This study reports on the effects of the combined use of an interactive whiteboard (IWB) and a virtual learning environment (VLE) on mathematics performance and motivation. Lessons taught with an IWB were made available on the VLE, so that they could be consulted regardless of time and place. Students’ mathematics performance was monitored during one school year and their motivation for mathematics was followed for 3 years. There was no relation between frequency of being taught with an IWB and mathematics performance. However, students’ motivation for mathematics appeared to be positively related to the combination of lessons made for the IWB and availability of these lessons on the VLE. This availability was also the main reason for students’ appreciation of the VLE. Students appeared to use the VLE mostly to prepare for tests and examinations.

Keywords: academic achievement, interactive whiteboard, mathematics education, motivation, virtual learning environment.

Introduction
In the study reported in this article, the focus is on two educational technology tools that are used in combination: the interactive whiteboard (IWB) and the virtual learning environment (VLE). During a 3-year period, mathematics lessons made for the IWB were later put on to the VLE to enable students to work on the lesson content regardless of time and place. Efficiency, as well as effectiveness, was the main reason for this reuse of IWB lessons. The study was performed in a naturalistic setting of a traditional school and with teachers who used Information and Communication Technology (ICT) tools in line with their existing teaching practices.

Overview of the literature
The use of the IWB in education has steadily increased in the last decade. In the Netherlands in 2011, 98% of secondary schools and 97% of primary schools had at least one IWB at their disposal (ten Brummelhuis & van Amerongen, 2011). International figures show the same tendency; in the UK in 2007, for example, Becta figures showed that nearly all primary and secondary schools already had access to IWBs (Kitchen, Finch, & Sinclair, 2007). Moreover, the average number of IWBs used in schools is still rising.

The IWB’s versatility is, in particular, an important motive for teachers to use it in their teaching (e.g., Kennewell, Tanner, Jones, & Beauchamp, 2008). Teachers can illustrate their instructions easily by using
pictures and real-time data from the Internet, for instance, to explain blood circulation or climate change in a more attractive and effective way. But the IWB also offers opportunities for increasing the interactivity of the teaching and learning process and for active and collaborative knowledge construction through class dialogue (Mercer, Dawes, & Kleine Staarman, 2009; Smith, Higgins, Wall, & Miller, 2005).

The popularity of the IWB is also noticeable in educational research. In the last 8 years, studies have been published on student perceptions of the IWB, on teachers’ practices and teaching approaches when using the IWB, and on teachers’ professional development (see, e.g., Hall & Higgins, 2005; Hennessy, Deaney, Ruthven, & Winterbottom, 2007; Lewin, Scrimshaw, Somekh, & Haldane, 2009). Several literature reviews have also been published (Glover, Miller, Averis, & Somekh, & Haldane, 2009). In a review of research on the effects of IWB use on student performance and learning, DiGregorio and Sobel-Lojeski (2010) concluded that the evidence of the effect of IWB use on students’ learning results and motivation is not conclusive. With regard to student motivation, however, there is some agreement that IWBs have a positive effect. For example, Torff and Tirotta (2010) found that the effect of IWB use on student motivation in primary mathematics education was positive but (given the effect sizes were between 0.01 and 0.02) very small. They concluded that more large-scale research is needed. The motivating effect may also be due to the novelty factor and thus decrease over time; longitudinal effects on motivation have not yet been the focus of research. With regard to learning effects, studies show different and sometimes contradictory results (DiGregorio & Sobel-Lojeski, 2010). The authors concluded that contextual factors such as teachers’ pedagogy and skills may interact with both motivation and learning effects. This may be seen in line with the opinion of some authors that although the IWB offers many opportunities for teachers to enrich their teaching and thus to promote student learning, possible constraints on effective use must be taken into account and studied further (e.g., Lewin et al., 2009; Smith et al., 2005).

One of the constraints mentioned in research refers to the time teachers have to invest in developing lessons for the IWB (Glover & Miller, 2001; Lai, 2010). This relatively large time investment makes it worthwhile to explore whether the teaching materials made for the IWB can be used for other purposes. A VLE on which learning materials are available to students at ‘anytime, anywhere’ may be a promising possibility.

A VLE (or learning platform) is ‘a software tool which brings together in an integrated environment, a range of resources that enable learners and staff to interact online, and includes content delivery and tracking’ (Becta, 2004, p. 1). As such, a VLE has a range of potential benefits. It may support students’ learning processes in several ways, for example, through the availability of online content and learning materials. Students can look up lessons or other instruction materials on a VLE when doing homework or preparing for an exam, or when they are ill. Moreover, the VLE’s log files show which students use which lesson materials when and as such can be used for diagnostic purposes. Like the IWB, VLEs are increasingly used in educational settings, at first mostly in higher education but in recent years also in primary and secondary education. In the Dutch situation in 2011, about 67% of all primary and secondary school teachers used a VLE eight times a month on average (ten Brummelhuis & van Amerongen, 2011). Figures for the UK show that in 2010, about 67% of primary schools and 93% of secondary schools had a VLE (Jewitt, Hadjithoma-Garstka, Clark, Banaji, & Selwyn, 2010).

Although there is ample research on the use of VLEs in higher education, there is less research on VLEs in primary and secondary education. Studies focusing on the effects of the use of VLEs on students’ learning results in particular are still quite scarce. Passey (2011) performed a large-scale study in a variety of schools in the UK and concluded that the use of VLEs could ‘potentially lead to a wide range of potential learning outcomes’ (p. 331). A study on the impact of VLE use on students’ learning performance and satisfaction in a Taiwan secondary school showed higher test scores in the VLE group, mediated by higher learner control (Chou & Liu, 2005).

Some recent studies focus on the way the VLE is used by school managers, teachers and students, and explore opportunities, conditions and constraints (e.g., Jewitt, Clark, & Hadjithoma-Garstka, 2011; Passey, 2011). A 2009 Ofsted study on the evaluation of VLEs used in various educational contexts revealed that primary schools made very limited use of the VLE. In secondary education, its use increased with students’
The common factor in effective VLE use was the teacher, especially his or her enthusiasm for both the subject taught and the use of technology in their teaching in general. VLEs were used best when the learning materials were helpful, for example, providing the chance to catch up on missed lessons or to reinforce certain lesson content. However, the impact on learning was unclear. Staff time to develop materials for the VLE was a concern in all secondary schools using them (Ofsted, 2009). This last finding, in particular, suggests that using lesson content developed for the IWB on the VLE could provide an opportunity for schools and teachers to use lesson preparation time more effectively and thus to provide a better context for student learning and motivation.

This study

Although combining IWB and VLE may not be a novel concept and seems a logical thing to do, the effects on student learning and motivation of such combination have not been studied in detail and in a naturalistic educational setting before. Therefore, this article reports the results of a study focusing on the combined use of the IWB and VLE in mathematics education in one Dutch secondary school. For 3 years, teachers developed digital teaching materials for the IWB they used in their mathematics teaching. They also made the lessons they developed for the IWB available on the VLE used by the school. The teachers had various motives for combining IWB and VLE. They wanted to offer students more opportunities to access the mathematics lessons, for example, during illness or when having problems with homework exercises. The teachers were also curious whether students would pay more attention (because they were less obliged to make notes during lessons) or less attention (because they were able to access the lessons afterwards) to the instruction.

In our study, we first looked at the short-term effect of IWB and VLE use on students’ performance in mathematics and at the long-term effect of the use of the IWB in mathematics lessons on students’ motivation for mathematics. Longitudinal or long-term effects on motivation have not been studied before, as far as we know. Second, we investigated how students used the VLE and their perceptions of using it, as well as their learning results in terms of mathematics test scores and motivation.

The following research questions were explored:

1. To what extent is students’ exposure to IWB lessons and the availability of these lessons on the VLE related to students’ learning outcomes in mathematics in one school year and motivation for mathematics over 3 years?
2a. How do students evaluate the VLE for mathematics, and how often and in what way do students use the IWB lessons and other mathematics learning materials that are available on the VLE?
2b. How are these perceptions and use related to perceived and factual effects on students’ learning outcomes and motivation for mathematics?

For the first research question, we formulated the following hypothesis: students with higher exposure to IWB lessons are more strongly motivated to study mathematics and achieve better learning results in mathematics than students with lower exposure to IWB lessons. Motivation was operationalized as specific motivation for mathematics (Kuhlemeier, van den Bergh, & Teunisse, 1990). Because research questions 2a and 2b are of a descriptive and explorative nature, no hypotheses were formulated. We addressed the two research questions in separate studies: research question 1 in study 1 and sub-questions 2a and 2b in study 2.

Method

Instrumentation

Specific motivation for mathematics was measured by the Mathematics Experience Questionnaire (MEQ), which has shown to be a reliable and valid indicator of students’ motivation to study mathematics in secondary school (Kuhlemeier et al., 1990; Meijer, Van Eck, & Felix, 2008). The latter found substantial correlations with mathematics performance. The MEQ consists of four scales, each represented by eight items. Each scale covers a specific aspect of mathematics attitude, namely relevance, effort, anxiety and pleasure. In this article, high anxiety scores are an indication of the contrary, that is, the higher the score on this aspect, the less anxious participants were. This was done to align this variable with the other mathematics attitude
variables, which should all be interpreted positively. An example of an item within each scale is given below.

- Relevance: ‘Mathematics is important for getting a job later in life.’
- Effort: ‘Sometimes I do mathematics in my leisure time.’
- Anxiety: ‘I do not understand much of our mathematics lessons.’
- Pleasure: ‘I like to solve mathematical problems on my own.’

Mathematics performance was measured by teacher-constructed mathematics tests, which were part of the regular mathematics curriculum.

Students’ evaluation of the VLE for mathematics was investigated by means of a questionnaire (see Table 2 of the results section). The questionnaire comprised six questions concerning students’ perceptions of the VLE that could be answered on a 5-point Likert scale. It also included questions about the nature of VLE use. Two teachers and four students provided the data for this part of the questionnaire. The teachers agreed on the final version of the questionnaire. Log files provided information on the frequency of VLE use and the type of files students consulted during the research period [i.e., IWB lessons, course-related files, files related to planning, test files (files of practice tests) and ‘other files’].

Design

The study lasted for 3 consecutive school years. One mathematics teacher in the school introduced the IWB in the school year 2007–2008. He always used it during his mathematics lessons and always made the content of his lessons available on the VLE, so his students could consult this content regardless of time and place. During this school year, only one other teacher sometimes had access to the classroom where the IWB was located. As a consequence, three modes of experience could be distinguished in this school year: students who were always taught mathematics with an IWB, students who were sometimes exposed to an IWB during mathematics classes, and students whose teachers never used an IWB during mathematics lessons.

In the following school year (2008–2009), another IWB was introduced. More mathematics teachers started using the board so that the number of students who had never experienced mathematics education with an IWB decreased quite dramatically. In the last school year of the research project, the two classrooms with an IWB were used as much as possible by the six mathematics teachers in the school (2009–2010). Consequently, there were hardly any students left who had never experienced the use of an IWB in their mathematics lessons. Based on the information about the availability of IWBs and the arrangement of classrooms, it was possible to divide students into three groups:

1. Those who were exposed to mathematics lessons with an IWB of approximately one-third or less of the time during their last 3 years of mathematics education (‘sometimes’).
2. Those who were exposed to mathematics lessons with an IWB of approximately two-thirds of the time or less, but more than one-third of the time, during their last 3 years of mathematics education (‘frequently’).
3. Those who were almost always taught mathematics with the aid of an IWB, that is, more than two-thirds of the time during their last 3 years of mathematics education (‘always’).

We will refer to these groups in this article as the ‘IWB condition’. During each of the first two school years, the MEQ was administered as a pre-test at the beginning of the school year and as a post-test at the end of the year. In the first year of the study, the intervention, that is, use of the IWB and making its content available on the VLE, had already started in a few classes before the MEQ was administered. Consequently, there is no true baseline measure available for mathematics motivation. In the school year 2009–2010, the MEQ was only administered once on a particular sample of students.

Sample

Between 2007 and 2009, students from various classes of the school completed the MEQ at the beginning and end of their school year.

Sample 1 (2007–2008)
The first sample consisted of 286 students, but only 214 took part both times the questionnaire was
administered. There were 173 boys and 98 girls in this sample. The gender of 15 students was unknown, as they had forgotten to enter this. Performance measures could only be compared in this sample. Two comparisons were possible between students who had taken identical mathematics tests. In the first case, only the group that was always taught with the IWB could be compared with the group that was taught with it sometimes. In the second case, a group that was sometimes taught with the IWB was compared with a group that was never taught with it. The first comparison involved 51 students (26 versus 25) and the second comparison involved 50 students (36 versus 14). In the other samples, no more data on mathematics performance were gathered.

**Sample 2 (2008–2009)**

The second sample was much larger and consisted of 849 students. However, only 191 had also been involved in the first phase of the project. There were 367 boys and 406 girls in this sample. The gender of 76 students was unknown, as they had forgotten to enter this.

**Sample 3 (2010)**

Finally, the third sample participated in 2010 but only completed the MEQ once. This sample consisted of 183 students; 146 of these also took part in samples 1 and 2. However, complete data on the five times the MEQ was administered were not available for all these students.

Table 1 gives the numbers of students who were involved in all the phases of the research project and the numbers of students for whom complete data on their motivation for mathematics were available. As can be seen, very few students remained for an analysis of the five MEQ measurements. Of these remaining 39 students, 23 were boys and 16 were girls. Twenty-one of the students were in grade 12, seventeen in grade 11, and one in grade 10.

### Results of study 1

Study 1 addressed the first research question:

To what extent is students’ exposure to IWB lessons and the availability of these lessons on the VLE related to students’ learning outcomes in mathematics in one school year and motivation for mathematics over 3 years?

#### Mathematics performance

It was only possible to compare students’ performance in two conditions in the school year 2007–2008 (sample 1) in identical mathematics tests. Because performance comparisons were only possible for students with different exposure to IWB lessons who had done identical mathematics tests, the number of students involved in these comparisons was severely restricted. Usually, these students were in parallel classes. First, two classes in grade 3 of senior secondary education were compared with each other. One of these classes was always taught mathematics with an IWB (experimental condition, $N = 26$), whereas in the other class an IWB was only used sometimes (control condition, $N = 25$). In total, these classes did 11 identical mathematics tests. Because 11 comparisons are made, a multivariate statistical analysis should be carried out in order to avoid chance capitalization. In this analysis, the 11 mathematics tests were the dependent variables, and condition was the independent variable. The score on the national scholastic ability test, which was administered at the end of primary school, was used as a covariate in this analysis to correct for possible differences in class composition. The effect of condition proved not to be significant (Roy’s $V = .44$, $F_{(11, 38)} = 1.52$, ns). Univariate statistical tests revealed only one mathematics test with a better average result for the experimental group (average score 6.9 versus 6.1, $F_{(1, 48)} = 4.06$, $p = .05$), but this result should be ascribed to chance capitalization, because the multivariate effect was not statistically significant.

<table>
<thead>
<tr>
<th>Experience with IWB in mathematics lessons</th>
<th>Participation in all phases of the research project</th>
<th>Complete data available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>None</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>Sometimes</td>
<td>68</td>
<td>14</td>
</tr>
<tr>
<td>Frequently</td>
<td>48</td>
<td>13</td>
</tr>
<tr>
<td>Always</td>
<td>26</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>146</td>
<td>39</td>
</tr>
</tbody>
</table>

IWB = interactive whiteboard.

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The second comparison that could be made was between 2 fourth-grade classes in senior secondary education, of which one was sometimes taught mathematics with an IWB (experimental condition, \(N = 34\)), whereas the students in the other class were never exposed to an IWB during their mathematics lessons (control condition, \(N = 16\)). All 40 students did the same eight mathematics tests. Multivariate covariance analysis showed no effect of condition. Again, univariate tests showed only an effect of condition on one mathematics test, but this was to the advantage of the control condition (average score 6.9 versus 5.9, \(F_{(1,47)} = 5.58, p = .02\)).

Finally, the correlations of mathematics test grades with the frequency of consultation of the mathematics content on the VLE were calculated. Only 1 out of 16 correlations was significant at the 5% level (\(r = .40, p = .03\)). However, this should also be ascribed to chance capitalization. When testing 16 correlations, the 5% level should be divided by approximately 16, which is smaller than 3%. All in all, there is no evidence that the use of an IWB in the mathematics lessons, as implemented in this experiment, contributed to students’ learning results in this particular school.

**Motivation**

In this paper, we tried to establish a relation between the exposure to mathematics lessons with an IWB and mathematics attitude. Therefore, the main effect of exposure to mathematics education with an IWB, operationalized as ‘sometimes’, ‘frequently’ and ‘always’, constitutes the independent variable. The four aspects of mathematics attitude, that is, relevance, effort, anxiety and pleasure, constitute the dependent variables.

There is no real pre-test measure because the first MEQ was not always administered immediately before the start of the intervention (see the Design section). Therefore, the test on the effect of the intervention is the main effect of condition, that is, exposure to an IWB during mathematics lessons. That is to say, the more experience students have with an IWB, the more positive their attitudes towards mathematics, or mathematics motivation, should be.

If accumulative experience with an IWB leads to an effect on mathematics motivation, this should particularly be revealed by a difference between the average motivation score in the fifth measurement versus the earlier measurements. Thus, we expected the last measurement to differ from the four previous measurements in higher average scores on the MEQ scales. Simple contrasts were chosen in an analysis of variance with repeated measurements, comparing the fifth measurement to each of the previous four.

The results of the analysis of variance with repeated measurements on the four dependent motivation variables, that is, effort, relevance, anxiety and pleasure regarding mathematics, will be reported below.

**Relevance**

For relevance, there was a significant effect of time (\(V = .55, F_{(4, 33)} = 4.56, p = .005\)) but not of condition. Contrasts showed that the first four measurements deviate from the last measurement. Figure 1a illustrates this effect. Average relevance scores declined sharply particularly after the fourth measurement. It can be seen that the patterns of development of the average scores of the three groups are remarkably similar. Although the group who was always taught with an IWB consistently scored the highest on average in each measurement moment, statistically speaking on average all three groups scored equally.

**Effort**

The analysis of repeated measures showed that there was no significant effect of experience with IWB mathematics lessons on average effort scores. This is illustrated in Figure 1b. Neither do the average effort scores of the fifth measurement deviate from the four previous measurements, implying that the hypothesis concerning effort should be rejected. The only significant difference as shown by post hoc tests was the one between the first and second measurements (\(M = 3.03 \text{ versus } 2.76, \text{ standard error } = .08, p = .017\)). In the school year 2007–2008, students scored significantly lower on the post-test compared with the pre-test.

**Anxiety**

The multivariate test on the effect of time on average anxiety scores was not significant. However, Mauchly’s test showed that the assumption concerning sphericity has been violated (\(\chi^2 = 19.17, df = 9, p = .024\)), indicating that the degrees of freedom for the \(F\)-test should be corrected. The Greenhouse–Geisser correction did indicate an effect of time (\(\varepsilon = .76, F_{(3.1, 110.1)} = 4.05, p = .009\)).
Looking at the simple contrasts, none of the four previous measurements appear to differ from the last measurement moment. Thus, doubt is cast on the effect of time on the average anxiety scores across the five measurement moments. The IWB condition did have an effect on anxiety scores ($F_{(2, 36)} = 3.65, p = .018$, one tailed). The effect size $\omega$ is .35, indicating quite a strong effect. Notwithstanding this, simple contrasts show that the group that was always taught with an IWB scored higher (i.e., less anxiety) than the group that was frequently exposed to an IWB in their mathematics lessons ($C = .57$, standard error = .22, $p = .012$), but not compared with the group that was taught mathematics with an IWB only sometimes (see Figure 1c).

**Pleasure**

Time had a significant effect on average pleasure scores ($V = .43$, $F_{(4, 33)} = 3.52, p = .017$). Contrasts show that only the third measurement moment deviates significantly from the last measurement ($F_{(1, 36)} = 9.50, p = .004$). In Figure 1d, it can be seen that the highest average score for pleasure occurred at the third measurement moment. IWB condition appeared to have an impact on average pleasure ($F_{(2, 36)} = 2.69, p = .040$, one tailed). Analysis of contrasts with the IWB condition ‘always’ as the referent category indicates a significant difference between ‘always’ and ‘sometimes’ ($C = .52$, standard error = .23, $p = .029$), but not between ‘always’ and ‘frequently’.

![Figure 1](image-url) Repeated Measures of the MEQ: (a) Relevance; (b) Effort; (c) Anxiety; (d) Pleasure
It is clear that the time of measurement had an effect on at least two of the MEQ scales. When visualizing the general pattern across the four scales in the figures, it appears that the motivation of students declined during both school years 2007–2008 (measurements 1 and 2) and 2008–2009 (measurements 3 and 4). Another pattern that catches the eye is that the motivation for mathematics appears to be stronger at the beginning of the school year 2008–2009 (measurement 3) compared with the end of the previous school year 2007–2008 (measurement 2).

It is rather striking that a similar increase at the beginning of the school year 2009–2010 (measurement 5) compared with the end of the school year 2008–2009 (measurement 4) did not occur. On the contrary, a further decline in motivation for mathematics seemed to occur. However, this decline is only significant in the case of the relevance scale.

The patterns in the development of the average motivation scores on the five measurements are remarkably consistent across the three IWB conditions. This also follows from the fact that none of the interactions between time and IWB condition were significant.

Although the IWB condition ‘always’ consistently showed higher average scores in almost every measurement moment compared with the other conditions, a significant main effect of IWB condition was only demonstrated for anxiety and pleasure. On these scales, the condition ‘always’ scored higher on average (i.e., less anxiety and more pleasure) compared with the condition with frequent usage of the IWB and the condition where it was used only sometimes, respectively. This finding constitutes partial support for our hypothesis.

### Results of study 2

Study 2 addressed the following two research sub-questions:

a) How do students evaluate the VLE for mathematics, and how often and in what way do students use the IWB lessons and other mathematics learning materials that are available on the VLE?

b) How are these perceptions and use related to perceived and factual effects on students’ learning outcomes and motivation for mathematics?

In this section, only data from the third sample were analysed (see Method section), unless specified otherwise.

### Evaluation and use of the VLE

In this section, we describe how students evaluated the VLE for mathematics as well as the frequency and the nature of its use during the research period. In order to explore differences in the way students use or benefit from the VLE for mathematics, differences between groups of students related to gender and the amount of time spent on mathematics homework will be presented. Only significant correlations and differences between groups are reported. Teachers’ assumptions concerning students’ use of the VLE are also discussed and analysed.

#### Evaluation of the VLE for mathematics

Students appeared to appreciate the IWB lessons available on the VLE. Most students reported positive perceptions about the effects of VLE use on their...
understanding of the content and on their feelings of security on this matter. Table 2 presents the frequencies of students’ responses to the items in the questionnaire. An analysis of differences between groups of students and correlations was carried out on the scale of VLE perceptions. The reliability of this 6-item scale was .74 (Cronbach’s $\alpha$, $N = 174$). A $t$-test showed gender differences in appreciation of the VLE. Boys’ perceptions of the VLE were more positive than girls’ perceptions (mean boys 3.29, mean girls 2.94, $t = 3.63$, $p < .001$, $N = 174$).

**Frequency of VLE use for mathematics**
We compared the use of VLE content for mathematics in three samples (see Method section). A different procedure was followed in these samples: in the first sample, teachers did not consistently put IWB lessons on the VLE, while in the third sample they did. The results are presented in Table 3.

In sample 3, the VLE was obviously used by more students than in the earlier samples.

This might suggest that students use the VLE more often when they are able to anticipate the availability of IWB lessons on the VLE. Because the teachers expected differences in frequency of VLE use between students in their examination year and other students, differences between these groups of students were investigated as well. Analysis supported the teachers’ expectation. Students in their final year did indeed use the VLE more often than other students (mean students in their final year 14.62, mean students in other years 7.80, $t = 3.17$, $p = .002$, $N = 183$).

**Nature of VLE use**
In the first place, we asked students in what situations they use the VLE for mathematics. Most students reported using the VLE for mathematics to prepare for tests and examinations (55%). Another large group of students used the VLE when they had difficulties understanding mathematics content (44%) and when they had been absent from lessons (43%). Use of the VLE to search for information, to improve understanding of assignments (36%) or other reasons (6%) was reported less frequently.

In the second place, we wanted to know which type of files students used on the VLE for mathematics, as different types of files were available. To explore the nature of VLE use on this aspect, we analysed the log files. As shown in Table 4, students mostly used the VLE to consult IWB lessons; consultation of the other types of files was less frequent.

Analysis showed differences between students in their final year and students in other years. Table 5 shows the results of this analysis. Students in their final year seemed to use IWB lessons, files related to planning and ‘other files’ more often than other students. No significant differences were found in relation to method-related files and test files.

<table>
<thead>
<tr>
<th>Table 3. Frequency of VLE Use for Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of students using the VLE</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Sample 1</td>
</tr>
<tr>
<td>Sample 2</td>
</tr>
<tr>
<td>Sample 3</td>
</tr>
</tbody>
</table>

VLE = virtual learning environment.

<table>
<thead>
<tr>
<th>Table 4. Type of Files Consulted When Students Used VLE for Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Files</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>IWB lessons</td>
</tr>
<tr>
<td>Method-related files</td>
</tr>
<tr>
<td>Files related to planning</td>
</tr>
<tr>
<td>Test files</td>
</tr>
<tr>
<td>Other files</td>
</tr>
</tbody>
</table>

IWB = interactive whiteboard; VLE = virtual learning environment.

<table>
<thead>
<tr>
<th>Table 5. Nature of VLE Use of Students in Their Final Year Compared With Other Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of files</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>IWB lessons</td>
</tr>
<tr>
<td>Files related to planning</td>
</tr>
<tr>
<td>Other files</td>
</tr>
</tbody>
</table>

IWB = interactive whiteboard; VLE = virtual learning environment.
Teachers raised the question whether students kept taking notes during class when they could consult the IWB lessons on the VLE. They were concerned about possible idleness in students. Students were asked about their note-taking strategies. As may be expected, two opposing strategies (taking fewer notes in order to understand the teacher’s instructions better and taking notes in order to remember the content) showed a negative correlation ($r = -.46$, $p < .001$, $N = 175$). Analysis revealed no correlations between the chosen strategies and the frequency of use of IWB lessons on the VLE.

We also asked students whether they agreed with the assumption that note-taking during class is less important if the content of IWB lessons is put on the VLE. The extent of agreement on this assumption was correlated to students’ own note-taking strategies and to the frequency of use of IWB lessons on the VLE.

Table 6 presents the results. They suggest that students benefited from IWB lessons on the VLE as they can then choose their preferred strategies. Students assuming that one can take fewer notes during class if the content of IWB lessons is put on the VLE used these IWB lessons on the VLE more often than other students. They also tended to take fewer notes so that they could pay more attention to the teacher’s instructions. Students who disagreed with this assumption tended to keep taking notes during class. No evidence was found for different learning outcomes between students with different strategies.

### Perceived and factual learning outcomes and motivation for mathematics related to perceptions and use of the VLE for mathematics

### Learning outcomes
As to perceived learning outcomes, analysis showed no evidence of correlations between students’ perceptions of having difficulty with mathematics and the frequency or nature of use of the VLE or perceptions on the VLE. With respect to factual learning outcomes, we did not find a relationship with the frequency or the nature of VLE use or with perceptions on the VLE.

### Motivation
With regard to aspects of motivation for mathematics we found some correlations. Table 7 presents significant correlations between students’ evaluation of the VLE for mathematics and aspects of motivation. First, students with the opinion that mathematics is highly relevant evaluated the VLE more positively than other students. Second, students who said they exerted a lot of effort on mathematics evaluated the VLE more positively than other students. There were no correlations between VLE perceptions and the other motivation variables, anxiety and pleasure. Analysis showed no support for the suggestion that motivation for mathematics and frequency of VLE use were related.

However, we did find a significant relationship between motivation and the nature of VLE use (see Table 8). The results show that students who said they exerted a lot of effort on mathematics used the IWB lessons on the VLE more often than other students. It is also clear that more motivated students consulted the test files on the VLE less often compared with less motivated students, as shown by the negative correlations in Table 8.

### Table 7. Correlations Between Evaluation of the VLE for Mathematics and Aspects of Motivation for Mathematics

<table>
<thead>
<tr>
<th>Motivation scale</th>
<th>$R$</th>
<th>$p$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort</td>
<td>.16</td>
<td>.036</td>
<td>175</td>
</tr>
<tr>
<td>Relevance</td>
<td>.17</td>
<td>.021</td>
<td>174</td>
</tr>
</tbody>
</table>

VLE = virtual learning environment.

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This was probably due to relatively low mathematics performance levels in the sense that low performers need to consult the VLE more and do more homework compared with high performers. Mathematics motivation shows a positive correlation with mathematics performance on average. Table 9 gives the correlations between the five consecutive times the MEQ was administered and the average grade for mathematics (analysis of three samples, see Method section).

It can be seen that the strongest and most consistent correlations are between mathematics performance and mathematics anxiety and pleasure, respectively, whereas the correlations with effort and relevance appear to fluctuate with time and are much weaker.

### Conclusions

The use of IWBs and VLEs in education is increasing. The opportunities created by both technologies, for example, for making lessons more interactive and supporting learning ‘anytime, anywhere’, are promising. However, one of the constraints of their introduction and implementation in schools is that they are time consuming for teachers and other staff. It may be efficient to combine the two technologies and to develop teaching materials for the IWB that are also made available to students on the VLE. This study focuses on an example of the combined use of IWB and VLE for mathematics and reports the results of a 3-year intervention in a secondary school in the Netherlands. Teachers developed digital learning materials for the IWB, used them in their lessons and then made the materials available on the VLE for students to use at any time.

The first research question was: to what extent is students’ exposure to IWB lessons and the availability of these lessons on the VLE related to students’ learning outcomes in mathematics in one school year and motivation for mathematics over 3 years? To answer this research question, we formulated the following hypothesis: students with higher exposure to IWB lessons are more motivated for mathematics and perform better than students with lower exposure to IWB lessons.

Our results did not support this hypothesis regarding learning outcomes. There was no evidence that the use of an IWB in mathematics lessons is associated with better learning results. However, with regard to the longitudinal study on motivation, we found partial support for our hypothesis. Students who were always taught mathematics with the IWB and had the option of using the VLE after lessons consistently showed higher average scores compared with the other two conditions, sometimes or frequently. Although a significant main effect was only demonstrated on two of the four motivation subscales, namely anxiety and pleasure (i.e., less anxiety and more pleasure in the IWB condition ‘always’), this is nevertheless an initial indication of a longitudinal effect on motivation. In earlier research, the effect of IWB use on students’ motivation was not decisive or considered to be a short-term effect.

The second research question is of a descriptive and explorative nature and is divided into two sub-questions:

- **a)** How do students evaluate the VLE for mathematics, and how often and in what way do students use the IWB lessons and other mathematics learning materials that are available on the VLE?

- **b)** How are these perceptions and use related to perceived and factual effects on students’ learning outcomes and motivation for mathematics?

Students in our research especially appreciated the VLE for mathematics because the IWB lessons were made available on it. They mostly used the VLE to consult the IWB lessons provided by teachers, in particular to prepare themselves for tests and

<table>
<thead>
<tr>
<th>Type of files used</th>
<th>Motivation scale</th>
<th>$r$</th>
<th>$p$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>IWB lessons</td>
<td>Effort</td>
<td>.27</td>
<td>.027</td>
<td>154</td>
</tr>
<tr>
<td>Effort</td>
<td>−.19</td>
<td>.018</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>Anxiety</td>
<td>−.27</td>
<td>.001</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>Pleasure</td>
<td>−.25</td>
<td>.002</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>Relevance</td>
<td>−.30</td>
<td>.001</td>
<td>154</td>
<td></td>
</tr>
</tbody>
</table>

Table 8. Correlations Between Nature of VLE Use and Aspects of Motivation for Mathematics

IWB = interactive whiteboard; VLE = virtual learning environment.
examinations. When the IWB lessons were put on the VLE, some students chose to make fewer notes during class so that they could pay more attention to the teacher’s instructions.

Differences in the way in which specific groups of students use or benefit from the VLE for mathematics were explored. Boys’ perceptions of the VLE were more positive than girls’ perceptions, although the frequency and nature of VLE use did not differ. The availability of the VLE for mathematics seems especially important for students in their final year. The results show that these students used the VLE more often than other students. Not only the frequency of VLE use was different for these students, but also its nature. Students in their final year used the IWB lessons and files related to planning more often than other students.

Our study shows no evidence of any association between learning outcomes and the frequency or nature of use of the VLE, or perceptions on the VLE for mathematics. The VLE was evaluated more positively by students who held the opinion that mathematics is highly relevant in society and by students who said they exerted a lot of effort on mathematics. Moreover, the nature of VLE use of the latter group was different from other students. They consulted the IWB lessons on the VLE more often than students who put less effort into mathematics, although there were no differences between the groups in relation to the overall frequency of VLE use. Test files tended to be consulted less by students who are more strongly motivated towards mathematics. Finally, anxiety and pleasure in particular were consistently related to learning results for mathematics (i.e., more pleasure and less anxiety were related to better learning outcomes).

Discussion

The study reported here has certain limitations. First of all, its predominantly explorative nature makes it difficult to draw more general conclusions. The research took place at only one school and both teachers and students were not randomly selected. Especially the longitudinal 3-year study focused only on a small subsample of students. Therefore, the results must only be interpreted as tentative support for the added value of combining IWB lessons and the use of the VLE.

Second, our study did not include observations of the lessons in which the IWB was used. This could have
have been useful to gain better knowledge of the materials that were available on the VLE. However, a review of the mathematics materials on the VLE showed that using the IWB and VLE did not transform participating teachers’ teaching practices. The IWB was used in a quite simple and straightforward way, which was reflected in the materials available on the VLE.

Third, the use of the words ‘sometimes’ and ‘frequently’ for characterizing exposure to the IWB for two groups of students is not in accordance with the standard definitions of these notions, which are ‘at short intervals’ and ‘from time to time’. In this paper, the terms refer to the amount of time students were taught mathematics with an IWB. So the characterization of two of the ‘IWB conditions’ may cause some confusion.

In all, our study may be a step towards more efficient use of ICT tools. Both teachers and students may profit from the relatively simple combination of IWB and VLE. For teachers, such a combination can be profitable in terms of time spent on lesson preparation. Students were satisfied with the VLE and found it useful. The results indicate that it is important that teachers consistently make their IWB lessons available on the VLE, otherwise students use the VLE less frequently, which in turn diminishes the positive effect on motivation. This is also important considering the finding that students may want to adjust their strategies regarding making notes in class.

Our study did not show an increase in students’ learning outcomes for mathematics. This may be due to insufficient and inconsistent use of the VLE. Therefore, more controlled experiments are needed in which both teachers and students use the VLE in a consistent way.

References


