Using SCORM to monitor student performance: Experiences from secondary school practice

by

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Abstract

In recent years the mathematical community has been enriched with various computer programs that facilitate and improve the learning of mathematics. Although many practical and didactical problems still exist, computer aided learning has become a valuable addition to education. However, these successes also lead to high expectations of teachers and learners. For a teacher it would be nice if he or she could review after a computer aided lesson what the students actually did, what progress they made, which problems arose during learning and to which mathematical subjects attention must be paid in the next lessons. A teacher also wants to reuse ICT-components and to exchange learning materials with colleagues without many conversion problems. Learners expect that they can consult their earlier work and intelligent feedback on this work. Using the SCORM standard could make this possible. In this paper we discuss our experiences on a secondary school.

1 Introduction

Since December 2004 the GALOIS Project[1] aims to realize an integrated learning environment for mathematics in which:

- students can practice mathematics anytime and anywhere;
- mathematical assignments can be generated 'at random', so that the amount of exercise material becomes nearly infinitely large;
- activities and answers of students are stored; and,
- 'intelligent' feedback on students' work is given automatically.

We wish to reach these goals by using open source technologies and open standards. We try to translate and extend existing technologies into concepts that work in the practice of school mathematics. We also make ICT-rich learning materials and try them out in the classroom. In this paper we describe our experiences with the SCORM standard in exercise material at secondary school level. We discuss:

- the use of the 'Digitale Wiskunde Oefenomgeving' [Digital Mathematical Exercise Environment] developed at the Freudenthal Institute [1];
- the use of mathematical Java applets from the Freudenthal Institute, called WisWeb applets [2], in an existing virtual learning environment, in this case the open source system Moodle [3]; and,
- the integration of the custom-made JavaScript-based testing and assignment environment DITwis [4] in an existing VLE, in this case Moodle again.

We do not describe the SCORM standard in technical detail, but we restrict ourselves to a report of our experiences with actual use of the standard.

2 Towards an integrated learning environment for mathematics

In recent years the mathematical community has been enriched with various computer programs that facilitate and improve the learning of mathematics. New programs include digital chapters for existing books, many Java applets, dynamic software for geometry and statistics,

[1] GALOIS is a Dutch acronym for **G**eïntegreerde **A**lgebraïsche **L**eer**O**mgeving **I**n **S**chool [Integrated Algebraic Learning Environment in School]. The Dutch Ministry of Education, Culture and Science financially supports this innovation project in the Vooruit! framework. For more information we refer to the website www.galoisproject.nl.

and many more. Some software is incorporated into a full curriculum. Although many practical and didactical problems still exist, computer aided learning seems to be a valuable addition to education [5].

However, these successes also lead to expectations. For a teacher it would be nice if he or she could review after a computer aided lesson what the students actually did, what progress they made, which problems arose during learning and to which mathematical subjects attention must be paid in the next lessons. Also, if assignments are given outside of class, this mechanism of 'student tracking' would aid a teacher in determining student ability. An even more basic advantage would be the possibility of seeing whether a student has actually done his or her homework. At secondary school level – with students between 12 and 18 – this added bonus is often overlooked.

All this would enable teachers to use their actual 'contact time' more efficiently. On the other hand, students also benefit from monitoring student performance: a digital archive of computer based activities gives these activities a firm place in the curriculum and improves the learning process while it enables students to review mistakes made and stores feedback. This systematic approach within one learning environment enhances the already positive effects of direct, instantaneous feedback.

Many Virtual Learning Environments (VLE) store student work, and it seems that the use of VLE's in secondary education in the Netherlands is on the rise. Nonetheless, with these environments, schools still have to add their own educational tools and lecture notes. Reuse of ICT-components and exchange of learning materials with colleagues without conversion problems promotes this. One could even argue that a VLE only deserves its name when one can actually learn within the system, which implies that an integrated learning environment actually has content [5]. A logical next step in creating an integrated learning environment for mathematics is to see whether mathematics programs can communicate with standard VLE's to store user feedback and aid sharing of content. For this we use the SCORM standard.

3 Digital mathematical exercise environment

To be able to store results from mathematical Java applets developed in the WisWeb project [2] the Freudenthal Institute started with a facility called 'Digitale Wiskunde Oefenomgeving' (DWO) which translates to 'Digital Mathematical Exercise Environment'. In this web-based application a student logs in on a central server, works with an applet, and automatically receives feedback from this applet. Student results are stored so that students can stop working in the DWO and return later, without loosing any results. Teachers can monitor the progress of individual students, but also entire classes (Fig. 2 and 3 show examples).

At the secondary school St. Michael College in Zaandam, the Netherlands, the DWO was used in combination with written material, replacing two chapters on algebra, in the second grade (12 to 14 year olds). This first learning unit gives students a first acquaintance with mathematical expressions and above all the important mathematical concept of 'variable'. It also aims to instil some 'symbol sense' and the ability to rewrite mathematical formulas. One of the applets used is the applet 'Area Algebra' (Fig. 1). This applet is an interactive version of the well-known geometrical representation of the distributive law of algebra. A formula like 4(2+x) is treated as the area of a rectangle with length 4 and width 2+x. This results in a 'stepwise formula' with a part 4x and a part 8. Students intuitively learn and see that 4(2+x) is equivalent to 8+4x. Of course, this model has some limitations when it comes to negative numbers. This is why it can easily be replaced with a simple table.

Feedback in this applet is direct: green symbols indicate which part of the answer is correct, and red, orange and green circles around the assignment numbers indicate wrong, incomplete and correct answers.

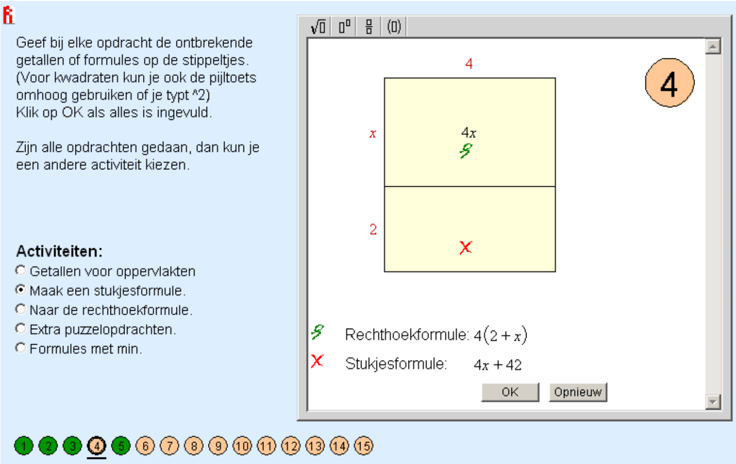

Fig 1 - 'Area Algebra' applet with immediate feedback

Not only can teachers quickly see which assignments a student has answered incorrectly, a teacher can also see the mistake in detail. Figure 1 gives an example. Perhaps this student was inattentive and forgot to fill in the appropriate value in the rectangle. It could also be that this student has an overly formal way of writing a product of two numbers. Just like one writes 4x for the expression '4 times x', this student could have written 42, where 4·2 ('four times two') was meant. It is up to the teacher to decide whether to review this mistake only with the particular student or to instruct all students about this common mistake.

Just the knowledge that most pupils do not have any problems with certain subjects is valuable information: the teacher can give more attention to the things pupils do not know instead of teaching about things students do know. Differentiation at this level takes into account the different levels of 'talent' for a certain subject. Furthermore it enables students to study at their own pace. Individual results from students from one class (Fig. 2) and from other classes (Fig. 3) help with tracking student performance at a global and a more detailed level.

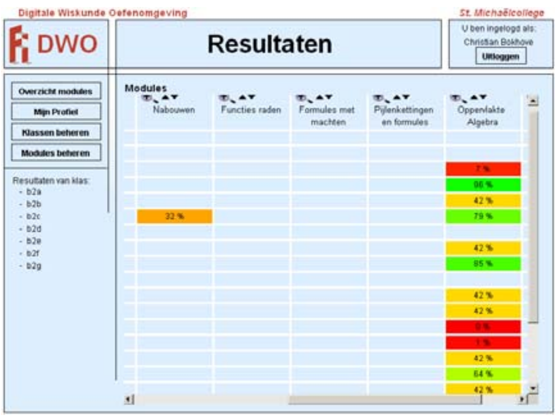

Fig 2 - Results of all students in a class

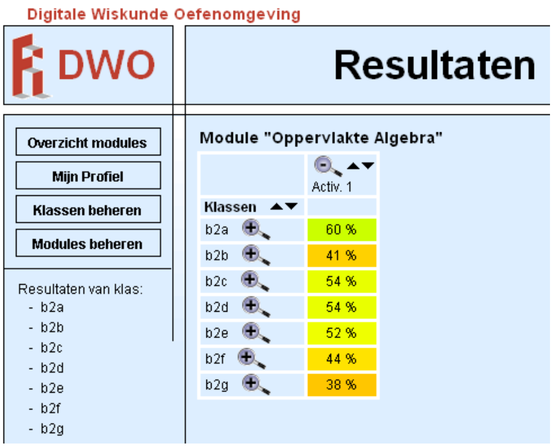

Fig 3 - Results of all classes

To correctly interpret these results, it is important to know that in this case teachers had given the students homework to make the first two parts of the applet, resulting in the highest attainable score of 42%. In this case five out of seven classes score higher than the expected percentage. Upon even closer inspection 25% of all students correctly made more than two thirds of all assignments, and 5% of all students even scored 100%.

In summary, use of the DWO helps the teacher to get good insight into the learning processes of pupils and to make grounded choices in the construction of his or her lessons. With the possibilities of such an interactive environment the age-old polarity between classroom and individual teaching has to be reconsidered. Teaching can shift from a classroom approach, with instruction and discussion, to a more individualistic approach with custom feedback. To students and teachers alike, the DWO is seen as a clear and intuitive environment with not too many options and features. Administration of the DWO is in the hands of an external organization (in this case the Freudenthal Institute) and teachers do not have to concern themselves with the technical side of things.

There also are some disadvantages. When a school already uses a VLE, it could be considered cumbersome that yet another environment is added to the already long list. Especially when more and more subjects start teaching with the aid of computers, the necessity of an integrated and uniform learning environment, becomes more and more apparent. In some cases it is preferable that administration of the system lies with the own organization (for example when one wants to indicate whether parts of a learning module belong to a basic or an advanced track). These pros and cons of the DWO were also mentioned during interviews with two teachers and two students. For one of the interviewed teachers the use of the DWO was a new experience, while the other had used an earlier version the year before. One student was a talented math student, while the other student was somewhat weaker and had other interests and ambitions. Below we summarize the pro’s and cons that were mentioned.

Practical problems, user wishes and other remarks (more from the teachers)

- The procedure that students have to enrol onto the DWO themselves causes some problems: some students unintentionally enrol into a wrong class and the regular teacher therefore cannot find their results. An experienced teacher solves this problem by booking a classroom with a data projector facility, and instructing students on how to enrol.
- When a student enrols for a second time, for example because he or she has lost his or her password, two identical names are listed. As a teacher it is not possible to distinguish between the two.

- When only part of the assignment has to be attempted, only closer inspection can reveal whether a student really has attempted the appropriate assignments or has scored on assignments not given as homework.
- It is not possible to quickly give feedback on the student results within the learning environment.
- Results cannot be printed or exported easily.
- With technical difficulties one depends on others, e.g., on the organization where the software is hosted.

However, the DWO is an application that is continuously improved in close co-operation with teachers and based on user feedback

Benefits of the DWO

With this tool teachers can effectively let students review certain mathematical subjects. The DWO quickly gives a clear overview of assignments to be made, but can also show whether student have actually done their work. One of the interviewed teachers puts it in words as follows:

> *"I see this as extra exercise material for students, without the need of a teacher to constantly look over the shoulder of a student. However, it is possible to monitor student performance, without having to grade written assignments.", "This way, the DWO is a powerful diagnostic tool."*

Students also find it an advantage that teacher scan see what and how they are doing; this enables them to ask better questions.

- Through this new mathematical learning environment digital 'drilling' is given a more prominent place in the mathematics curriculum. Not only do students seem to enjoy working with applets more, but also:
    - *"It is a welcome break from making assignments on paper.";*
    - *"If I understand everything, this program enables me to solve an equation directly.";*
    - *"I can use this tool at home whilst doing other things like using MSN and listening to my favourite music.";* and,
    - *"I can try until I answer the question correctly; the program tells me whether I'm right, half-right or wrong."*

  Students also seem to understand formulas better:
    - *"I can directly see what I have done wrong, often followed with a hint like 'we ask this but your answer was…'. This makes practicing easier and more fun.",*
    - *"It is quite enjoyable. I can use this program at home and I even learn something from it. So, it does help."*

  and subsequently students seem to feel better prepared for the exam:

    - "I can practise this just before a written exam. A few more assignments just to check whether I'm well prepared."

- It is also possible (with a WisWeb-plus subscription) to construct new assignments within a couple of Java applets. This feature aids a teacher in making custom made assignments for every school level within a given subject. To evaluate the performance of students it is also possible to give an exam within the DWO environment. A teacher makes a new module that can be accessed during a limited time span. In this module buttons for feedback and marking have been removed, so now a student has to do everything themself. A teacher does have access to the marking button to facilitate the marking of these assignments.

4 WisWeb applets in an existing virtual learning environment

To solve some practical problems with student enrolment, a logical next step would be to integrate the Wisweb-applets into an existing learning environment. There are a couple of requirements when aiming for this:

- An applet and the VLE have to be able to communicate with each other.
- It should be possible to share the content in various VLEs, for it could very well be that existing programs and learning environments change over the years.
- It should be possible to use this mechanism for other applets or programs.

The use of existing standards seems to be the best method to reach these goals, with a clear distinction between the role a VLE plays and the role the program -- in this case an applet -- plays. This distinction also means that suppliers of learning environments can operate independently from the suppliers of educational programs, but with the certainty that both work well together. A well-known and often used model is the Sharable Content Object Reference Model (SCORM [6]). It aims to integrate several specifications into one standard describing technical requirements for storing digital learning materials and the interaction between VLE and these materials. SCORM 2004 consists of seven different standards, including requirements:

- for metadata (What type of material? What is the target audience? Who has made this material? How can use this material? etc);
- for constructing SCORM packages;
- for navigation through the package; and,
- for “running” the package in a given VLE.

Many system suppliers already support the SCORM model, under whom Moodle [3] and Blackboard [7]. Within the Galois project we have adapted applets and test programs so that they would be SCORM compliant. We intend to use SCORM compliant packages in Moodle, but by using a standard we want to ensure that our results can be used in any SCORM compliant learning environment.

One of the applets we made SCORM compliant is an applet called ‘Herleiden’. This applet was used in a fourth grade class (16 year olds, O levels) to practise rewriting of given expressions and to reinforce symbol sense. Examples of given assignments concern expanding and rewriting expressions like: $(a+b)(b+c)-2ac$, $2-3(2a+2b)-2c+a-(a+2)$, and $(2x+y)^2-(2x-y)^2$ (see Fig. 4).

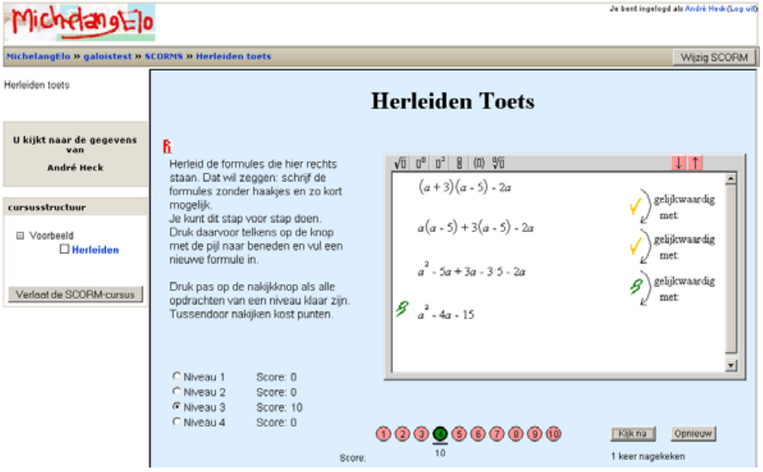

Fig 4 - Use of the WisWeb-applet 'Herleiden' in Moodle

Many students have problems with this type of assignments, despite the attention given to formula manipulation in the years before and the (apparent) successes. A common mistake in teaching and learning is: not only does one have to teach/learn a certain mathematical skill or ability, it also has to be maintained. In this case, rewriting formulas is essential when teaching on differentiation. When using the quotient rule students often are able to apply the rule, but they are not able to rewrite the obtained formula in such a way that it resembles the teacher's answer. Practice makes perfect, but in this case it would be helpful if students can practice a lot without giving the teacher an unnecessary extra workload. A web-based exercise program makes this possible. In our school situation, students can practice rewriting formulas during computer workshops at school as well as at home. Just like in the DWO, student scores and results are stored in the system, which enables a teacher to see whether students have a good command of this skill.

Within MichelangElo (the name St. Michaël College in Zaandam gave to their incarnation of Moodle) it is possible to check student results. Results can also be exported to text and Excel format. With slight modifications they can even be imported into existing school administration systems. When giving assignments, there naturally are students who do not do their homework. The low scores easily reveal this. Moodle's internal messenger can be used to address these students. Problems are also discovered easily, especially because 'the road to an answer' is also stored in the VLE. For example, some students still made the common mistake to rewrite $(2a+b)^2$ as $4a^2+b^2$. This misconception can be addressed in the next lesson by using the surface model to explain why this equivalence doesn't hold.

Whether students actually have more structural knowledge of rewriting formulas after digital practice, only time can tell. However, we noticed that students – at the difficult age of 16 – are highly motivated by this novel way of practising an otherwise difficult and boring subject. Applets are not only good tools for younger students, but they can be used at any level in school. The short-term effect of using the applets in the VLE is that students seem to get a better understanding of the structure of formulas and that teachers can monitor student performances and address common mistakes more easily. All this happens within a VLE that is already in use at a school and that both teachers and students are familiar with. It would be even better if an applet could be configured within the learning environment in such a way that custom assignments could be made. We will explore this possibility in the near future.

5 Intelligent feedback with DITwis

In the GALOIS project we also make use of the custom-made JavaScript-based testing and assignment environment [4]. This system responds to student answers by providing a (limited) form of intelligent feedback; Fig. 5 shows a typical example from one of the tests [8]. At first, DITwis was developed as an independent means to practice and test certain concepts without teacher's intervention. However, we thought it would be useful to see whether integration of DITwis into an existing VLE would be beneficial. Again we made this program SCORM compliant and used the system in a third grade (trigonometry) and a fourth grade (combinatorics and probability) class.

Question. With a certain product there is a chance of 25% that it doesn't function. A random sample of 12 products is drawn. Calculate the probability that **exactly** 4 products do not function. Round your answer to five decimal places.[2]

Envisioned replies and appropriate feedback

Reply	***Feedback***	***Explanation***
0.19358	*Correct!*	*The student has calculated the probability correctly.*
0.00239	*Have you read the question correctly? Note that 25% of all products do* ***not*** *function.*	*Apparently the student used 75% in stead of 25%.*
0,00039	*You have forgotten that several* ***combinations*** *are possible.*	*Students often forget to multiply a probability with the possible combinations.*
0,00124	*4 out of 12* ***not*** *functioning means 8 out of 12 products do function.*	*The student has used 0.75^4 (but did remember to use combinations)*
0,19357	*Close to the correct*	*Round-off error*

[2] The numbers used in the question text are randomly chosen and this is taken into account in the marking and the feedback.

	answer. *A **round-off** error?*	
Other	*Wrong answer; review the **section on probabilities**.*	*God knows what went wrong*

Fig 5 - Example of a DITwis question and the scheme for giving feedback to responses

The advantages of integration soon became apparent, as well as (hopefully temporarily) some disadvantages. Many of these findings overlap with the aforementioned ones, with an emphasis on: better insight in student work and problems that students face, technical difficulties sometimes resulting in information not being stored, the possibility of practising anytime, anywhere, and the added bonus in the communication facilities of a standard VLE.

6 Conclusion

Existing mathematical tools become even more powerful and useful when results and performance of students can be tracked online. Use of a common standard, in this case SCORM, enables the sharing of content, but also of storing student performance. Students know that they can be and are monitored by their teacher. Together with other features in virtual learning environments, especially for communication, students are stimulated to do their homework, or even more than that. Students do not seem to mind this ‘big brother is watching you’ concept. On the contrary, they seem to appreciate the fact that a teacher has good insight into common mistakes and can use this knowledge to address certain problems more effectively. They also seem to find that computer practice prepares them better for written exams than making assignments from a book. Computer aided learning is also seen as a more ‘fun’ way of practising otherwise boring subjects. Direct feedback adds to this appreciation as well as the fact that small mistakes can easily be corrected. Giving students hints and enabling a ‘trial and error’ approach makes it possible for students to explore different strategies for solving a given problem. This also poses a danger; this is why applets without these facilities have also been developed at the Freudenthal Institute.

In our opinion, digital assignments and diagnostic testing add to the motivation and performance of students in mathematics education. By making use of computers, the extra time involved for teachers is acceptable. Contact time can effectively be reorganised because students that need extra attention are signalled earlier. One of the success factors of the use of ICT would be that all teachers in an organization agree on the vision they have on mathematics education. Ideally, less experienced teachers would be supported by experienced teachers and experiences are shared alike to evaluate and improve the use of ICT in the classroom. From technological point of view, SCORM contributes to the realisation of meaningful ICT-rich education.

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