginners were not or hardly prepared for the use of ICT in mathematics education!

• A last conclusion refers to higher education. The mathematics teachers of secondary education had the feeling that higher education was not following the same evolution with respect to the use of ICT.
  
  – Young teachers didn’t use ICT very often in their lessons because as a student they never used ICT in higher education.
  
  – The respondents also had the feeling that the use of ICT in higher education is arbitrary. Professor X allows his students to use a computer algebra system anytime and everywhere. While Professor Y even forbids the use of a scientific calculator in his course.

These remarks do not confirm our experiences. In the first year bachelor of engineering we intensively use Maple. Our students use Maple for the exercises and also for the exams. The use of a symbolic or graphic calculator is allowed during the lessons but not encouraged and forbidden during the exams. So, from our point of view the remarks of the mathematics teachers of secondary education were not correct. Of course, we can not generalize our experiences or the remarks of the teachers without an in-depth research. At the end of 2001 we tried to make a survey of the use of ICT in higher education. We used the websites of the high schools and universities and searched through their programs. This was not a very good method. The programs were often incomplete or out-of-date. We never completed this survey.
3 Poll 2005: Secondary education

Four years later, in June 2005, we had finished our teaching experiment and we were wondering how the implementation and the use of ICT in secondary education had evolved during the last four years. We decided to make a new online questionnaire and we sent by e-mail an invitation to the principals of all Flemish secondary schools and to their mathematics teachers.

382 teachers completed the questionnaire and now we can compare the results of 2001 with the recent data of 2005:

- 96% of the respondents use ICT in their course; 10% uses exclusively a graphic calculator, 36% uses a computer algebra system on a computer or mathematical software and 50% of the teachers use both systems. Only 5 respondents use symbolic calculators TI-89 or TI-92 in their lessons.

- The popularity of the graphic calculators has increased. 60% of the mathematics teachers use a graphic calculator intensively in their lessons and the majority of these teachers oblige their pupils to buy a graphic calculator. Mathematical software and computer algebra systems are also popular. Most respondents have Cabri, Derive and/or Excel at their disposal.

- The mathematics teachers still motivate their use of ICT mainly with practical arguments, but there are some other reasons as well:
  - The motivation of the pupils increases when they use ICT in mathematics education.
  - The use of ICT gives them the opportunity to use different points of view: graphic, algebraic and numeric.
  - Because of the visual aspects the pupils better understand and better remember the mathematical concepts.

- 90% of the teachers call themselves supporters of well-considered use of ICT. They still stress the word ‘well-considered’.

- There are still large differences between our respondents with respect to frequency and method.

- In 2005 we can’t make a distinction anymore between older and younger mathematics teachers. Almost every teacher uses ICT and even the young teachers who just finished their training are able to implement ICT in their mathematical lessons. The use of ICT is implemented in the training of young teachers.

- In 2005 the respondents still have the feeling that higher education is not following the same evolution as secondary education. One of the teachers wrote this remark:
"It would be a great improvement if students were allowed to use ICT in higher education. Until now students are not allowed to use a graphic calculator in a mathematics Olympiad or an entrance examination. Sometimes I have the feeling that I pay too much attention to use of ICT. (...) As long as my pupils perform well in higher education I won’t change my ICT approach."

In the poll of 2005 there were some new questions and as a result there are some new elements that we can’t compare to the results of 2001:

- Graphmatica is a popular alternative in secondary education. 39% of the respondents use this program and mainly because it’s for free and because their students can use it at home.
- 22% of the respondents use applets or online exercises. Even the mathematics teachers of professional secondary education are very enthusiastic about these new tools. Their pupils learn mathematics without effort and they even like it.
- The use of a CD-ROM, provided by the handbook, is a new phenomenon. Especially the teachers of the first grade (first and second year of secondary education) often use this CD-ROM.
- Half of the Flemish secondary schools have a virtual learning environment like Blackboard or Smartschool. 42% of the respondents use this environment for communication with the pupils and for sharing files. 17% uses this environment only for communication with the principal and with the other teachers.
- The infrastructure of the schools has changed. Most schools created multimedia rooms and new classrooms named open learning environments. These classrooms are the fusion of a normal classroom and a computer lab and they are mainly used for project work but mathematics teachers can reserve these classrooms as well.
- Although the infrastructure has changed teachers are not satisfied yet. 34% says that the infrastructure is not sufficient. The computer labs are often occupied, because the use of ICT became also popular in other courses. The teachers have to make their reservations a few weeks in advance and as a result they have a very strict schedule to follow.

In the poll of 2005 we also posed some questions about the use of ICT during tests and exams.

- 58% of the mathematics teachers allow their pupils to use a graphic calculator during tests and exams. But we noticed two different opinions. One group of teachers allows the use of a graphic calculator in every test and in every exam. Another group of teachers provides an exam in two parts: one part with and one part without a graphic calculator.
• 21% of the teachers organize sometimes a test or written exam in a computer lab or open learning environment. 86% of the respondents use a computer algebra system or mathematical software. So, there is a big difference between the use in the lessons and the use during tests and exams. There are several causes for this difference:
  
  – The teachers have organizational problems. There are too little computers in a computer lab for all pupils and other courses like accounting and informatics often have priority.
  
  – Not every pupil has a computer at home. So, according to some teachers, it wouldn’t be fare to give a test or exam with the use of a computer algebra system.
  
  – 86% of the respondents use a computer algebra system or mathematical software but there are big differences between the teachers. 13% of the respondents only used the computer for demonstrations and 46% used the computer only a few times a year. In this case the use of mathematical software on an exam is not justified.

4 Poll 2005: Higher education

Four years after our first poll we were still curious about the situation in higher education. We decided to use the same method as before: a poll. We designed a short online questionnaire with some closed questions. With the use of the websites of the different high schools and universities we collected the e-mail addresses of all lectors and professors of mathematics and statistics and courses related to mathematics and statistics. All these courses were on a program of a first year bachelor. We sent an invitation to all these lectors from 27 different schools and universities. We received 159 answers from 120 different lectors.

![Figure 1: The respondents](image)

In this figure we make a distinction between the courses of the respondents. There are
four categories: mathematics, statistics, a course called 'mathematics and statistics' and the category 'other'. In the category 'other' we find courses like physics and mechanics. The categories 'mathematics and statistics' and 'other' are rather small, so we’ll have to be careful with data of these categories.

4.1 The use of ICT tools during the lessons

Let’s first take a look at the data of higher education about the use of ICT during the course. Our question was: ”Do you stimulate the use of this tool during the course?”

<table>
<thead>
<tr>
<th>Tool</th>
<th>Scientific calculator</th>
<th>Graphic calculator</th>
<th>Computer</th>
<th>Applets</th>
<th>Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>High school</td>
<td>30%</td>
<td>27%</td>
<td>55%</td>
<td>25%</td>
<td>44%</td>
</tr>
<tr>
<td>University</td>
<td>20%</td>
<td>15%</td>
<td>53%</td>
<td>21%</td>
<td>38%</td>
</tr>
<tr>
<td>Total</td>
<td>26%</td>
<td>22%</td>
<td>54%</td>
<td>23%</td>
<td>45%</td>
</tr>
</tbody>
</table>

In the given table we see that there is actually a difference between high schools and universities. The use of ICT is more common in high schools (especially the use of scientific and graphic calculators) but the differences are rather small.

![Figure 2: The use of ICT during the course](image)

In Figure 2\(^1\) we compare the use of the different tools in the courses of the categories 'mathematics', 'statistics' and 'others'. There are some obvious differences: in statistics the lectors stimulate the use of a scientific calculator and as compensation we notice less use of software in statistics. We can also see that the use of applets is less popular in mathematics than in statistics, physics and mechanics.

\(^1\)SC = Scientific Calculator, GC = Graphic Calculator
4.2 The use of ICT tools during the exams

In the first year bachelor of engineering of our university the use of Maple is stimulated and the use of a scientific, graphic or symbolic calculator is allowed but not stimulated. The use of these calculators is even forbidden during the exams! How is the situation in the other universities and high schools?

![Figure 3: The use of ICT during the exams](image)

In Figure 3 we can see that several lectors and professors allow the use of a scientific or graphic calculator during the exam although they haven’t stimulated this use and although they haven’t taught their students how to use efficiently such a calculator! Does this mean that the students who have used a graphic calculator during their secondary education are better prepared for the exam? Or does this mean that a graphic calculator is probably not useful during these exams?

The use of a computer during the exams shows a lot of similarities with the use in secondary education. A lot of the respondents stimulate the use of a computer algebra system or mathematical software during their course but the students are not allowed to use these tools during the exam. The fact that the students are not allowed to use a computer during the exams is often caused by organizational problems.

When we take a look at the different courses (Figure 4) we notice the same characteristics as in Figure 3.

4.3 Conclusions

What are the results when we compare the answers of the respondents of higher education and the remarks of the mathematics teachers of secondary education? The answers of
the respondents tell us that professors and lectors do stimulate the use of ICT in higher education but the use is not as common as it is in secondary education. On the other hand we have to be careful with these results. Some lectors and professors sent us a few remarks after they completed the questionnaire. They brought to our attention the fact that the use of ICT in the first year bachelor is not necessarily similar to use of ICT in the other years of the bachelor or the master. In some courses of the first year bachelor the lectors and professors teach only 'basic' subjects without any tools. So we may not generalize these data. Some others lectors told me that they didn’t use ICT because they were not able to use it. There was no suitable infrastructure because mathematics was an unimportant course of the program. Some of these lectors even bought a portable computer and beamer themselves! Now they are able to give some demonstrations to their students.

In Flanders the integration of ICT in mathematics education is a slow and difficult process. But enthusiastic people in the field are working on it every day, trying to convince pupils, students and colleagues of the many benefits of an efficient use of ICT in mathematics education.

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