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How to cite:

Hosein, Anesa; Aczel, James; Clow, Doug and Richardson, John T. E. (2007). An Illustration of Students'
Engagement with Mathematical Software using Remote Observation. In: 31st Conference of the International Group
for the Psychology of Mathematics Education, 8-13 Jul 2007, Seoul.

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AN ILLUSTRATION OF STUDENTS' ENGAGEMENT WITH MATHEMATICAL SOFTWARE USING REMOTE OBSERVATION

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Students using three types of spreadsheet calculators for understanding expected value were observed remotely. This remote observation involves the use of webcams and application sharing for observing students learning mathematics. The study illustrates how remote observation can be used for collecting mathematical education data and raises questions about the extent to which such a method can be used in future experiments.

INTRODUCTION

Various studies have investigated how students learn mathematics with software such as computer algebra systems (e.g. Bardini, Pierce, & Stacey, 2004; Berry, Graham, & Smith, 2006) and spreadsheets (e.g. Clarke, Ayres, & Sweller, 2005). However, traditional observation studies of students using software occurs when students are invited to a specially-configured computer laboratory or "user-lab" where they are video and audio recorded or the researcher visits and sets up audio and video recording facilities at the student's place of study (e.g. San Diego, Aczel, & Hodgson, 2006; Vale & Leder, 2004). Whilst user-labs provide controlled recording conditions and the possibility of more sophisticated technology such as eye-tracking (e.g. San Diego et al., 2006) these either remove or intrude on students in their natural studying environments. Less intrusive observation practices have included the logging of students' computer strokes and mouse clicks (e.g. Berry et al., 2006; Thomas & Paine, 2002) but this means rich video data is lost.

A method for observing students using software via the internet has recently been investigated called remote observation (Hosein, Aczel, Clow, & Richardson, 2007) which records both audio and video data, mouse clicks and keyboard entry. In remote observation, students use a remote application facility on their computer to connect to the researcher's computer where they are able to interact and use software on it (see Figure 1). Through the students' webcams and video conversation facilities in instant messengers (IMs), students are observed and interviewed whilst using the software. By using screen and audio capture software, students' on-screen actions, webcam video and audio can all be recorded. Hosein et al. (2007) indicated that students eventually forgot about being video recorded and observed since the window showing the webcam image was covered up. This perhaps may help in providing a more naturalistic approach to observing the students (Guba & Lincoln, 1981). This paper reports on proof-of-concept work on the use of remote observation of students using mathematical software.
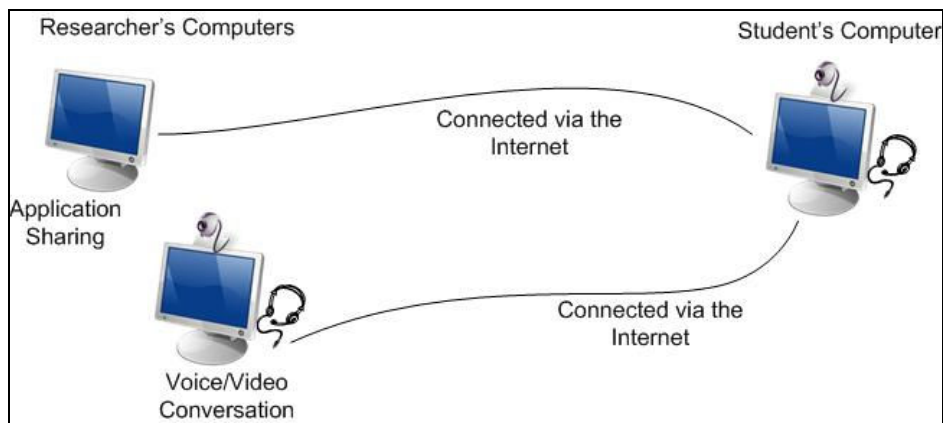
Figure 1: Remote Observation Process

METHODOLOGY

To understand how remote observation can be used for investigating students' learning of mathematics, a method was used to encompass both quantitative and qualitative data collection. The method followed that of quasi-experimental methods used in mathematical cognitive load theory (CLT) literature (e.g. Große & Renkl, 2006; Renkl, Atkinson, & Große, 2004; Schworm & Renkl, 2006). The quasi-experimental methods in CLT use a five-part procedure, usually to investigate to what extent students have learnt a topic (see Figure 2).

Steps	Instructions
1. Demographic Questionnaire	Students are asked to fill in a demographic questionnaire, including questions asking for mathematical level, age and gender
2. Instructional/ Study Materials	Students peruse materials to understand the fundamental concepts required for the learning of the topic
3. Pre-test	Students to determine what extent they have prior knowledge of the topic before the stimulus is provided for the experiment. The pre-test problems is at a lower difficulty level than the post-test problems
4. Experiment	Students are provided with the interventions/ factors that are being studied
5. Post-test	Students work on a set of questions to acquire quantitative data to compare the investigated interventions/ factors

Figure 2: Quasi-experimental method used by Atkinson, Renkl and colleagues

There is sometimes a variation in the literature, in that the second and third step of this method may be interchanged (e.g. Große & Renkl, 2006; Renkl et al., 2004). The preference for this paper is the way it is presented as this means that the learning from the instructional/ study materials do not have to be taken into account when comparing data between the pre-test and the post-test. This quasi-experimental design is used for collecting mainly quantitative data but by added on talk-aloud strategies Ericsson & Simon (1984), interviews and videoing, qualitative data is also collected.

Data collection in remote observation

In order to investigate remote observation as a method for observing students learning when using mathematical software, a simple mathematical topic was chosen: expected values. Expected values area is part of decision theory in operations research where probabilities are used to compare and determine best options. The aim of the study was to determine to what extent students may learn differently depending on the problem-solving software they employ. The software chosen for learning expected values was an Excel spreadsheet in which three types of spreadsheet calculators were used (coded using Visual Basic for Applications, VBA). Excel was chosen as it is familiar to many students and thus minimized the effect that familiarity with the software might have on the learning of the topic. The three types of spreadsheet calculator were black-box, white-box and grey-box. Black-box calculators are considered to be software in which calculations are performed without showing steps whilst grey-box calculators perform calculations showing the steps. White-box calculators allow the students to interact with the software at each step to determine the next action when calculating the answer.

The consent form for students participating in a remote observation study is problematic as signed consent is difficult to obtain when students are at a distance. In this study prior to the scheduled experimental time, students were required to fill in their names in a web-consent form and then submit the webpage. However, this meant there were no guarantees that this was indeed the student filling in the form. Perhaps, to circumvent this problem, the participants should also enter their email address, so that a confirmation email of their consent can be sent to them. However, to remedy this problem during the actual experimentation period students were asked for permission again as to whether they consented to be video and audio recorded via instant messaging and there was no objection.

The demographic and pre-test questionnaires were also produced as web pages. The links to the consent form and demographic questionnaires were emailed to the students prior to experimental period to fill in and submit. The pre-test was based solely on simple probability since Renkl et al. (2004) suggested using a level of difficulty that was lower than the post-test. Only when these two questionnaires were completed, an email was sent to the student to set up a date and time for the experiment. This was done to minimize experimental time required by the student and provided more flexibility. The pre-test questionnaire link was provided to the student via an IM and was filled in during the experimental period. The instructional/ study materials included information on how to use the spreadsheet calculators and guidance on expected values. The instructional materials, the practice questions and post-test materials were sent prior to the experiment so that students could print these and use it as a reference during the experiment. They were also told that it was not necessary to read these materials prior to the experiment. This reminder was placed to minimize students preparing or learning the topic prior to using the software. During the experiment, students were given time to read through the instructional materials on

expected values and the software materials. Although this study used only 6 students for understanding the remote observation process, a rotational confounded study design (Campbell & Stanley, 1963) was tested, where each student used the three spreadsheet calculators in the 6 permutations (see Figure 3).

Student	Calculator	Calculator	Calculator
1	White	Black	Grey
2	Grey	White	Black
3	White	Grey	Black
4	Grey	Black	White
5	Black	Grey	White
6	Black	White	Grey

Figure 3: The order that the spreadsheet calculators were used by each student

The students were allowed to use a practice question for testing the three spreadsheet calculators and also practice the talk-aloud strategy which constituted step 4 of the CLT method. The practice session is similar to that done by San Diego et al. (2006) in their user-lab work. Students were required to solve the various problems using the three spreadsheets calculators and entering their answers into a spreadsheet. There were 9 problems in the post-test: the first 6 problems were multiple-choice whilst the last three questions required the entering of the answer along with an explanation. The answer sheet for the post-test used a spreadsheet for this purpose. Following the post-test a short interview was conducted with the students to elicit their opinions on the three types of calculators and on expected values.

ILLUSTRATION OF DATA COLLECTED

Quantitative Data

Firstly from the pre-test and post-test questionnaires, quantitative data was collected in which a marking scheme was used to allocate points to the student. These points can be used for further statistical analysis if a large sample is used to compare the different factors. Although 6 questions were multiple-choice, the researcher can revisit the video and audio recordings to determine how students acquired their answers for allocating points, as in some cases the students provided the correct answer, although their reasoning and method were sometimes wrong. Interestingly, students often neglected to use the spreadsheet calculators and opted instead to use pen and paper or a calculator. This data was thus lost and makes it difficult to compare spreadsheet factors, highlighting an important limitation of remote observation.

Qualitative Data

However, the qualitative observational data proved to be quite useful and can be used to triangulate with the quantitative data. From the six students, an episode is illustrated on the type of data that can be collected and what analysis can be performed. Figure 4 presents data from a student (no. 6) doing the practice question during the experimental session.

Which of the following games would I get the best expected value for?

Game 1:
1st prize: 20% probability of winning £90
2nd prize: 80% probability of winning £46

Game 2:
1st prize: 30% probability of winning £60
2nd prize: 70% probability of winning £40

Game 3:
1st prize: 10% probability of winning £100
2nd prize: 90% probability of winning £10

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Game 1

Game 2

Game 3

Best?

Game	Prize 1		Prize 2		Expected Value
	Probability	Winnings	Probability	Winnings	
1	20%	£ 90.00	80%	£ 46.00	£ 54.80
2	30%	£ 60.00	70%	£ 40.00	£ 46.00
3	10%	£ 100.00	90%	£ 10.00	

Student/ Researcher	Time	Action	Utterance
Student	14:02	Checks data on screen against the practice question on paper	Right, so I've got me data in ... 20, 80, 30, 70, 10, 90, 90, 46, 60, 40, 100, 10
Student	14:12		That looks alright. Ok, So now I can go to the black-box?
Researcher	14:15		Yep
Student	14:17	Clicks black-box button	Right.
Student	14:19	Reads question on the practice question paper	Ok. Which of the following games will I get the best expected value for?
Student	14:29	Looks for definition in instructional material	Let's look and see what expected value meant again
Student	14:32	Reads from instructional materials	Tell's me what my average prize will be
Student	14:36	Looks at the black-box calculator	OK.
Student	14:42		So....
Student	14:50		Right
Student	14:54		And I'm not doing Game 1, Game 2 or Game 3, I'm doing the practice. Wait I am doing the Game 1, Game 2 and Game 3. So, if I click on Game 1...
Student	15:05	Clicks on the buttons representing Game 1, Game 2 and Game 3	Oh it gives me an answer. Right, that's really interesting. Game 2 gives me an answer and Game 3 gives me an answer.
Student	15:14		Right so Game 1 would obviously give me the best expected value and I wasn't paying any attention to what I was doing there at all and I've got an answer.
Researcher	15:25		Right, can you just click best just to show you what you can do with the best button if you want to
Student	15:30		Oh ok
Researcher	15:33		Yeah ... you don't have to but...
Student	15:35	Clicks on the Best Button	Right the best game can tell me what the biggest number is... very clever.
Student	15:40		Right, I appeared to have done that, don't I? Without any comprehension whatsoever.

Figure 4: Transcript data corresponding to audio and video data recorded from the remote observation exercise for the Excel spreadsheet

The upper left-hand corner of the figure shows the practice question whilst the upper right-hand corner shows the Excel spreadsheet that both the researcher and the student can see. Below this, a transcript of the student's utterance is shown along with the timeline in the experimental period. The actions of the student are also noted after the experiment. These actions, such as the clicking and entering of data, can be seen from watching the screen capture video, whilst the actions such as reading printed materials are noted through the webcam video. A webcam picture of a student reading printed materials is shown to the side of the transcript. In this particular episode, we note that in this practice question the student is looking at the black-box spreadsheet and there seems to be some confusion as to what to do. The data shows that from time 14:17 upon entering the black-box calculator spreadsheet, the student decides to read back

the question and then tries to understand what the term 'expected value' means before proceeding to click the buttons to see what happens (15:05). We note that the student was able to achieve the answer ("I wasn't paying any attention to what I was doing there at all and I've got an answer", 15:14). Although the student claims later that they did this "without any comprehension whatsoever" (15:40), we note that at 15:14 they were able to tell which was the best game without clicking the 'best button', and this was part of the object of the task. Thus, this task shows that for the black-box spreadsheet calculator, although a student may be uncertain what the command buttons are used for with their limited understanding of the mathematical concepts and the ease of use of software which comes with a black-box type spreadsheet, the student can still work towards achieving the answer.

Looking at other students utterances using the three calculators, all students felt some amount of confusion when starting with all three calculators, but students were less likely to know what to do when they started off with the white-box calculator (students 1 and 3). However, most students who used white-box after the black-box and grey-box spreadsheets, were still uncertain on how to calculate expected values and had to check back the instructional materials (student 6) or intuitively guess what to (student 4 felt that multiplication would be the best arithmetic operation). It appears from this limited study that whilst black-box and grey-box calculators may help the students in calculating the answer, it does not help in understanding the steps. Even though the grey-box showed the steps, only two students (students 2 and 4) took time to look through to see what the steps meant, this may mean since the solution was provided for them that students did less self-explanations to seek understanding (Schworm & Renkl, 2006). Also, when using the white-box calculator students found that after understanding the steps, that the iterations became tedious and this may impede learning (Renkl et al., 2004).

DISCUSSION

Remote observation provided some challenges when trying to observe students learning new areas without them having any prior indication of the materials. Although students here were asked to print out the instructional materials, students could have easily been redirected to another webpage where they could read the materials. However, this would require them switching between windows when doing the post-test questions and perhaps creating a higher split-attention effect Mayer & Moreno, 1998; Sweller & Chandler, 1991) than that of between paper and screen. When using paper and screen, students are able to have a direct comparison without the need to hold information in their working memory between one window and the next. Students can divide their screens to accommodate both of these windows, but would only be successful if their screen is large enough to accommodate sufficient information to be seen on both windows without requiring them to hold information in their working memory whilst they scroll down the windows.

Further, although Excel is used here, in classroom/course situations more sophisticated software such as computer algebra systems may be investigated. It was noted that some students chose to use pen and paper for working out some problems or the calculator on the computer. In face-to-face observation environments, such actions can be recorded in field notes (e.g. Pirie, 1996), but in remote observation the actions might be out of the field of view of the webcam. Meanwhile, in their user-lab, San Diego et al. (2006) used a Tablet PC to record writing and sketches, but this equipment is not available in typical student settings. So unfortunately under this remote observation process this data is lost unless special requests are made that the student post or scan these and send them to the researcher. Or a directive can be made to ensure that students only use software but this may hamper their natural learning process as well as defeat the purpose of observing students in their natural learning environment (Guba & Lincoln, 1981). Also, remote observation for quasi-experimental methods does not lend itself easily to statistical analysis which requires large sample sizes. In this paper, students generally took between 1 ½ to 2 hours to complete the exercise and thus if a larger number of students is expected, a rotational design should be used to minimize the number of remote observations and also decrease the time required for tasks to be accomplished to probably between ½ to 1 hour if possible.

CONCLUSION

Remote observation for capturing students' use of software when learning mathematics seems a viable option where there is an inability to bring students to user-labs and other laboratory settings or go to them. Useful qualitative and quantitative data can be collected. Particularly for the qualitative data, talk-aloud strategies can still be employed and the actions that students undertake in the mathematical software is able to be observed and recorded, however, the recording of students activities outside of the sphere of the shared application software is lost. Therefore, in research such as this for understanding students use software for problem-solving, researchers are not limited to students in a particular setting but to any student connected to the internet that will allow them to collect rich qualitative and quantitative data.

References

Bardini, C., Pierce, R. U., & Stacey, K. (2004). Teaching linear functions in context with graphics calculators: students' responses and the impact of the approach on their use of algebraic symbols. *International Journal of Science and Math Education, 2*(3), 353-376.

Berry, J., Graham, E., & Smith, A. (2006). Observing student working styles when using graphic calculators to solve mathematics problems. *International Journal of Mathematical Education in Science and Technology, 37*(3), 291-308.

Campbell, D. T., & Stanley, J. C. (1963). Experimental and quasi-experimental designs for research and teaching. In N. L. Gage (Ed.), *Handbook of Research on Teaching* (pp. 171-246). Chicago, IL: Rand McNally.

Clarke, T., Ayres, P., & Sweller, J. (2005). The impact of sequencing and prior knowledge on learning mathematics through spreadsheet applications. *Educational Technology, Research and Development, 53*(3), 15-24.

Ericsson, K. A., & Simon, H. A. (1984). *Protocol Analysis: Verbal Reports as Data*. London: MIT Press.

Große, C. S., & Renkl, A. (2006). Effects of multiple solution methods in mathematics learning. *Learning and Instruction, 16*(2), 122-138.

Guba, E., & Lincoln, Y. (1981). *Effective Evaluation: Improving the Usefulness of Evaluation Results Through Responsive and Naturalistic Approaches*. London: Jossey-Bass.

Hosein, A., Aczel, J., Clow, D., & Richardson, J. T. E. (2007). *Technology: empowering the educational researcher through remote observation.* Paper presented at the Computer Assisted Learning Conference (CAL '07) (to be presented), Dublin, Ireland.

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multi-media learning: evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90*(2), 312-320.

Pirie, S. (1996). *What are data? An exploration of the use of video recording as a data gathering tool in the mathematics classroom.* Paper presented at the Proceedings of the 16th Annual Meeting of the International Group for the Psychology of Mathematics Education (PME 16), Florida State University, Panama City, USA.

Renkl, A., Atkinson, R. K., & Große, C. S. (2004). How fading worked solution steps works – a cognitive load perspective. *Instructional Science, 32*(1-2), 59-82.

San Diego, J. P., Aczel, J. C., & Hodgson, B. (2006). *There's more than meets the eye': analysing verbal protocols, gazes and sketches on external mathematical representations.* Paper presented at the Proceedings of the 30th annual conference of the International Group for the Psychology of Mathematics Education (PME 30), Prague, Czech Republic.

Schworm, S., & Renkl, A. (2006). Computer-supported example-based learning: when instructional explanations reduce self-explanations. *Computers and Education, 46*(4), 426-445.

Sweller, J., & Chandler, P. (1991). Evidence for cognitive load. *Cognition and Instruction, 8*(4), 351-362.

Thomas, P., & Paine, C. (2002). Monitoring distance education students' practical programming activities. *Educational Technology and Society, 5*(3), 101-112.

Vale, C. M., & Leder, G. C. (2004). Student views of computer-based mathematics in the middle years: does gender make a difference? *Educational Studies in Mathematics, 56*(2-3), 287-312.