The relationship between gender and performance using a web based mathematics learning environment

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Abstract

There has already been research on the difference between boys and girls while working with web based learning environments for mathematics education. Although various researchers have found significant differences in attitude towards mathematics and computer use, suggesting that boys have a more positive attitude, results on the difference in achievement while working with a web based mathematics learning environment have indicated no clear cut difference between boys and girls. This study examines the different problems that boys and girls face while working with a web based mathematics learning environment and the ways in which they try to solve these problems.

It has long been known that there is a significant difference between genders when looking at attitude towards computers or achievement in computer based tasks (Nachmias, Mioduser & Shemla, 2001). Although this gender gap seems to be getting smaller, differences still remain (Imhof, Vollmeyer & Beierlein, 2006; van Boven, 2011; van de Gaer, de Munter & van Damme, 2004). Boys tend to use computers more often, especially for non-educational activities. The boys' attitude towards computer-related themes tends to be more positive. Boys score better on tasks involving computer-related activities and girls tend to be more anxious about computers than boys (Colley & Comber, 2003; Imhof et al., 2006; Kolovou, 2011; Nachmias et al., 2001; van Boven, 2011; van den Heuvel-Panhuizen & Vermeer, 1999).

Besides the higher self-efficacy concerning computer-related tasks that boys seem to have, there are some differences between boys and girls in type of activity when they are using a computer for purposes other than study (Imhof et al., 2006). Boys tend to play computer games more often than girls (Kim & Chang, 2010), giving them more experience with failure of a task and exploring the environment for finding a solution, when using a computer, since these are inherent aspects of most computer games. It can be expected that this makes boys generally more able and willing to cope with the problems they are facing or to explore the unknown, when using web based learning environments, while girls might be inclined to 'blame the computer' for the problems they face. Problem solving of an explorative nature can often be seen in web based learning environments for mathematics education. To successfully finish the process of instrumental genesis (Guin & Trouche, 1999), often an explorative phase is needed. The aforementioned difference between boys and girls therefore might predict that the learning effect of web based learning environments for mathematics education on boys are higher, since boys will more likely look for a mathematical solution to the problems they face, while girls might more easily be defeated by the problems for which they blame the computer. Furthermore research has shown that positive attitude towards mathematics and computer use has a beneficial effect on mathematics performance (Hyde et al., 1990).

Research involving various web based learning environments for mathematics education has already shown that positive effects on both mathematics performance and attitude towards mathematics can be gained from integrating ICT into mathematics classroom practice (Bokhove, 2011; Li & Ma, 2010). However, unlike the difference in attitude and computer use would suggest, there does not seem to been any clear-cut difference between boys and girls in mathematics performance when using a web based learning environment (Bokhove, 2011; Kolovou, 2011; Li & Ma, 2010). In order to create effective teaching strategies using web based learning environments that benefit both boys and girls, it is of great importance to understand the various underlying factors that play a part in the influence of ICT on mathematics performance and attitude towards mathematics, and how these factors might differ between boys and girls. To further understand the impact of ICT on mathematics learning and differences between boys and girls there is need for studies that look at both cognitive and affective domains (Li & Ma, 2010).

1. Theoretical framework

Instrumental genesis

Verillon and Rabardel (1995) make a distinction between *artefact* and *instrument*, when looking at technological tools. An artefact is the physical tool itself, a material object, while an instrument is a psychological construct, a relationship between the subject and the artefact. Only when the subject has developed efficient procedures and meaningful instrumentation schemes to manipulate the artefact (a process that Guin & Trouche (1999) call instrumental genesis), can the artefact become an instrument. After the process of instrumental genesis is completed, an instrument can be used in a cognitive learning process. Bokhove (2011) indicates that a certain amount of initial play with a technological tool can be beneficial, since it stimulates a student to build a meaningful relationship with the tool and therefore facilitates instrumental genesis.

As noted above boys tend to play computer games more often than girls (Kim & Chang, 2010), it should be expected that boys have more experience in the process of instrumental genesis, because most computer games have a unique user interface and require specific instrumentation schemes to use effectively. This higher amount of experience should enable boys to adapt to new technological tools faster, making the process of instrumental genesis more efficient.

Self-efficacy

Self-efficacy is defined as one's belief in one's ability to succeed in specific situations (Bandura, 1994). A student with high self-efficacy in a certain task is likely to put more effort in that task than a students with low self-efficacy (Schunk, 1990). In their meta-analysis of 114 studies Stajkovic & Luthans (1998) showed a clear relation between self-efficacy and educational achievement.

Role of gender

Several studies have indicated that gender is a major factor when looking at achievement and attitude towards mathematics and computer use (Colley & Comber, 2003; Imhof et al. 2006; Kolovou, 2011; Li & Ma, 2010; Nachmias et al., 2001; van den Heuvel-Panhuizen & Vermeer, 1999). Boys tend to have a more positive attitude towards computers than girls and use the computer on a more regular basis (Colley & Comber, 2003; Imhof et al. 2006; Kolovou, 2011; Nachmias et al., 2001). Research has also indicated that a positive attitude towards mathematics and computer use has a beneficial influence on mathematics performance when using technological learning tools (Bokhove & Drijvers, 2012; Hyde, Fennema, Ryan, Frost & Hopp, 1990; Nachmias et al., 2001), therefore predicting that boys will benefit more from web based learning environments for mathematics than girls.

Girls tend to score higher on tests involving algebra and arithmetic, while boys are better at geometry and mathematical reasoning (van de Gaer et al., 2004). Van de Gaer

et al. indicate that the gender difference in mathematical performance is not biological, meaning that there must be other (environmental) factors that play a part.
Girls comply with the rules more frequently than boys (van de Gaer et al., 2004) and are often more devoted to their schoolwork (Kolovou, 2011; van de Gaer et al., 2004), while boys more frequently display an anti-school attitude (van de Gaer et al, 2004). Girls tend to score better on tasks requiring the student to work precisely or involving a standard procedure (van den Heuvel-Panhuizen & Vermeer, 1999).

2. Aim and research questions

Recently the Dutch FIsme (Freudenthal Institute for science and mathematics education) has started an investigation focusing on the effects of a web based mathematics learning environment called DWO (*Digitale Wiskunde Omgeving*, which is Dutch for *Digital Mathematics Environment*) on the learning process of students in the second year of Dutch general and pre-university education (Kiewiet, Molendijk & den Ouden, 2011; van Boven, 2011), which are 13 to 14 year old students. This investigation focuses on the learning and retaining of skills in solving linear and quadratic equations. The FIsme has already collected data in thirteen schools throughout the Netherlands, looking at both achievement and attitude of students.

The DWO is a web based learning environment for mathematics, developed at the University of Utrecht by the FIsme, aiming mostly at Dutch secondary education. After creating an account, students can choose from a varied collection of mathematical activities to work on. By correctly solving exercises, students are able to score points, which are stored and can be viewed by a teacher, thereby simultaneously creating a motivational factor for the students and a monitoring tool for the teacher.
Bokhove & Drijvers (2010) conducted a research on the relevant criteria for the evaluation of digital tools for algebra education, in which they also looked at which tool meets these criteria best. They concluded that the DWO meets these criteria best, reporting that it is easy to use, stores the solution process of the student, offers several kinds of direct feedback (a feature that Li & Ma (2010) also indicate to be very effective) and enables a stepwise problem solving strategy.
Before any benefit can be gained from such features however, a student must first get acquainted with the digital tool. The appropriation of the tool ideally follows a process of *instrumental genesis*.

The aforementioned gender difference in attitude towards mathematics and computer use, together with the issue of instrumental genesis, suggests a better mathematics performance for boys compared to girls when using web based learning environments for mathematics. However, preceding research doesn't seem to indicate a clear-cut difference in mathematics performance when using digital tools. We will try to identify the underlying factors of this *gender issue*, paying extra attention to the ways in which students react to and solve the problems they encounter while using the DWO.
The primary aim of this research is to identify the underlying factors of the gender issue. Secondly we will try to contribute to the evaluation of the DWO, which was created by the FIsme in order to assist mathematics learning with respect to the algebra of solving linear and quadratic equations.
The following research question has been formulated:
What are the factors that influence the gender issue of students using web based mathematics learning environments?

To aid in the answering of this main research question, the following sub questions have been formulated:
1. Is there a difference between boys and girls in attitude towards mathematics and computer use?
2. Is there a difference between boys and girls in mathematics achievement when using the DWO?
3. Is there a difference between boys and girls in problems they encounter when using the DWO?
4. Is there a difference between boys and girls in strategies they use to overcome the problems they encounter when using the DWO?

3. Method

To answer the first two sub questions we will perform an analysis on a large set of quantitative data already collected by the FIsme in the frame of the ffDWO project[1]. In order to answer the last two sub questions however, we will need more qualitative data and we will therefore conduct a small-scale investigation.

Setting

In the light of investigating the effects of the DWO on the mathematics achievement of students, the FIsme has collected data from 13 different Dutch secondary schools. Half of the students participating in this investigation worked on two algebraic topics (i.e., solving linear equations and solving quadratic equations) using the normal Dutch curriculum (pen and paper work), while the experimental group worked on these two topics using the DWO. All students participating in this investigation were in the second year of Dutch general and pre-university education (about 13 to 14 year-olds). Data was collected using a pre-test consisting of exercises about linear functions, a post-test consisting of exercises about solving linear equations and a post-test consisting of exercises about solving quadratic equations. Each student received a grade between 0 (very bad) and 10 (excellent) for each of these tests. The students who worked with the DWO were also asked in advance to fill in a questionnaire concerning their attitude towards mathematics and computer use.
For the small-scale investigation we looked at two classes from a school for secondary education in a town in the centre of the Netherlands that are being taught by the author of this article. The students participating in this small-scale research (N=40) are from the second year of Dutch general and pre-university education (about 13 to 14 year-olds). All students worked with the DWO on the topic of solving linear equations.

Instruments

To measure students' attitude towards mathematics and computer use we used a questionnaire consisting of, in total, 43 items, of which 22 items were related to attitude towards mathematics and 21 items were related to attitude towards computer use (see appendix A). Each item contained a statement and asked the students to indicate their agreement with this statement on a Likert scale from 1 (total disagreement) to 5 (total agreement). This questionnaire was used in both the large-scale investigation as well as the small-scale investigation.
We used the answers of a total of 348 students from the dataset of the FIsme in a factor analysis, using SPSS, to determine the underlying factors of the questionnaire. In accordance with the Kaiser criterion (Kaiser & Caffrey, 1965), we let SPSS extract only the factors with an eigenvalue greater than 1. Then we used a scree plot to confirm that SPSS extracted a reasonable number of factors (Cattell, 1966).

[1] http://www.fisme.science.uu.nl/ffdwo/

Two factors were extracted from the questions on attitude towards mathematics. Looking at the questions that supported them, we named these factors: *Low self-efficacy in mathematics* and *Joy in mathematics*. Table 1 shows the eigenvalues of the items on the two factors (which can be seen as the extent to which an item accounts for that factor), with the meaningful values (greater than 0.4 or smaller than -0.4) in bolt.

Item	Eigenvalue	
	Low self-efficacy	*Joy*
I have no talent for mathematics	**.615**	-.170
I'm sick and tired of mathematics	.350	**-.748**
I can accomplish good results in mathematics	**-.641**	.260
Especially during mathematics I'm glad when class is over	.171	**-.754**
I think mathematics is fun	-.324	**.795**
With mathematics I'm more scared to make mistakes than in other classes	**.735**	.096
I have a lot of confidence concerning mathematics	**-.761**	.259
Without mathematics, school would be much more fun	.328	**-.697**
That I have to learn difficult subjects during mathematics doesn't worry me	**-.616**	.236
I would rather not have any mathematics classes at all	.384	**-.715**
I'm more anxious about mathematics than any other subject	**.784**	-.069
I sometimes make more homework for mathematics than was assigned	.103	**.408**
During mathematics class I frequently don't understand much	**.555**	**-.420**
I feel confident when I answer a teacher's question during mathematics class	**-.615**	.167
During mathematics class time passes quickly	-.164	**.698**
No matter how hard I study, mathematics stays difficult for me	**.783**	-.205
I enjoy solving a mathematics exercise on my own	-.020	**.597**
Our mathematics classes are often interesting	-.153	**.723**
I nearly always understand what is being taught during mathematics class	**-.674**	.232
The prospect of learning new things in mathematics makes me anxious	**.676**	-.077
Mathematics is a subject where my efforts are being rewarded	**-.480**	**.412**
Mathematics will not easily become one of my hobbies	.280	**-.648**

Table 1. Eigenvalues of the various mathematics related items of the questionnaire, corresponding to the two attitude factors, after applying Varimax rotation.

We tested the reliability of these factors by looking at Cronbach's alpha (a commonly used measure of reliability). We consider a scale of items reliable if Cronbach's alpha is greater than 0.7 (George & Mallery, 2003). The scale of items belonging to *Low self-efficacy in mathematics* has a Cronbach's alpha of 0.901, making it very reliable. The scale of items belonging to *Joy in mathematics* has a Cronbach's alpha of 0.895, also making it very reliable.

Five factors were extracted from the items on attitude towards computer use. Looking at the questions that supported them, we named these factors: *Joy in computer use*, *Self-efficacy in computer use*, *Computer anxiety*, *Problem solving with computers* and *Time spent using computers*. Table 2 shows the eigenvalues of the items on the five factors, again with the meaningful values in bolt.

Item	Eigenvalue				
	Joy	*Self-efficacy*	*Anxiety*	*Problem solving*	*Time*
I'm not skilled at using the computer	-.098	**-.734**	.249	.029	.021
When I've started on the computer, I find it difficult to stop	.119	.116	.077	.113	**.833**
I'm not the type to handle computers well	-.095	**-.733**	.217	.133	-.082
I have a lot of self-confidence concerning computers	.169	**.774**	-.251	.059	.094
I find working with computers fun and motivating	**.631**	.396	-.254	-.009	.169
The thought of using a computer disheartens me	-.254	-.193	**.701**	-.003	-.071
For me it's not an interesting challenge to work with computers	-.227	.104	.129	**.656**	.312
I don't understand that people can spend so much time on computers and even seem to enjoy it	-.183	-.010	**.420**	.397	**-.519**
I like to use computers for my school work	**.799**	.058	-.200	-.181	.069
I'd rather use the computer as little as possible	**-.563**	-.023	**.442**	.253	-.333
I feel comfortable when using a computer	.346	.245	**-.418**	-.047	.231
If there is a problem with the computer that I cannot immediately solve, I keep searching until I find a solution	.213	**.460**	.012	**-.407**	.183
I find solving computer problems interesting	-.031	**-.451**	-.101	**.660**	-.156
I learn more in classes where we use the computer	**.767**	.132	-.004	-.063	.003
I enjoy working with computers	**.641**	.284	-.338	-.181	.208
I'm not afraid of computers	-.046	.080	**-.511**	.117	-.073
With the computer school work gets more interesting	**.859**	.101	-.115	-.122	.094
Working with the computer makes me nervous	-.196	-.193	**.696**	.089	.026
I feel fine when I address a new problem on the computer	.396	**.532**	-.191	-.073	-.023
Using a computer is very difficult for me	-.067	-.318	**.644**	.201	-.042
The computer helps me to study more effectively	**.837**	.121	.018	.021	-.030

Table 2. Eigenvalues of the various computer use related items of the questionnaire, corresponding to the five attitude factors, after applying Varimax rotation.

Again, we tested the reliability of these factors by looking at Cronbach's alpha. The scale of items belonging to *Joy in computer use* has a Cronbach's alpha of 0.901. The scale of items belonging to *Self-efficacy in computer use* has a Cronbach's alpha of 0.777. The scale of items belonging to *Computer* anxiety has a Cronbach's alpha of 0.757. The scale of items belonging to *Problem solving with computers* has a Cronbach's alpha of 0.428 (by deleting items from this scale a Cronbach's alpha of at most 0.543 can be achieved). The scale of items belonging to *Time spent using computers* has a Cronbach's alpha of 0.340 (no items can be deleted from this scale, since it consists of only two items).
Considering these values for Cronbach's alpha it seems reasonable to take all mathematics attitude factors and only the first three computer use attitude factors (*Joy in computer use*, *Self-efficacy in computer use* and *Computer anxiety*) into account, since the other factors are too unreliable.

To measure mathematics achievement the large-scale investigation used a pre-test and two post-tests. All these tests were regular school exams, but unfortunately differed between schools in specifics. In all cases the subject of the pre-test was linear functions. The first post-test was about solving linear equations and was taken after the students had worked with the DWO on that topic. The second pre-test was about solving quadratic equations and was taken after the students had worked with the DWO on that topic.
For the small-scale investigation we only used a pre-test about linear functions and a post-test about solving linear equations, both being a regular school exam.

In order to get a better understanding of the factors contributing to the gender issue, we needed not only quantitative data, but felt a need for qualitative data. We were particularly interested in the kind of problems students encountered and the strategies that students used to solve these problems, believing these to be major factors in the gender issue. Hoping to get some more insight in the strategies involved in the problem solving of students working with the DWO, we videotaped a total of seven pairs of students during the small-scale investigation, while they were working with the DWO, asking them to 'think aloud' when solving problems. These sessions were about 40 minutes long and divided over three weeks time. The pairs of students were selected in such a way as to make them as homogenous as possible, in sense of gender, mathematics achievement and attitude towards mathematics and computer use, preferring students with low mathematics achievement and negative attitude, so as to maximize the chances of the students encountering problems while using the DWO. This yielded a total of four pairs of boys and three pairs of girls, who are described in more details in the results section of this article.

During the small-scale investigation, after the post-test on solving linear equations, the students were asked to fill in a questionnaire about the problems they encountered while using the DWO and the way they solved these problems (see appendix B). The questionnaire posed six different problems the students could have encountered while working with the DWO and asked the students to report how many times they had encountered these problems, what strategy they (most frequently) used to solve these problems and if this strategy had been successful. These six problems were selected from the various problems that the seven pairs of students encountered during the videotaped sessions, in such a way that three problems were mathematics-related and three were ICT-related. At the end of the questionnaire students were able to comment on the use of the DWO.

Data analysis
After having extracted a total of five attitude factors from the items of the questionnaire, we used the large dataset from the FIsme to compare the mean values of these factors between boys and girls. As Shapiro-Wilk tests of normality (Shapiro & Wilk, 1965) indicated that none of the factors were normally distributed, we used the non-parametric Mann-Whitney U tests (Mann & Whitney, 1947) to try to identify any significant differences in attitude between boys and girls, since other kinds of tests assume the analyzed data are normally distributed.

Next we looked for a difference in mathematics performance between boys and girls. We used the data from the FIsme of the pre-test and the two post-tests. For these tests, all students were given a grade ranging from 0 (very bad) to 10 (excellent). We looked at the average grades of boys and girls from both the DWO group and the control group.

In order to assess the difference between boys and girls in attitude towards mathematics and computer use from the small-scale investigation, we used the same method as with the large-scale investigation, namely comparing the mean values of the attitude factors using Mann-Whitney U tests.

To gain an image of the mathematics achievement in the small-scale investigation we used the average grades of boys and girls for the pre- and post-tests and compared these, like we did before with the large-scale investigation.

During the videotaped sessions of pairs of students working with the DWO we noticed two types of problems the students faced. The first type of problem is what we call an ICT-related problem (e.g., the student is not able to use the appropriate function of the DWO to denote fractions), indicating a problem in the process of instrumental genesis. The second type of problem is what we call a mathematics-related problem (e.g., the student is unsure of what is expected of them when they are asked to "solve the following equation"), indicating a problem in the process of mathematics learning. Since both types of problems refer to a different phase in the learning process and require different kinds of strategies to solve, we distinguished between these two types.
Not only the problems that students faced came in different types, also the solution strategies students used to solve these problems: some solution strategies were mathematically oriented (e.g., reasoning about the shape of graphs), some strategies were ICT oriented (e.g., asking feedback from the DWO) and some strategies evaded the development of a solution from which any mathematical learning could be achieved, which we called evasive strategies (e.g., skipping the exercise). However, most of the time the solution strategies used by the students didn't fit in any one category, but were a combination of two types of strategies, e.g. a trial-and-error strategy, which heavily depends on the feature of the DWO to give direct feedback on a given answer, but also evades any mathematical thinking (if the student immediately continues to the next exercise after having reached the correct answer), making it a combination of ICT oriented and evasive. Therefore we divided the solution strategies into six categories: mathematically oriented, ICT oriented, evasive, mathematically oriented/ICT oriented, mathematically oriented/evasive and ICT oriented/evasive.
We coded the videotaped sessions of pairs of students working with the DWO using the Atlas-ti software. We specifically looked at the problems that the pairs of students faced while working with the DWO and the strategies the students adopted to solve these problems. As mentioned before, we categorized the problems into two groups and the solution strategies into six groups.
Using the analysis of the videotaped sessions and the data on attitude variables and mathematics performance, we created profiles for each pair of students, so as to get a better image of the characteristics of each pair of students. After having created these profiles, we tried to identify a difference in the preferred solution strategies of boys and girls to solve the problems they encountered. To get a better image of these preferred solution strategies, we listed the frequency with which each pair of students used a solution strategy from each category. In doing so we distinguished between students implementing a solution strategy in a correct fashion, students failing to use a strategy correctly and students only mentioning a certain solution strategy, a method similar to the one used by Roorda (2012).

Having established a detailed image of these seven pairs of students, we looked at the patterns we found from a distance to see if they are reflected in the group of students as a whole. The students were asked to fill in a questionnaire about the types of problems they encountered and the strategies they used to solve these problems. A total of 30 students filled in and returned this questionnaire.
We first looked at the number of times a student encountered a certain problem as reported by the students themselves. Since the question about how many times a student encountered a certain problem was an open one, we received answers varying

from “never” and “2” to “very often” and “10 000 million times”. We divided the answers into three categories, namely *never*, *incidentally* and *recurring*. We randomly selected the answers of 20 students for an inter-rater test on reliability, yielding total agreement. After having established the reliability of our method, we used several bar charts (one per encountered problem) to get an image of the differences between boys and girls.
We then looked at the solution strategies that the students reported to use to solve the mentioned problems. To ask about solution strategies, the questionnaire we developed again used open questions, yielding a large variety of answers. We categorized these answers using the same six categories for solution strategies that we used in analyzing the videotaped sessions. Again we randomly selected the answers of 20 students for an inter-rater test on reliability, yielding yet again total agreement. We then used several bar charts (one per encountered problem) to get an image of the differences between boys and girls.

4. Results

We will first look at students’ attitude towards mathematics and computer use and their mathematics achievement, leading to what we have called the *gender issue*.

Attitude and achievement (large-scale)
Table 3 shows the means of the mathematics and computer use attitude variables for boys and girls from the dataset of the FIsme. The Mann-Whitney U tests indicated that only the differences in the self-efficacy variables were significant (both having p=0.000), indicating that boys have a higher self-efficacy in both mathematics and computer use.

Gender	Low self-efficacy in mathematics	Joy in mathematics	Joy in computer use	Self-efficacy in computer use	Computer anxiety
Boys (N=176)	-.317	-.124	.012	.276	-.068
Girls (N=189)	.312	.008	.046	-.266	.076

Table 3. Means of standardized attitude variables for boys and girls of the DWO-group (large-scale).

Table 4 shows the average grades of the students that used the DWO and those of the control group, both from the dataset of the FIsme. The Mann-Whitney U tests didn’t indicate any significance in the difference between the scores of boys and girls. Note that the boys tend to score similar in both groups, while the girls of the control group score slightly better at the first two tests then those of the DWO group, a difference that is all but gone when looking at the second post-test. All in all this data doesn’t seem to indicate that either boys or girls have more benefit from the DWO, when looking at mathematics performance. This leads to a discrepancy with the boys’ more positive attitude towards mathematics and computer use and the literature stating that attitude influences achievement. We call this discrepancy the *gender issue*.

Gender	Pre-test score	Post-test 1 score	Post-test 2 score
Boys DWO group (N=199)	6.48	6.91	6.35
Girls DWO group (N=201)	6.47	6.78	6.32
Boys control group (N=173)	6.50	6.90	6.18
Girls control group (N=236)	6.79	7.46	6.35

Table 4. Means of grades for boys and girls of the DWO group and control group (large-scale).

Attitude and achievement (small-scale)
When looking at the attitude factors of the students from the small-scale investigation (stable 5) we see that boys scored more positive than girls on every attitude variable, except *Computer anxiety*. Mann-Whitney U tests indicated that only the difference in *Self-efficacy in computer use* was significant (p=0.000). Altogether this gives the image of boys having a more positive attitude towards mathematics and computer use than girls, as we have seen before with the data of the FIsme.

Gender	Low self-efficacy in mathematics	Joy in mathematics	Joy in computer use	Self-efficacy in computer use	Computer anxiety
Boys (N=20)	.266	.326	4.956	2.022	2.041
Girls (N=20)	.676	.174	4.797	.591	1.826

Table 5. Means of standardized attitude variables for boys and girls (small-scale).

Table 6 shows the average grades of boys and girls on the pre- and post-test. It is clear that there is an enormous increase in grade average when looking at the girls, while the increase in average grades of the boys is far less. Together with the boys' more positive attitude towards mathematics and computer use (as mentioned above), this shows that what we have called the *gender issue* is also evident for the students participating in this research.

Gender	Pre-test score	Post-test score
Boys (N=20)	5,7 (SD=2,1)	6,9 (SD=2,0)
Girls (N=20)	4,8 (SD=2,1)	7,1 (SD=2,7)

Table 6. Means of grades for boys and girls (small-scale).

Note that there is a great increase in the standard deviation of the grades of the girls, while the standard deviation of the grades of the boys drops a little. Apparently low achieving girls had less benefit from working with the DWO than high achieving girls did.

Videotaped sessions
We created profiles for each pair of students we videotaped during the small-scale investigation, so as to get a better image of the characteristics of each pair of students. These profiles can be viewed below.

<u>Pair 1 (boys): Anton and Bas</u>
Both Anton and Bas scored low on the pre-test (4.3 and 5.0) and have a low self-efficacy in computer use compared to the other boys. Bas' self-efficacy in mathematics was also very low, while that of Anton was considerably higher. For the post-test Anton scored a 4.5 and Bas scored a 6.8.
During the videotaped session these boys seemed to have a lot of difficulty understanding the mathematics involved in solving the exercises they had to work on. Most of the time these students adopted solution strategies involving the use of ICT such as making use of the feedback provided by the DWO, opening windows with examples and even resorting to trial-and-error.

The following excerpt from the videotaped session of Anton and Bas is an example of how these boys use ICT to solve the problems they encounter, but don't lose track of the mathematics involved.

Anton and Bas are trying to determine the coordinates of the y-intercept of a graph. Anton tries some values, all of which the DWO doesn't accept.
Anton: 0.0...0.1...
Bas: No Anton, we're not going to try them all.
Bas ponders the exercise.
Bas: Ehm...
Anton tries (0,-1), which the DWO accepts.
Bas: How did you know that?
Anton points at the y-intercept of the graph.
Anton: -1... 0...
Bas: I told you so!
Anton: You did not!

Pair 2 (boys): Coen and Daan
Both Coen and Daan have a low self-efficacy in computer use compared to the other boys and also a low self-efficacy in mathematics. Daan scored very low on the pre-test (3.3), while Coen scored considerably higher (6.7). Both boys scored low on the post-test (4.8 and 3.8).
During the videotaped session these boys worked on solving linear equations by using the so-called *cover-up strategy*. Instead of using the tools available in the DWO to aid them in the implementation of this strategy, the boys solved the equations by working it out in their head.
The following excerpt from the videotaped session of Coen and Daan illustrates how the boys solved the equations by working them out mentally using the cover-up strategy.

Coen and Daan are trying to solve the equation 5x+2=10.
Coen: Five times hmhm, plus two equals ten.
Daan: *(laughs)* Hmhmhm. Okay, okay. Five times six equals thirty. No, that's not it. I think it's.. Yes, look.. Because plus two is eight. So, five times hmhm equals eight. And that's five divided by eight.
Coen: No.
Daan: No, eight divided by five. And that's 1.6.

Pair 3 (boys): Edwin and Frans
Both Edwin and Frans scored rather high on the pre-test (8.3 and 8.7) and have a high self-efficacy in mathematics. Noteworthy is their very low self-efficacy in computer use, compared to the other boys. Both boys scored high in the post-test (7.5 and 9.3).
During the videotaped session Edwin and Frans were struggling with the use of the DWO, encountering several ICT-related problems, like not being able to log into the DWO, encountering error-messages and not knowing how to fill in fractions. These problems led to much desperation and moved Edwin and Frans to skip many exercises.
The following excerpt from the videotaped session of Edwin and Frans is an example of how these boys had no problem with the mathematics involved in the exercises, but were held back by ICT-related problems.

Edwin and Frans have to solve the equation 2/5t+6=4/5
Edwin: Look, 2/5t must equal 5 1/5.
Frans: -5 1/5!
Edwin: Yes, -5 1/5. So..
Frans: So, how many times do you need 2/5 to get 5 1/5?

Edwin: Well, once equals 2/5, twice equals 4/5, three times equals 1 1/5. Then six times make 2 2/5.
Frans: Thirteen times.
Edwin: Yes?
Frans: Yes, so it's -13. If I'm correct. Is that's possible?
Edwin: No idea.
Edwin pushes a few buttons in the interface of the DWO so the equation is moved down on the screen.
Frans: Oh, crap! What are you doing?
Edwin: This way you can see it more clearly. Ehm...
Frans: -13.
Edwin pushes a button used for manipulating the equation and fills in -13. The equation changes to 2/5t-7=-12 1/5.
Edwin: Okay, this isn't correct.
Frans: t=-13, I mean.
Edwin undoes the previous step.
Frans: But I don't know... *(points at the spot where Edwin had filled in -13)* What does it do if you fill in -13 over there.
Edwin: Well, look. I know the answer, but I can't fill it in!

Pair 4 (boys): Gerard and Harry
Both Gerard and Harry scored low on the pre-test (3.3 and 4.0) and have a high self-efficacy in computer use. While Gerard's self-efficacy in mathematics is very low, Harry's can be considered average. Gerard scored a 2.8 for the post-test, while Harry scored an 8.5.
During the videotaped session Gerard and Harry solved all the exercises without much trouble, initially making a lot of use of the examples the DWO offered.

Pair 5 (girls): Ines and Janine
Both Ines and Janine have a low self-efficacy in computer use. Janine scored low on the pre-test (5.0) and Ines scored even worse (1.0). Ines has a low self-efficacy in mathematics, while Janine scores average on self-efficacy in mathematics. On the post-test Ines scored a 3.8 and Janine scored a 7.5.
During the videotaped session Ines and Janine made extensive use of the various kinds of feedback the DWO offered, looking at examples and trying to find out why the DWO didn't accept certain answers. Regrettably the girls also encountered a lot of error-messages, interrupting their progress.

Pair 6 (girls): Katharina and Linda
Both Katharina and Linda scored a 3.3 on the pre-test and have a low self-efficacy in mathematics. Compared to the other girls Katharina and Linda have a high self-efficacy in computer use. Katharina scored a 7.0 on the post-test and Linda scored a 1.0.
During the videotaped session Katharina and Linda made a lot of use of the theory that's explained next to the exercises. Concerning the solving of the exercises the girls often resorted to a trial-and-error strategy, skipping the exercise if that didn't work.
The following excerpt from the videotaped session of Katharina and Linda is an example of the highly evasive strategies used by the girls.

Katharina and Linda have to determine the gradient of a linear graph.
After having tried to identify the gradient by looking at the graph Katharina fills in some random values, all of which are not accepted by the DWO.
Katharina: *(reading aloud)* Use the F4 button to fill in fractions... So it's a fraction! How do I have to know that!
Katharina skips the exercise.

Pair 7 (girls): Marlous and Nina

Both Marlous and Nina have a low self-efficacy in mathematics and computer use. Marlous scored high on the pre-test (7.3), while Nina scored very low (2.7). On the post-test Marlous scored a 6.0 and Nina scored a 10.0.

During the videotaped session Marlous and Nina made a lot of use of the theory that's explained next to the exercises. The girls seemed to have no great problems solving the exercises they had to work on.

Figures 1 and 2 show pie charts of the different kinds of strategies used by the boys and girls to solve the problems of a mathematical nature they encountered. For the boys we see a clear tendency to resort to mathematically oriented solution strategies or to a combination of mathematically and ICT oriented strategies. The girls however don't show any one preference in their solution strategies: Marlous and Nina seem to prefer mathematically oriented strategies, Katharina and Linda seem to prefer evasive strategies and Ines and Janine don't show any clear preference at all.

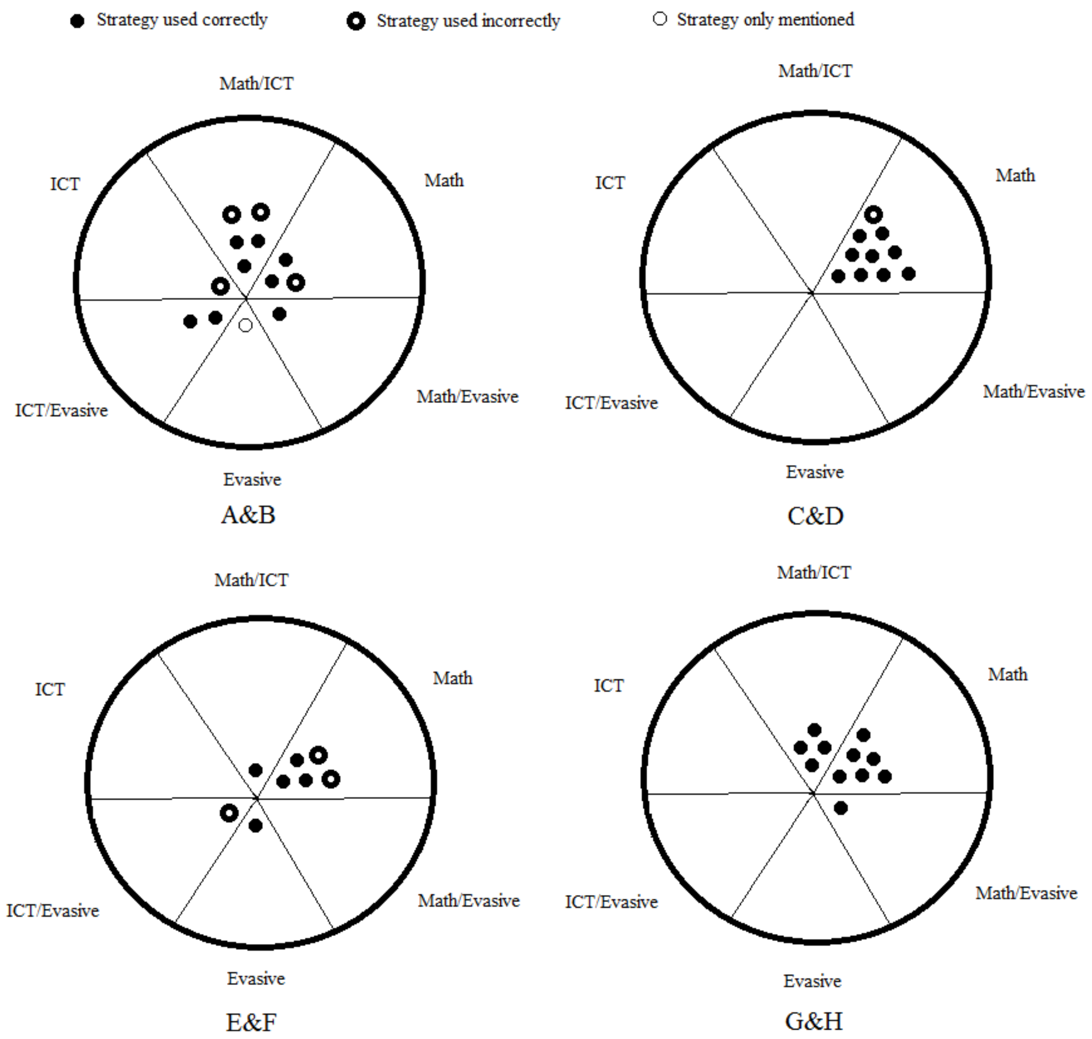

Figure 1. Frequencies of the different kinds of strategies used by the boys (small-scale)

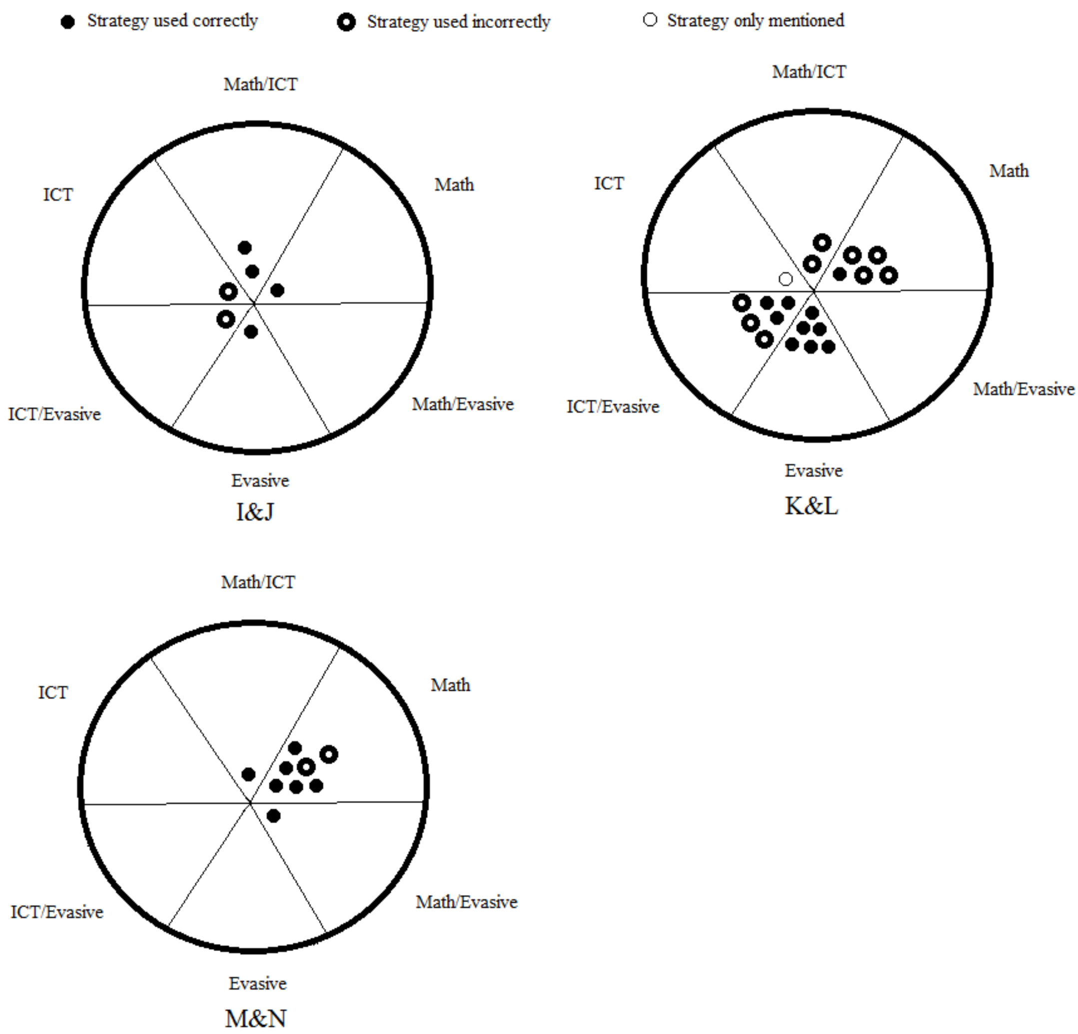

Figure 2. Frequencies of the different kinds of strategies used by the girls (small-scale)

Questionnaire on encountered problems

Figure 3 consists of several bar charts, showing with what frequency boys (N=15) and girls (N=15) reported to have encountered a certain problem *never*, *incidentally* or *recurring*.

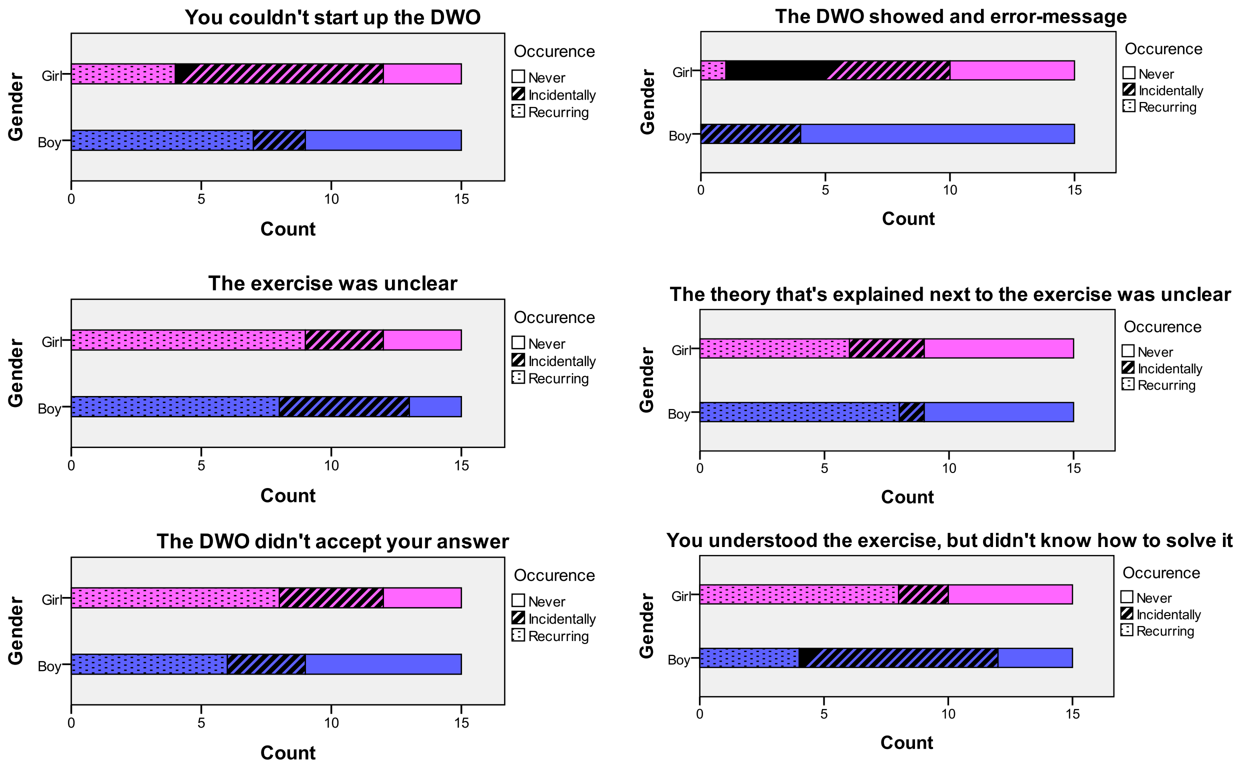

Figure 3. frequency students reported to encounter a certain problem *never*, *incidentally* or *recurring* (small-scale)

It is noteworthy that the problems, that a majority of boys reported to never encounter are exactly the problems that are ICT-related. This suggests that boys indeed encounter far fewer difficulties in the instrumental genesis process than girls.
The last bar chart is of special interest, since it represents a problem (i.e., *I understood the exercise, but didn't know how to solve it*) that explicitly indicates a lack of mathematical knowledge or skill. When looking at this bar chart we see that boys generally indicated to encounter this problem incidentally, while girls report encountering this problem recurrently. This phenomenon could be a direct result of girls' lower self-efficacy in mathematics.

Figure 4 consists of several bar charts, showing the reported solution strategies of boys and girls to various problems that the students encountered while using the DWO. Note that only those students that didn't indicate to have never encountered the mentioned problem answered this question, therefore the total number of answers differs per encountered problem.
When looking at the ICT-related problems, we see that girls have, far more than boys, a tendency to resort to evasive strategies. It is therefore extra noteworthy to notice that with respect to the last problem the roles are reversed and boys seem to prefer the evasive strategies, an image that is reflected in the other mathematics-related problems, albeit the effect is less clear.

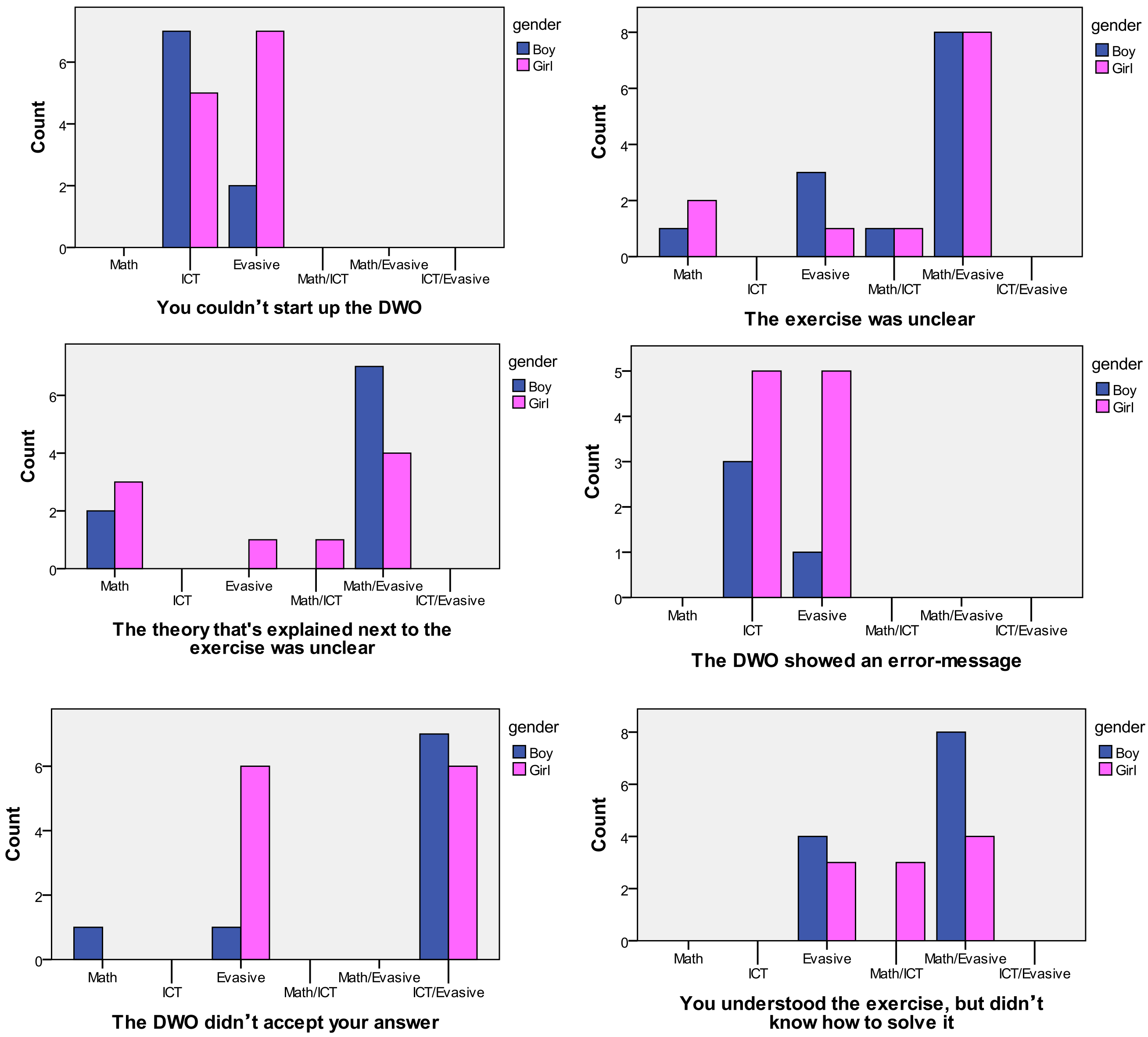

Figure 4. Solution strategies of boys and girls to problems that the students encountered (small-scale)

5. Conclusion and discussion

By analyzing the data from the questionnaire on attitude towards mathematics and computer use and the grades for the pre- and post-test, we have identified the gender issue in both the group of students used for the large-scale investigation and that of the small-scale investigation that we investigated. Thereby we have addressed the first two sub questions (i.e., *Is there a difference between boys and girls in attitude towards mathematics and computer use?* and *Is there a difference between boys and girls in mathematics achievement when using the DWO?*), finding a significant difference between boys and girls concerning self-efficacy in both mathematics and computer use (boys having a more positive view of their own skills), while not finding any significant difference in mathematics performance.

We videotaped seven pairs of students (4 pairs of boys and 3 pairs of girls) while they were working with the DWO and tried to identify the difference in type of problem (ICT- or mathematics-related) they encountered. We didn't find any meaningful difference in type of problem the students encountered (sub question 3: *Is there a difference between boys and girls in problems they encounter when using the DWO?*), since both boys and girls mostly encountered problems of mathematical nature, encountering ICT-related problems between 1 and 5 times per session. A total of thirty students from the small-scale investigation filled in a questionnaire on the type of problems they encountered

while working with the DWO. Looking at the results from this questionnaire, we see that the problems where a majority of boys reported to never have encountered them are exactly the problems that are ICT-related. This suggests that boys indeed encounter far fewer difficulties in the instrumental genesis process than girls.
To answer the fourth sub question (*Is there a difference between boys and girls in strategies they use to overcome the problems they encounter when using the DWO?*), we looked at seven pairs of students in more detail by means of videotaping them while working with the DWO and have seen that the boys prefer non-evasive strategies to solve the mathematics-related problems they encounter, while girls don't have any specific preference. A questionnaire on the type of strategy students use to solve encountered problems (which was filled in by thirty students in the small-scale investigation), however, suggests that girls in general resort less to evasive strategies than boys. These two observations seem to contradict each other, yet this seeming discrepancy can be explained by the fact that the pairs of students we used in the videotaped sessions were selected to be low achievers and having a low self-efficacy. Therefore these results seem to suggest that mostly high achieving girls prefer non-evasive solution strategies, thereby increasing their mathematical learning, and that low achieving girls are more keen to resort to evasive strategies. This claim seems to be supported by the increase in standard deviation found when looking at the pre- and post-test in the small-scale investigation.
Focusing on the main research question (*What are the factors that influence the gender issue of students using web based mathematics learning environments?*) we first established, by means of answering the first two sub questions, that the gender issue is relevant for the web based mathematics learning environment the DWO. The answers to the last two sub questions seem to suggest that the process of instrumental genesis plays a great part in the difference between boys and girls when using web based mathematics learning environments, since girls report to have encountered more ICT-related problems, indicating that the girls had not yet (successfully) finished the instrumental genesis process. Furthermore, we found that on the whole boys were more eager to deal with mathematics-related problems using evasive strategies, while girls chose more mathematically-oriented strategies. An image that was reversed when we looked at the low achievers. This suggests that low-achieving girls have not yet successfully finished the process of instrumental genesis and are therefore seriously hindered in their ability to come up with effective solution strategies, while low achieving boys have already finished this process and can focus on mathematically-oriented or mathematically-oriented/ICT-oriented strategies. The results from the questionnaire on encountered problems suggests that, when girls have finally finished the process of instrumental genesis, they tend to resort to non-evasive strategies more often than boys, which has a positive effect on the learning process. However, no clear image of the difference between boys and girls in the instrumental genesis process can be gained from these results, leaving the need for further research in this area.
With respect to the development of the DWO we suggest more attention should be devoted to the process of instrumental genesis, in particular supporting (low achieving) girls to more efficiently acquire a meaningful relationship with the tool.

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Appendix A

This is the questionnaire used to determine students' attitude towards mathematics and computer use.

Questionnaire

Name:

	I disagree	I mostly disagree	I don't agree nor disagree	I mostly agree	I agree
I have no talent for mathematics					
I'm sick and tired of mathematics					
I can accomplish good results in mathematics					
Especially during mathematics I'm glad when class is over					
I think mathematics is fun					
With mathematics I'm more scared to make mistakes than in other classes					
I have a lot of confidence concerning mathematics					
Without mathematics, school would be much more fun					
That I have to learn difficult subjects during mathematics doesn't worry me					
I would rather not have any mathematics classes at all					
I'm more anxious about mathematics than any other subject					
I sometimes make more homework for mathematics than was assigned					
During mathematics class I frequently don't understand much					
I feel confident when I answer a teacher's question during mathematics class					
During mathematics class time passes quickly					
No matter how hard I study, mathematics stays difficult for me					
I enjoy solving a mathematics exercise on my own					

Our mathematics classes are often interesting					
I nearly always understand what is being taught during mathematics class					
The prospect of learning new things in mathematics makes me anxious					
Mathematics is a subject where my efforts are being rewarded					
Mathematics will not easily become one of my hobbies					
I'm not skilled at using the computer					
When I've started on the computer, I find it difficult to stop					
I'm not the type to handle computers well					
I have a lot of self-confidence concerning computers					
I find working with computers fun and motivating					
The thought of using a computer disheartens me					
For me it's not an interesting challenge to work with computers					
I don't understand that people can spend so much time on computers and even seem to enjoy it					
I like to use computers for my school work					
I'd rather use the computer as little as possible					
I feel comfortable when using a computer					
If there is a problem with the computer that I cannot immediately solve, I keep searching until I find a solution					
I find solving computer problems interesting					
I learn more in classes where we use the computer					
I enjoy working with computers					
I'm not afraid of computers					
With the computer school work gets more interesting					
Working with the computer makes me nervous					
I feel fine when I address a new problem on the computer					

Using a computer is very difficult for me					
The computer helps me to study more effectively					

Appendix B

This is the questionnaire used in the small-scale investigation to determine the kind of problems students encountered while working with the DWO and how they solved these problems.

Problems encountered while using the DWO

Name:

Below are some problems you might have encountered while working with the DWO. Please report for every such problem the number of times you encountered this problem, the solution strategy you (mostly) used to solve the problem and whether that strategy worked.

Problem	**You couldn't start up the DWO**
How many times did you encounter it?	
Which strategy did you (mostly) use to solve it?	
Was your solution strategy successful?	

Problem	**The exercise was unclear**
How many times did you encounter it?	
Which strategy did you (mostly) use to solve it?	
Was your solution strategy successful?	

Problem	**The theory that's explained next to the exercises was unclear**
How many times did you encounter it?	
Which strategy did you (mostly) use to solve it?	
Was your solution strategy successful?	

Problem	**The DWO showed an error-message**
How many times did you encounter it?	
Which strategy did you (mostly) use to solve it?	
Was your solution strategy successful?	

Problem	**The DWO didn't accept your answer**
How many times did you encounter it?	
Which strategy did you (mostly) use to solve it?	
Was your solution strategy successful?	

Problem	**You understood the exercise, but didn't know how to solve it**
How many times did you encounter it?	
Which strategy did you (mostly) use to solve it?	
Was your solution strategy successful?	

Did you encounter any other problems? If so, which problems and what strategy did you mostly use to solve them?

Other remarks concerning working with the DWO.

Thanks for filling in this questionnaire!