

Advanced Teaching with Virtual Chalk and Four Parallel Video Signals

(revised and expanded)

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Synopsis

Traditionally, mathematics lecturers have mainly been using chalkboards for formula derivation, presentation of results and illustration by examples. Beside this chalkboard didactics several Information and Communication Technologies (ICT) and computer programmes are brought into action. Moreover, in the coming decades online education practices will intermix with conventional ones asking for tools that can be used for both worlds. As a consequence, it is important to equip lecture halls and classrooms henceforth with teaching environments that facilitate virtual chalk combined with ICT tools.

At Delft University of Technology a pilot scheme has been launched in April 2012 to introduce more advanced technological tools for teaching mathematics and technical-scientific subjects. A virtual chalkboard was integrated with an Audio-Visual Information Technology (AV-IT) facility. Now, projection of four computer programs next to each other became available for our lecturers. They teach courses with a low latency interactive SMARTboard and four different video signals that are presented simultaneously. Video signals are for example a PowerPoint presentation, one or more digital chalkboard instances from the interactive board, a Maple application, a PDF document, a video clip or a browser window. As is indicated in Figure 1, students watch all video signals at once.



Figure 1: Impression of Virtual Chalkboard and Four Parallel Video Signals; Still and in Practice

The classroom computer contains a quad graphics video card to support the four video signals, which are arranged in a quadrant set-up; top left, top right, bottom left and bottom right. The top right quadrant represents the classroom computer's desktop. An application is started just as on any computer. The teacher can rotate this desktop signal clockwise or counter clockwise over the four quadrants with the DisplayControl application, as is described in section 1.3. Normally, multiple applications are operating in one and the same screen. With this projection system a presentation can be organized in such a way that different applications run simultaneously and independently in the four different quadrants of the projection screen.

Several lecturers at Delft University of Technology have participated in the pilot scheme. In this paper two mathematics case studies are described, one lecturer with the courses Linear Algebra and Calculus and the other lecturer with Calculus. In section 3 of the paper a detailed description is given in which way these two lecturers applied the new system (SMARTboard in combination with four video signals) in their practices. The operation of virtual chalk and signal navigation is easy and mastered within a few minutes. The new way of lecturing, however, takes considerable time for the lecturer to become familiar. It requires navigation skills in direct relation with the simultaneous presentation of subject matter over the four video signals through different applications.

Since the start, eight evaluation periods have been taken place. Paper-based surveys were held among the students at the end of each 10-week course periods. The questions and results of 457 completed questionnaires and 238 students' comments are described in section 4 of this revised paper. Students are very enthusiastic and prefer the SMARTboard with four quadrants over the old-fashioned chalkboard. They are very positive about the use of these advanced instruction tools. Such encourages us to apply the system at more lecture halls.

Today, a second hall is equipped with a state-of-the-art AV-IT installation, three 30-person design studios are using AV-IT systems with two parallel video signals, a training set for physics lecturers is to be installed soon, the upgrade of five larger lecture halls are under discussion, and a new faculty building in 2016 will be provided with similar AV-IT installations. Meanwhile, the pilot scheme continues.

1 Lecture Hall AV-IT Equipment

Many lecturers at our technical university prefer to use chalkboards when they give lectures, which involves the derivation and explanation of various scientific formulae, sketches, graphs or diagrams. Chalkboard didactics seems to be appropriate for explaining difficult derivations, i.e. the structural and stepwise appearance of the formulae on the chalkboard with its corresponding clarification supports the cognitive flow from teacher to student. The easy handling of chalk has become a second nature for teachers; it is easy, quick and fault-tolerant. An alternative medium must have the potential to be equally user-friendly.

1.1 Virtual Chalk from Interactive SMARTboard

The 8070i interactive SMARTboard with its Notebook application resembles chalkboard writing and sketching. This particular SMARTboard has a very low latency of 14 milliseconds (ms). We assumed with figures for eye-hand coordination taking about 80 to 150 ms [1] and the arm movement from rest to writing position taking approximately 350 ms [2] that chalkboard writers could easily be accustomed to handle this very fast SMARTboard. This assumption was substantiated in several try-

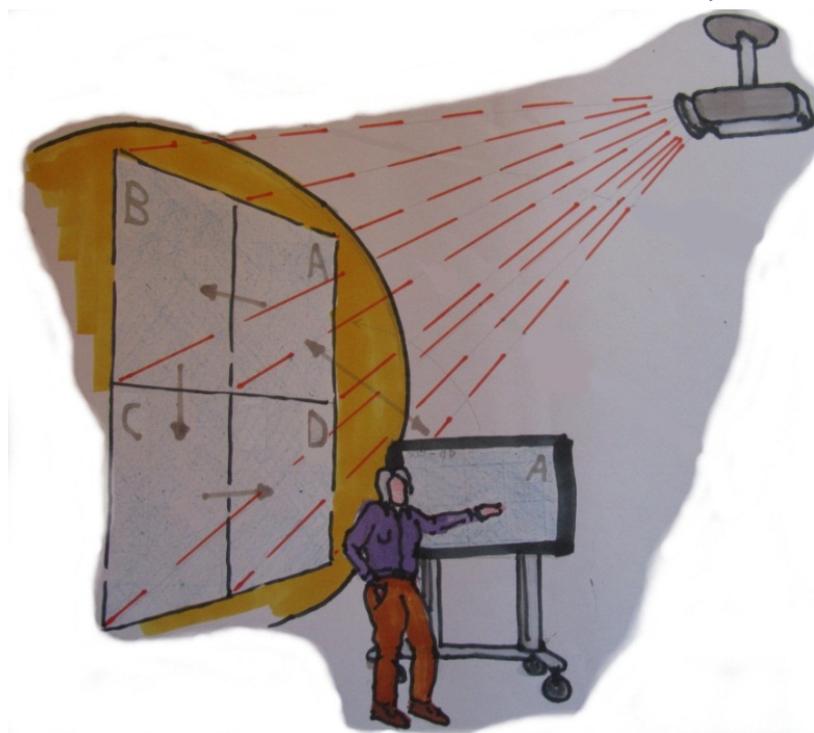
out sessions with more than ninety teachers. On average it took only a minute to get used to the pen and to write and sketch digitally.

Nearly all default available Notebook functionalities were removed from the menu to make the operation of the SMARTboard easy and convenient. Teachers only need the pen to write and draw in four default colours, they need their finger to select and navigate, and they need the back of their hand to erase. These three main functions “write”, “select” and “erase” make it easy for lecturers to turn over from real chalk to virtual chalk.

Unfortunately, the writeable surface area of the 70” SMARTboard is only 1.35 m², while chalkboards in classrooms cover at least 4 m². Chalkboard writers are in need of a similar writing surface area when they want to use the virtual chalk. One way of creating more writing surface is by enlarging the Notebook slide virtually, but in such way the text is moving out of sight, out of the visible SMARTboard window. Only objects presented within the SMARTboard window remain visible for the public. A solution was found with the introduction of multiple windows.

1.2 Four Quadrants to Expand the SMARTboard Writing Surface Area

Written texts and sketched diagrams should remain visible, at least for a while. Students want to be able to copy the formula derivation from a fully written SMARTboard window in their notebooks while the teacher proceeds with writing on the next SMARTboard window. Therefore, at least a second SMARTboard window is needed to show the history of drawn-up derivations. In consultation



with teachers we have decided that four visible windows seemed a proper number. Two windows with Notebook for the virtual chalk, one window for a PowerPoint or PDF presentation and one window for additional use, for example an Internet browser, a demonstration application, or a third virtual chalk window.

For the pilot scheme an interactive SMARTboard, mounted on a trolley, was connected to the audio-visual (AV) installation of the James Watt lecture hall at the Faculty

Figure 2: Impression of Movable SMARTboard combined with a Four Quadrants Projection system

of Mechanical, Maritime and Materials Engineering (3mE). Its AV-IT installation has been altered to switch parallel video signals over four quadrants. The projection screen measures a total surface area of 10 m², which was electronically divided into four quadrants of 2 by 1.25 meters. The top right video signal (quadrant A) shows the same image as the one projected on the SMARTboard, which is the very same signal as the desk monitor of the classroom computer. In such way the restriction of

limited SMARTboard writing surface was overcome. Figure 2 shows an impression of the teaching environment.

1.3 Driving the Four Video Signals

Applications can be started on the classroom computer or via the interactive SMARTboard. DisplayControl software was developed in-house to rotate the “A” video signal clockwise or counter clockwise. After rotation the desktop is cleared again from which a next application can be started and rotated also. In such way teachers have the opportunity to show multiple and different images at the same time or to expand the digital chalkboard surface.



Figure 3: DisplayControl: blue arrows rotate the four quadrants, rectangular blue button interchanges quadrants 1 and 3, red arrows navigate through PowerPoint slides and green arrows navigate through PDF pages

In Januari 2014 an enhanced version of DisplayControl became available. Figure 3 shows different appearances of DisplayControl dependent on the applied computer programs. With the blue “left-right” arrow buttons of DisplayControl the four quadrants can be rotated clockwise or counter clockwise. These buttons are used at the start of the lecture to place the different video signals in the right quadrants. The rectangular blue button can interchange quadrants 1 and 3 during lecturing. For example is it used in case the SMARTboard window from quadrant 1 is fully written. Activating the button interchanges quadrants 1 and 3 and the lecturer furthers the explanation while students still see the written notes from the former quadrant 1, now presented in quadrant 3. With this interchange button quadrants 2 and 4 remain stationary instead of rotating too as they did before. The interchange function was added due to students’ feedback for they commented that sometimes rotation of all images was too distracting.

In case a Microsoft PowerPoint presentation starts two red “previous-next” arrow buttons will immediately appear next to the blue ones for navigating PowerPoint to its previous or its next slide. The lecturer may operate the PowerPoint presentation from any quadrant while writing formulae at the SMARTboard. Furthermore, two green “previous-next” arrow buttons appear instantly when a PDF document is opened. The lecturer is able to operate the PDF pages next to the PowerPoint presentation. In such way the teacher is able to direct multiple sorts of video signals over the four quadrants.

NB: Due to Windows only one PowerPoint presentation can be shown in full screen mode, but with Adobe Reader a second simultaneous presentation is possible.

1.4 Audio-Visual Functionalities in Class

The AV-IT installation must support different educational practices. When lecturers want to present from their laptop computer then such scenario must be available as an option at the operation panel. If teachers want to present with four quadrants they have to make use of the classroom computer due to its video card functionalities, thus such scenario must be available too at the operation panel.

The SMARTboard is connected through its VGA connector and USB interface for interactive use. Hence video signal A, as indicated in Figure 4, is permanently connected to the video processor and SMARTboard. Later versions support HDMI as well. If teachers want to mix multiple video signals on inputs 2, 3 and 4 of the video processor then these inputs can be connected to the remaining video

outputs of the classroom computer (B,C,D), or to the guest laptop, or to the lecture capture camera, or to the visualizer.

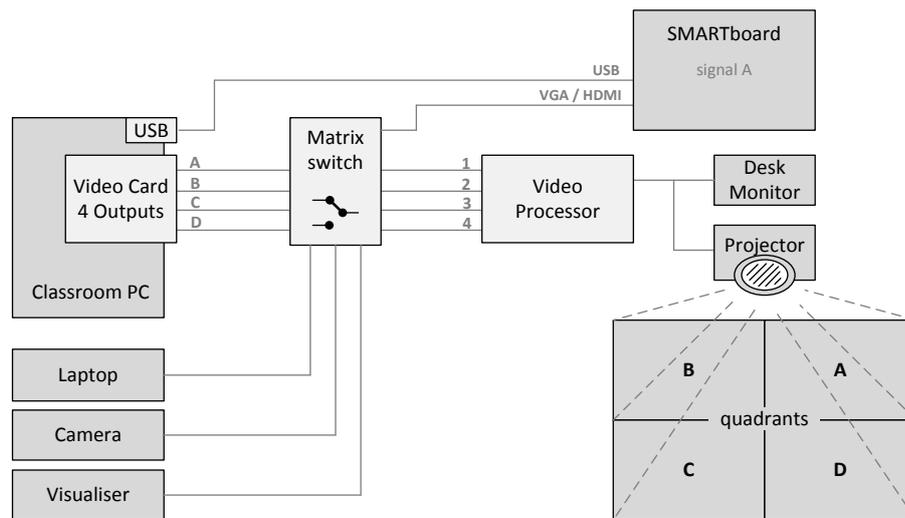


Figure 4: Functional Diagram for the Pilot Scheme Equipment

The circuitry is to be configured in scenarios that must be available at the AV operation panel to support the multiple educational practices. The pilot scheme equipment in the James Watt Hall provides the teacher with possibilities that go beyond the traditional chalkboard

practice. Additionally, an extra feature was built in to show a

quadrant in full screen mode in case the video signal contains too small characters to be read at the rear of the classroom.

2 Chalkboard Writing versus SMARTboard Writing

Chalkboard users often lecture in halls with more than hundred seats. The maximum reading distance in lecture halls is determined by the distance from chalkboard to back row. Most of the reading distances vary from 12 to 20 meters dependent on the hall. How large then should the written characters be to be legible at rear seats?

2.1 Heights of Characters Written on the Chalkboard

Several rules of thumb give indication for the height of written characters on chalkboards. One rule advises to follow a ratio of 1 to 200 compared to the viewing distance, another claims that lower-case lettering must not be smaller than 3 cm in height for every 10 metres of distance to the board, and a third recommends that the character height should be about 1 percent of reading distance.

According to the Human Factor Research & Engineering Group of Federal Aviation Administration (FAA) character heights for presentations en written texts should be around 20 arc minutes [3]. Observations at campus showed that our chalkboard lecturers have been writing characters with heights between 7 to 10 centimetres. Dependent on the lecture hall those character heights varied between 17 and 23 arc minutes.

2.2 Heights of Characters Written on the SMARTboard

When chalkboard writers use the SMARTboard for the first time they start with a character height of approximately 6 cm. After a short while the user adapts the character height, reducing it to 4 or even 3 cm. The representation of the Notebook slides on the large 10 m² screen showed characters that were perfectly readable at the rear seats of the lecture hall. Furthermore, when the lecturer uses smaller characters then relatively more writing surface is available on the SMARTboard.

2.3 White Characters Written on Black Background

The legibility of white characters on a black chalkboard is really good due to its contrast. It is similar at the front row as it is at the back row of the lecture hall. Computer applications, which often have black characters on white backgrounds, are quite the opposite unless the brightness is high enough. For our pilot scheme we have chosen for white characters on a black background due to the wonderful contrast of chalkboards. Moreover, with white on black the 70 inch electronic SMARTboard shows a very still image. Black characters on white, however, with such a large display generate too bright images causing headaches and squeezing eyes within minutes.

2.4 Reading Distance of White Characters on SMARTboard

How would the legibility of the SMARTboard versus its reading distance be now that we have chosen white characters on a pitch-black background? A few tests were organised on a small scale with a group of twelve lecturers. Electronic fonts such as Arial and Calibri were displayed in different heights where their reading distance were empirically determined by the group. Table 1 shows the results.

The contrast between the white characters and the black backgrounds on the SMARTboard has not shown any restrictions for the viewing distance. However, one must be aware that the displaying surface area might be too small for an audience in larger spaces. It is not convenient to stare at a relatively small display, hence projection on wall or projection screen is to be advised.

Table 1: Character Height versus Reading Distance

Character Height (cm)	Reading distance (m)
1,5	7
2	10
2,5	13
3	15
3,5	20
4	25
5	30
6	40

The James Watt hall equipment is provided with a 10 m² presentation screen and a reading distance of 12 meters at the back row. The written characters between 3 and 4 cm on the SMARTboard should be very readable for all attendants in the lecture hall considering the figures of Table 1. Moreover, its representation in one of the quadrants magnifies the image with a factor of 1.85 (ratio of 2.5 m² versus 1.35 m²) making it even more readable.

3 Case Descriptions

The system as described has been operational in the James Watt Hall at the Faculty of Mechanical, Maritime and Materials Engineering at Delft University of Technology. Two mathematics lecturers were keen to try out this system with the courses they lecture at this Faculty, namely J.G. Maks¹ with Linear Algebra and Calculus courses and I.A.M. Goddijn² with Calculus courses.

Mathematics lecturers are traditionally known to prefer working with chalkboards. Chalkboard didactics remains to be fundamental for the presentation of mathematics. On the other hand modern day mathematics teachers are avid users of ICT applications while giving their lectures. Hence this system, where chalkboard didactics can be fully integrated with the use of ICT applications, seems to provide the ideal setting for the modern day math lecturer. Described are two examples in which way the system was used:

3.1 J. Maks, Linear Algebra and Calculus, 4th period of 2011-2012, 2nd and 4th periods of 2012-2013, 1st and 2nd periods of 2013-2014

The lecturer uses one quadrant for a prepared PowerPoint presentation, two diagonally opposite



Figure 5: Lecturer Maks: Mathematical Discourse with Four Quadrants

quadrants for the SMARTboard's Notebook and the remaining quadrant for computer application Maple. Didactics roughly works as follows: the lecturer uses a prepared PowerPoint document to present main definitions, concepts and theorems of the course. He uses the SMARTboard, pretty much in the same way as he would use a chalkboard for the derivation of the results and the illustration by means of small examples. The lecturer interchanges the two opposite SMARTboard quadrants (two hits on the blue Display Control button) if the interactive one (top right quadrant) is fully written. In such way the next SMARTboard quadrant (bottom left quadrant) always contains the most recent history of written notes. The MAPLE software in the last quadrant is used at any time during the lecture to demonstrate the method or result by means of an example that would be too complex to work out by hand. Soon after, Maks began using colours and copy-paste options and over time he initiated Adobe as well to introduce subject matter assignments. During such in-depth sessions earlier notes were retrieved from memory to explain or to resume. Since the 7th period Maks imported pictures of computer generated graphs to lecture from and to draw upon. Figure 5 shows an impression of his mathematical practice.

3.2 I. Goddijn, Calculus, 1st and 3rd periods of 2012-2013

The lecturer uses one quadrant with prepared course materials in PDF, two quadrants for SMARTboard's Notebook applications and the remaining quadrant either for an Internet browser or the computer application Maple. In this case the lecturer uses an interactive PDF document (instead

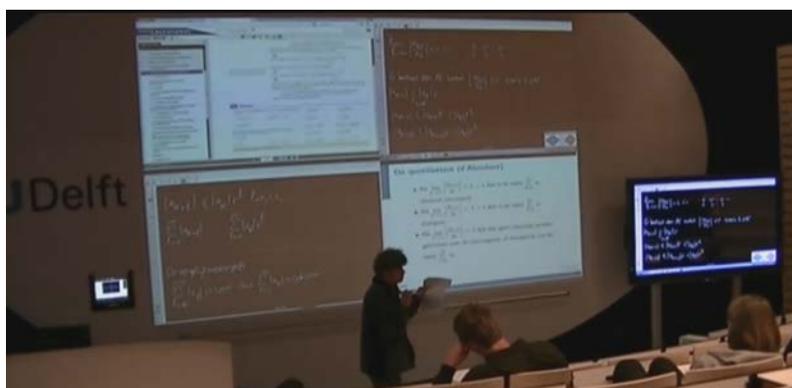


Figure 6: Lecturer Goddijn: Mathematical Discourse with Four Quadrants

of a PowerPoint document) for the prepared presentation of the course. A disadvantage at the time of using PDF for the presentation in comparison to PowerPoint was that DisplayControl did not support a previous-next button to navigate through it. Hence the PDF document had to be in the top right quadrant when the

lecturer interchanges the two opposite SMARTboard quadrants (two hits on the blue Display Control button) if the interactive one (top right quadrant) is fully written. In such way the next SMARTboard quadrant (bottom left quadrant) always contains the most recent history of written notes. The MAPLE software in the last quadrant is used at any time during the lecture to demonstrate the method or result by means of an example that would be too complex to work out by hand. Soon after, Maks began using colours and copy-paste options and over time he initiated Adobe as well to introduce subject matter assignments. During such in-depth sessions earlier notes were retrieved from memory to explain or to resume. Since the 7th period Maks imported pictures of computer generated graphs to lecture from and to draw upon. Figure 5 shows an impression of his mathematical practice.

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lecturer needed to go to the next or previous slide of the presentation. The two SMARTboard quadrants are used in a similar way as described in case 1.

Finally, the lecturer used not just one but various applications in the remaining fourth quadrant: either for the use of Internet to show materials from the publisher's website of the Calculus textbook or for giving demonstrations with the software package MAPLE. Figure 6 shows a picture of Goddijn's education practice.

4 Evaluation Results

The math lecturers J. Maks and I. Goddijn are very enthusiastic about this advanced set of tools for teaching math courses at university level. Unfortunately some complex technical problems occurred during the 6th and 7th periods. After considerable investigation the intermittent errors caused by Adobe Reader's interaction in combination with Matrox Technologies videodrivers were finally solved.

Both lecturers do see many advantages with this system that facilitates new didactic possibilities, which certainly will enhance the quality of their lectures. Improved conditions have already been demonstrated when students work out assignments in class. On demand earlier SMARTboard formulae derivations and crucial notes are retrieved from the system's memory to be presented in the quadrants again. Students love this possibility. Maks and Goddijn hope that more lecture halls across the university will be equipped with this AV-IT equipment.

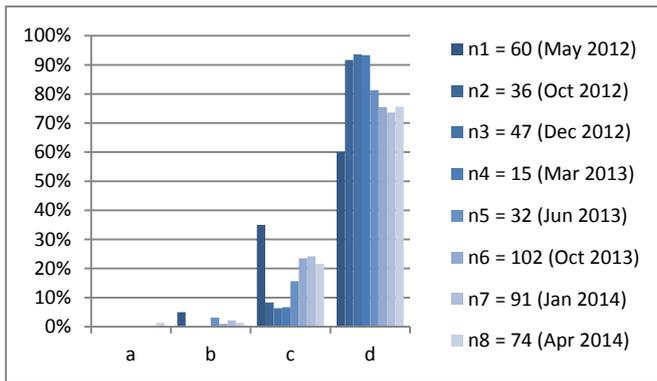
The SMARTboard and four quadrants projection facility is operational since April 2012. It has since been used in education for eight 10-week periods. It has potential to become standard lecture hall equipment, but how do students value this lecture hall equipment?

4.1 Student survey

Eight student cohorts, who followed the before-mentioned mathematical classes, were approached to assess the advanced lecture hall equipment. The first cohort of 60 students in May 2012 followed Linear Algebra, a second cohort of 36 students in October 2012 followed Calculus, a third cohort of 47 students in December 2012, a fourth of 15 in March 2013, a fifth of 32 in June 2013, a sixth of 102 in October 2013, a seventh of 91 in January 2014 and a eighth cohort of 74 students in April 2014. Each cohort was given the following set of seven paper-based multiple choice questions. There is one exception: Since the eighth period question 4 about rotation was slightly altered, because DisplayControl got an update with an interchange possibility thanks to students' suggestions.

4.1.1 Question 1: How do you experience the SMARTboard's legibility?

In the first period the SMARTboard's default settings for the colours red, green and blue on a white background were used. These default colours did not do well on the pitch-black background. Such explains the "b" score (white is good, colours are not) and high "c" score (white is perfect, colours are doable) of the n1 cohort. Henceforth the colours were changed; red into bright orange, green into bright green and blue into cyan. Results of the following cohorts show that the new colours are fine. The questionnaire results are presented in bar graphs on the left for each cohort and summarised in pie charts on the right.



- a. White and colours are barely legible (0% of 457)
- b. White is good, colours are not (2%)
- c. White is perfect, colours are doable (21%)
- d. White and colours are both perfect (77%)

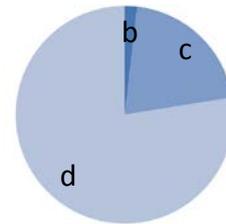
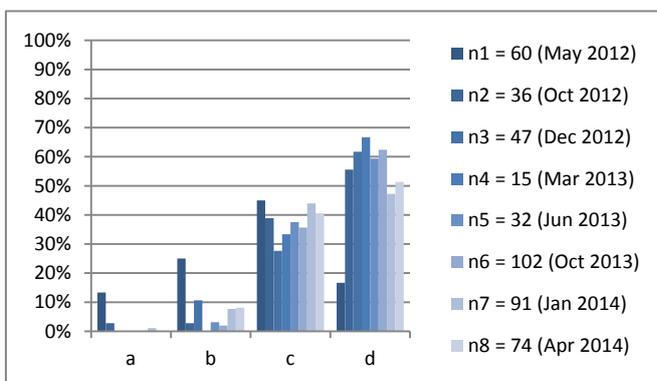


Figure 7: Legibility of SMARTboard (N = 457)

4.1.2 Question 2: How do you experience the legibility of the four video signals on the projection screen?

During the first evaluation period the classroom's projection screen had back-view projectors in all four quadrants. Each one had a High Definition (HD) resolution of 1280*800 pixels. Those projectors in combination with the applied projection glass caused unbalanced intensities in each of the quadrants. Furthermore, the adjacent images could not be outlined properly because no edgeblending was used. Such explains the critical answers of the first cohort n1. In summer of 2012 a new WQXGA projector with 2560*1600 resolution has been installed, delivering a sharp and regular image over all four quadrants. The results of following cohorts corroborate with the improved legibility and changed colours. Another issue is the use of window shades instead of opaque blinds. As a consequence, sunshine still has its influence when it shines right on the shades. Students mentioned this in open comments, see section 4.1.8.



- a. White and colours are barely legible (2% of 456)
- b. White is good, colours are not (8%)
- c. White is perfect, colours are doable (39%)
- d. White and colours are both perfect (51%)

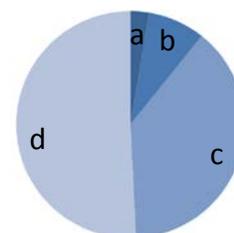
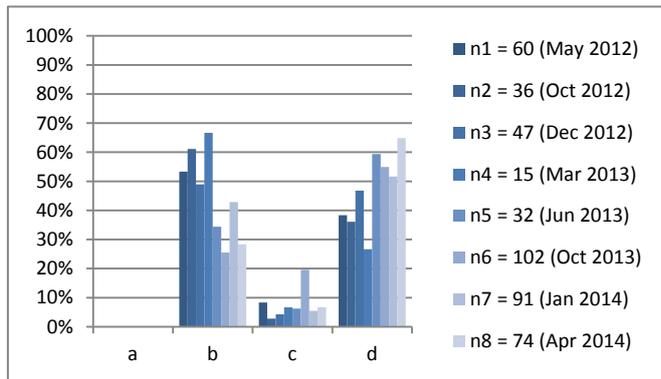


Figure 8: Legibility of Projection Screen (N = 456)

4.1.3 Question 3: Do you follow the teacher's writings on the SMARTboard or from the projection screen?

Teachers appreciate if students follow their chalkboard writings directly. Before the project started teachers worried that the video wall would distract the students when writing virtually. As the results show, teachers do not have to worry at all. More than half the students follows the teacher's writing directly while the other half switches between SMARTboard and projection screen. Students commented that while copying the notes they could look these up on Quadrant 1 in case the teacher stands in the way. Striking is that students want to follow the (digital) chalk itself. They consider the

chalk as the item from which the knowledge flows supported by its vocal explanation. The fact that the lecturer's back is turned to the audience is not relevant at all.



- a. I do not know (0% of 457)
- b. More often from SMARTboard (40%)
- c. More often from projection screen (9%)
- d. About fifty-fifty (51%)

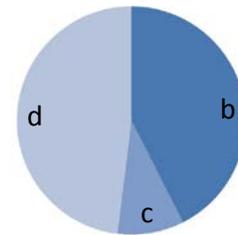


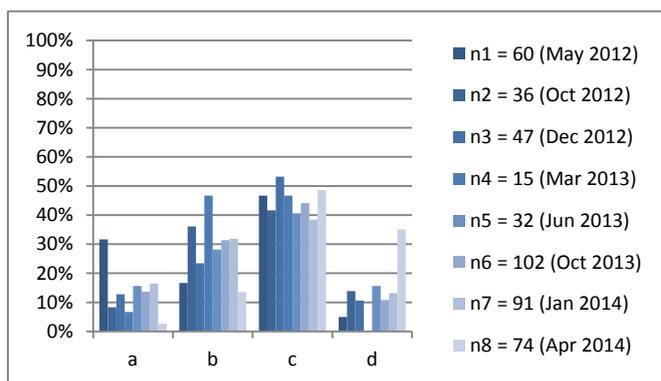
Figure 9: Reading from SMARTboard or Projection Screen (N = 457)

4.1.4 Question 4: How do you experience the clockwise or counter-clockwise rotation?

Clockwise and counter-clockwise rotation of the quadrants is confusing in the beginning, not only for students, but especially for the teacher. Working with four parallel video signals demands a thus far unknown navigation skill from the teacher. The four video signals including their presented subject matter and their rotation have to be in focus and in sync with each other. That is hard work!

If we consider the answers then maybe this unaccustomed search for the right quadrant played a role with the valuation. Yet, comparing the averaged numbers of "not good" (14%) to "good" (45%) plus "perfect" (15%) delivers a one-to-four ratio with which continuation should be granted.

Still, due to students' comments, an interchange button was added to DisplayControl in January 2014. With this new feature quadrants 1 and 3 can be interchanged while quadrants 2 and 4 remain in place. In such way the negative effect of rotating all quadrants is overcome.



- a. Not good (14% of 457)
- b. No comment (26%)
- c. Good (45%)
- d. Perfect (15%)

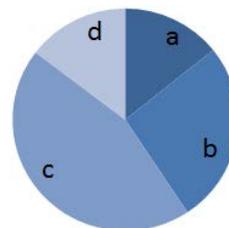
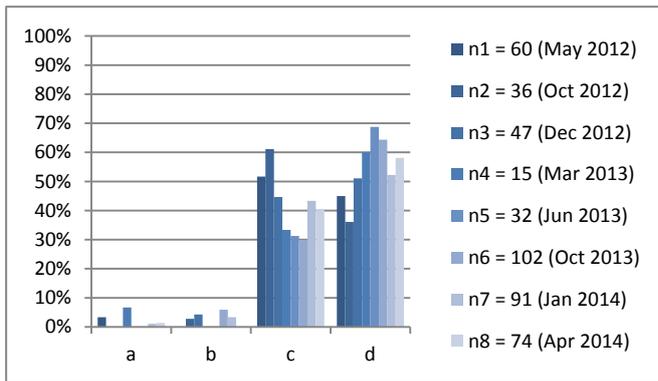


Figure 10: Quadrant Rotation Experience (N = 457)

4.1.5 Question 5: How do you experience the parallel presentation over four quadrants?

The mathematical courses become more coherent and perhaps more understandable with this equipment. We assume that the parallel presentation of proposition, method of its derivation and demonstration of its outcome helps for better comprehension. At the least students are very positive. The four quadrants with even so many or more parallel video signals scored 96 percent positive with a decreasing "good" in favour of an increasing "perfect", taking lecturing to a next level.



- a. Not good (1% of 455)
- b. No comment (3%)
- c. Good (41%)
- d. Perfect (55%)

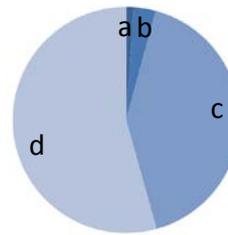
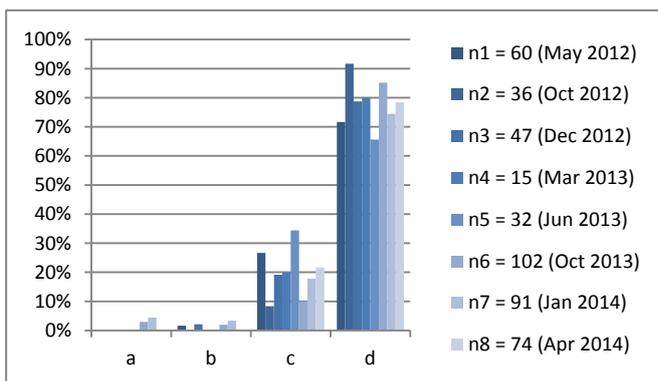


Figure 11: Parallel Projected Video Signals (N = 455)

4.1.6 Question 6: How do you think about the replacement of chalkboards?

Discussions are on-going about the replacement of chalkboards. Scientific teachers are persistent users because serious alternatives to facilitate proper chalkboard didactics have not yet come forward. This question was posed to obtain a general feel of how students think about the use of chalkboards and a possible replacement with similar lecture hall equipment. Considering their responses we may conclude that they love this new teaching environment.



- a. No comment (2% of 455)
- b. No, do not replace chalkboards (2%)
- c. It depends on the situation (18%)
- d. Yes, replace chalkboards with SMARTboards (78%)

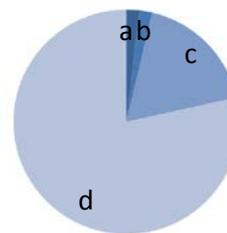
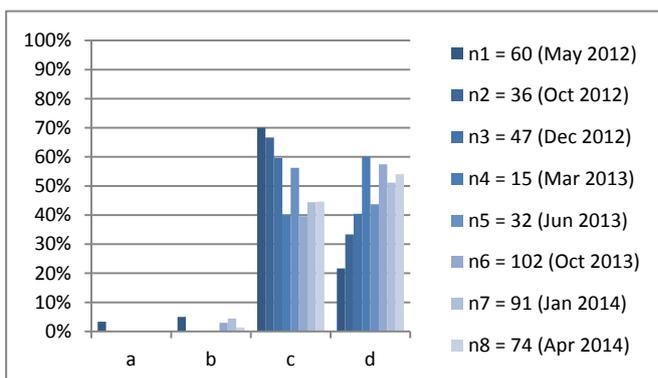


Figure 12: Chalkboard or SMARTboard (N = 455)

4.1.7 Question 7: How do you experience the education's quality with this installation?

The quality of education is a multifaceted and objective concept. It is hard to give a clear definition. Still the personal meaning of students was asked for concerning the continuing presentation of the joined-up video signals and SMARTboard. Striking is the very positive response of 97%. Moreover, a positive trend is observable from a decreasing "good" to an increasing "perfect".



- a. Not good (0% of 455)
- b. No comment (2%)
- c. Good (51%)
- d. Perfect (46%)

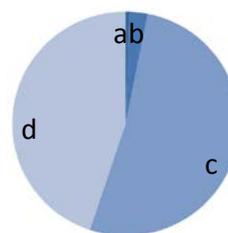


Figure 13: Quality of Education (N = 455)

4.1.8 Do you want to comment on something or make a statement about a subject?

Students have had the possibility to comment freely in an open text field. One has to keep in mind that the paper-based questionnaires were distributed during math classes, however, their responses concerned all lecturers scheduled in the James Watt Hall.

A total of 238 written comments have been collected from 209 students. After analysis the comments were subdivided into six distinct categories: “Train Lecturers”, “Rotation confuses”, “Notes visible is perfect”, “Publish on VLE”, “Lecture Capture” and “Fabulous System”. A seventh category holds 63 remaining comments about the insufficient window shades (see section 4.1.2), the wish to use two PowerPoint presentations simultaneously, proposals for different quadrant set-ups and a comment about keeping a chalkboard in reserve when errors arise.

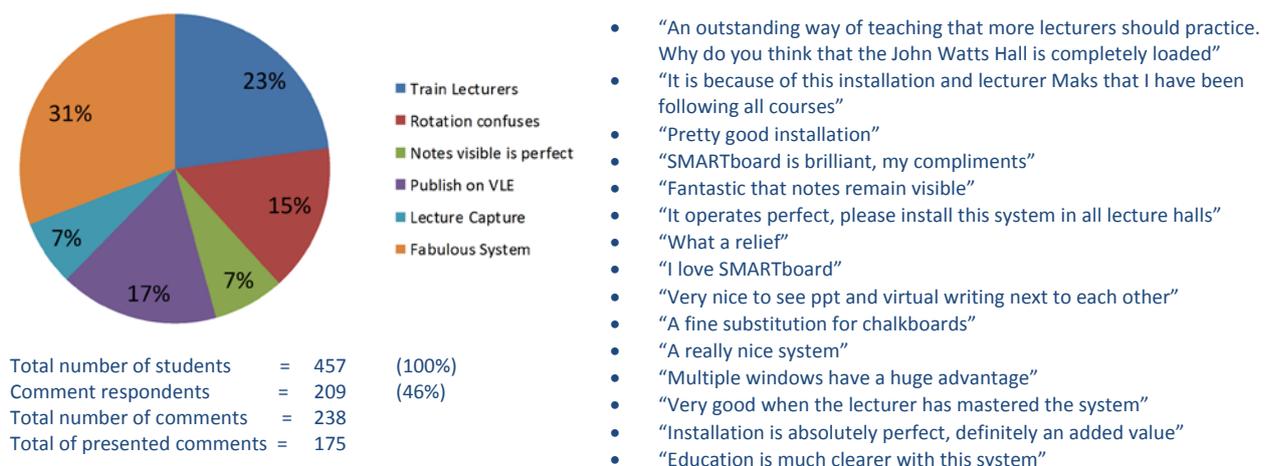


Figure 14: Students’ Comments (N = 175)

Figure 14 shows a pie-chart of the six categories including their ratio. On the right a few written comments are listed to indicate the positive opinions and feelings from the “fabulous system” category. Vocal comments that were given by the dozen are not collected in this paper.

5 Conclusion

At Delft University of Technology the lecture hall equipment discussed in this paper (interactive SMARTboard combined with four quadrants display and additional software) has been put into practice since April 2012. With the help of parallel video signals the writing surface area of standing virtual chalkboards is no longer limited to its physical dimensions. The electronic representation of white characters on a black background showed very readable virtual chalk images.

Two mathematicians have made extensive use of the new installation in the context of their lecture courses for large groups of students in the John Watts Lecture Hall at the Faculty of Mechanical, Maritime and Materials Engineering. To become accustomed to the basics of the new technology, no more than half an hour of practice was needed. The adjustment of didactics, however, does require a lot of thinking over a longer period of time. This will no doubt be the main challenge for lecturers who might use this system in the future. Now that J.G. Maks and I.A.M. Goddijn have been accustomed with the new possibilities they would not like to go back to a lecture hall situation without this advanced technological equipment.

Eight 10-week education periods have already led to success. The image quality of the presentation screen was improved right after the first period where colours and projectors were changed. Since

then the overall feel has motivated the teachers to ask faculty management to provide more lecture halls with this equipment. Another three to five lecture halls may be configured with a similar situation in the near future. First a technical study is to be conducted how to optimally integrate this advanced equipment in standing lecture hall installations. Meanwhile, a second lecture hall is fully equipped with a state-of-the-art AV-IT system next to three smaller design studios with two parallel video signals. Thus, the experiment goes on.

6 Discussion

We believe that the launching of new technologies in teaching environments must be done in small steps. At first, innovators and early adopters should be invited to explore the new system in a pilot experiment [4]. At this early stage shortcomings of the system and problems by its uses are to be indicated and solved before implementation on a larger scale is considered.

Secondly, the system's operation must start at a low level with only a few functions [5]. The present configuration of the SMARTboard is plain, it focuses on the functions "write", "select" and "erase". Our lecturers have been demonstrating that they gradually make more use of various SMARTboard functionalities. For example, after a short time they started to use different colours to highlight important parts. Some time later the copy-paste became a regularity to multiply matrices from one quadrant to another in order to save time. Now, lecturers make use of the more sophisticated functionalities such as exporting the notes into PDF documents for easy distribution over the Virtual Learning Environment and importing images to draw upon.

Thirdly, exploring the use of this lecture hall equipment with other avid chalkboard users requires a continuing evaluation practice. The simultaneous display of different applications on different screens offers lots of new didactic possibilities. For instance, what kind of experiences would lecturers from other fields such as physics, chemistry or hydrodynamics have if they would start to use this lecture hall equipment? Meanwhile, it can be mentioned that physics lecturers are so enthusiastic that they want similar AV-IT installations for at least four lecture halls in their new faculty building in 2016.

Fourthly, once this installation has become common practice, the creation of remedial materials, online instructions and Open Course Ware will be much easier; chalkboard notes shall become virtual notes. Now, a very same type of SMARTboard is used to make online materials for our MOOC's.

Fifthly, when this type of equipment is used on a large scale within an organization such as ours (Delft University of Technology) a technical support group with appropriate size must be available. The combination of AV technology and ICT requires technical staff who understand the ins and outs of both worlds. Since 2013, a multidisciplinary taskforce was established. Furthermore, a discussion has been started to institute expertise in a new AV-IT support group, to install equipment for lecturer training and to start new policy for lecture halls and classrooms at the Delft University of Technology. Such radical measurements will take time before being operational. Management for the SMARTboard's software and DisplayControl are already set.

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Acknowledgement

The author would like to express sincere gratitude to the co-operative mathematics lecturers:

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