Conduction of Exams: Analogous vs. Digital

Bastian Küppers[1], Thomas Eifert[2], Ulrik Schroeder[3]

[1]IT Center / Learning Technologies Research Group, RWTH Aachen University, Seffenter Weg 23, 52074 Aachen, kueppers@itc.rwth-aachen.de
[2]IT Center, RWTH Aachen University, Seffenter Weg 23, 52074 Aachen, eifert@itc.rwth-aachen.de
[3]Learning Technologies Research Group, RWTH Aachen University, Ahornstraße 55, 52074 Aachen, schroeder@informatik.rwth-aachen.de

Keywords
Computer based examinations, e-Assessment, Digital Examinations, Paper-based Examinations

1. ABSTRACT

Digital examinations and paper-based, analogous examinations differ in substantial aspects, concerning both the formalities and the preparation, conduction and grading of the exam. As with digital exams, often security issues are mentioned as reasons against them. This paper focuses on the conduction of the exam and points out why digital exams cannot only provide a similar notion of security and practicality as analogous exams, but how digital exams can excel the analogous variants of exams. For the course of the paper, exams for programming courses in a computer science study course as well as a math course, as offered in the bachelor study program "Applied Mathematics and Computer Science" at FH Aachen University of Applied Sciences, will serve as an example to illustrate certain points.

2. INTRODUCTION

The process of a written, i.e. non-oral, examination is structured in three phases: the preparation, the exam itself, and afterwards the grading. These three phases are valid for all types of written examinations, not only for analogous, i.e. paper-based, examinations. Notable differences between digital exams and analogous exams, however, exist in particular for the conduction of the exam and somewhat for the grading phase. The latter is affected to the extent that the answers of the students can be available on paper sheets or in digital form.

In general, security is a topic of high importance for exams, but it is not for all of the three phases equally important. The preparation takes place in an (digital) environment that students do not have access to and which is generally accepted as sufficiently secure. The grading phase, too, exists in a closed environment. Therefore, these steps do not have to be considered more or less than for analogous exams. However, the conduction of the exam has to be considered, because it is the phase where students interact with the exam (environment) and thus can deliberately influence the life cycle of the exam. The introduction of computers into an exam, as is the case for digital exams, the students have new possibilities at hand in comparison to analogous exams. These new possibilities do not only affect the way students can solve the assignments, but can theoretically affect the way students can cheat during the conduction of the exam (Dawson, 2015).

The rest of the paper is organized as follows: First, we describe the regular process of the conduction of an exam as we do it for courses in the bachelor program "Applied Mathematics and Computer Science" at FH Aachen University of Applied Sciences and point out which steps involve predetermined breaking points. Second, we describe how electronic exams can improve these points. Third, we discuss potential security threats to electronic exams and show how these same threats apply to analogous exams. The paper closes with a brief summary and an outlook.

3. ANALOGOUS EXAMS

3.1. CONDUCTION

The conduction of an analogous exam starts with printing the exam sheets. These sheets then have to be transported to the examination room and handed out to the students. Handing out can be carried out in two different ways: First, all the exam sheets can be placed on the tables before the students enter the room. However, this implies the risk that the students can get a glimpse on the contents of the exam sheets during the turmoil that emerges when the students enter the examination room. Second, the exam sheets can be handed out once all students are seated. Nevertheless, this situation still comprises the risk of students getting a glimpse on the contents of the exam sheets, again going unnoticed, because the invigilators are busy handing out the exam sheets to the other students **[I1].**

Once all students have gotten an exam sheet, they can start solving the assignments simultaneously. While the students are working on the solution on the assignments, one of the invigilators walks around and has the students sign an attendance list. Here, it could be the case that students leave the examination room, most likely in in resignation, before the invigilator reaches them. This can lead to a situation where these students would not have signed the attendance list, which causes formal implications. An additional issue regarding the attendance list concerns the actuality of the list. At the moment the list has to be printed before the exam, which means that the printed version could be already outdated during the exam. This could be, for example, the case if a student gets ill before the exam and hands in a sick note **[I2].**

During the exam, several "extraordinary" situations can occur, such as students having to go to the toilet or students having questions. These situations bring a need for synchronization with them. For going to the toilet, it has to be ensured that only one student visits the toilet at a time. In the best case, a student that visits the toilet should hint this to all the other students to prevent complications **[I3]**. Another tricky situation is concerning students asking questions regarding the assignments during the exam. Having to treat all students equally, this actually means that the invigilator would have to repeat the question publicly followed by the answer. In that case, all students have the same information at the same time. If the invigilator only answers the question to the asking student, there may remain obscurities regarding the assignments for other students, which may handicap those students. However, to interrupt the examination every time a student asks something to publicly announce the answers, could be seen as a handicap itself, because all of the students are torn from work every time **[I4]**.

At the end of the examination, it has to be ensured that all students finish at the same time, respectively that all students had the same amount of time to work on the assignments. For an analogous examination, this again implies the need for a procedure that asserts these requirements during collecting the exams. Asking all students to drop their pens and stop writing at the end of the examination time, while the invigilators collect all the exams might enable some students to write a little more unnoticed by the invigilators. Nevertheless, the same holds for the situation in which the students are asked to bring their exams to the invigilators themselves, because that would cause sort of a turmoil **[I5]**.

Once the exam sheets have been collected, it has to be ensured that no sheets of paper get lots. The original set of exam sheets is stapled, normally. However, if a student needs more paper, these additional sheets have to be taken care of **[I6]**.

3.2. GRADING

To grade the exam sheets, the students' answers have to be read by the correctors. However, that sometimes turns out to be a tricky thing to do, because of very different levels of legibility of the particular handwritings **[I7]**. Apart from this issue, grading is a straight-forward process, which is not dependent on digital or analogous execution of an examination. For both scenarios, the grading takes places in the same medium as the exam, analogous or digital: Analogous exams are graded with a pen on the exam sheets and digital exams are graded by reviewing the digital answers of the students and taking notes on a computer.

However, keeping track of the given grades is a little bit more complicated. For an analogous exam, the grading itself takes place on the exam sheets. However, the achieved points and the resulting

grade are handled digitally. Therefore, the points achieved by the correction have to be typed into a computer, for example into a spreadsheet. This spreadsheet then computes the corresponding grade, which then has to be written back to the exam sheets and to the attendance list, which was signed by the students during the examination. To publish the grades in the online student portal, this list is sent via mail to the student's office where the list is then – again – typed into a computer **[I8]**.

4. DIGITAL IMPROVEMENTS

In this section we will discuss how the issues raised in section 3 can be solved with the digital conduction of exams. This discussion will be based on our model for examination software as described in detail in our paper *Practical Security for Electronic Examinations on Students' Devices* (Küppers, 2019), which is shortly summarized in the next paragraphs.

The examination software that we propose in our paper implements several security measures. The most basic principle is monitoring the examination software itself:

"The [examination software] is started in fullscreen mode, therefore not overlapped by any other window. From its start, it monitors whether the fullscreen mode is left and if a part or the whole window is overlapped by another window. This can, for example, be done by processing the native paint event. If no overlapping windows are detected, no other window was shown, therefore no other program consisting of a graphical user interface (GUI) was used besides the [examination software]. If [a student] has a device with more than one screen, […] additional screens will be filled with a blank window, which does the same monitoring. Additionally, keyboard inputs are checked to really originate from a keyboard and not from another process simulating key strokes or from content being pasted from the clipboard. Since there are valid use cases for the clipboard, an own implementation of a clipboard is provided, which is completely monitored by the [examination software]. Also the mouse is monitored in order to ensure that the pointer is not used by a background process to establish any sort of [external] communication […]." (Küppers, 2019)

To ensure that the software has not been modified, the concept of *Remote Attestation* is used to perform live checks of the software:

"Since the [examination software] is deployed prior to the [digital examination] to [the students' devices], [they] could potentially modify the application so that certain things work in [their] favor, e.g. the application does not monitor its state anymore. Therefore, the integrity of the application has to be verified during the [digital examination]." (Küppers, 2019)

The working of *Remote Attestation* can be described as follows:

"A trusted challenger issues an authenticated challenge to a perhaps corrupt responder. […] [The] issued challenge is an executable program that can potentially compute any function on the responder. The responder must compute not only the correct value implied by the agent, but also must complete this computation within time bounds prescribed by the challenger." (Garay, 2006)

4.1. Timing Problems [I1, I5]

Timing problems as mentioned in section 3.1 can be easily solved with digital examinations. For a digital setting it is a very simple to make the exam available to all students and collect all exams at the same time. Since a server, which is the same for all students taking the exam, is responsible for making the exam available and collecting the students' results, it is easy to implement a timeframe for the exam on the server, which is the same for all students. At the start of that timeframe, the exam is made available to the students and at the end of the timeframe, the server denies requests to save new answers. It is even possible to keep track which student retrieved the exam at which specific time at the start of the exam and to accept answers of that particular student exactly as long as the exam is intended to last.

4.2. Attendance Lists [I2]

The handling of attendance lists can be simplified by using computer during the examination. Not only is it possible to get the most recent, digital version of the attendance list at the beginning of the exam, but the students can also be obliged to digitally sign the attendance list *before* they are able

to download the examination from the server. This way, it is impossible that a student attended the exam but did not sign the attendance list.

4.3. Visiting the Toilet [I3]

Conducting exams digitally brings the possibility of synchronous communication with it. In difference to the traditional way of simply speaking to the students, the digital way of synchronous communication does not interrupt the students' workflow directly. In case a student wants to go to the toilet, the current "toilet status" can be retrieved in the examination client and in case the toilet is occupied at that moment, a virtual queue can be built to ensure a fair handling of the toilet.

4.4. Questions during the Exam [I4]

A similar issue with synchronous communication regards questions that students ask during the examination. Again, a digitally conducted exam offers the possibility to answer questions for all students at the same time without a forced interruption of the students' workflows. For newly answered questions, a decent notification can be shown and if students have a question regarding a specific assignment, they can view the log of already answered questions whether their question has already been answered.

4.5. Handling Sheets of Paper [I6]

If students have to used additional sheets of paper in an analogous exam, these sheets can get lost due to inadvertence. In digital exams, this situation cannot occur per se, because digital answers are not limited to a predefined amount of space for writing. However, it still would be possible that a part or a complete set of answers is deleted – either due to faulty software or hardware or even viciously to harm a particular student. To prevent this situation completely, digital signatures can be used to protect the integrity of a set of answers. To make sure that neither student nor examiner can alter a set of answers after the deadline of an examination has passed, a set of answers has to be signed twice: first with the students' signature and then with the examiner's signature. If one of both would try to alter the set of answers in bad faith, the signature of the other one would be missing.

4.6. Handwriting [I7]

It is easy to see how digital exams can improve the legibility of the students' answers. However, by abandoning handwriting, an identity marker is lost. Therefore, as already discussed in section 4.5, the use of digital signatures is important to be able to map a particular set of answers to the student who authored that set of answers.

4.7. Grading [I8]

In the case of a digitally conducted exam, the process of grading becomes digital. Therefore, no switch between digital data and analogous paper, which is prone to error, is necessary anymore. Digital exams can even be corrected (semi-)automatically, for example in the case of programming assignments in computer science (Jara, 2015)(Striewe, 2009).

5. SECURITY THREATS

For every form of examination exist security threats, which will be exploited by students (Dick, 2002). The use of computers that comes with migrating to a digital examination setting opens up new possibilities of cheating – in theory. This potential threat gets worse in a Bring Your Own Device (BYOD) setting, where the students are allowed to use their own devices to answer a digital exam. These threats and how they can be realized are listed in Table 1.

Table 1: Threats to Examinations

Threat	*Analogous Exam*	*Digital Exam*
Access to unauthorized Information	- Cribs (in pocket, at toilet, …) - Books (at the toilet, …) - …	- Cribs (…, on the computer) - Books (…, on the computer) - …
Communication with other students	- Inside the exam room (e.g. whispering, sign language) - Outside the exam room (e.g. at the toilet at an agreed time) - …	- Inside the exam room (e.g. whispering, sign language) - Outside the exam room (e.g. at the toilet at an agreed time) - Digitally via the computer - …

The apprehension seems to be that the introduction of computer into an examination enables the students to cheat easily, e.g. by using the internet or by accessing materials stored on the computer prior to the exam. However, we argue that cheating for students is something that has to have a good cost-benefit ratio. Therefore, students would choose ways of cheating that give them the best possible advantage during the exam under the condition that the chosen way does not produce too much overhead and, which may be even more important, has a low risk of being caught. However, attacking a digital examination software, which was designed in a way similar to our own design described in (Küppers, 2019), which has not only security features built-in, but introduces concepts like *Remote Attestation* to monitor the integrity of the software throughout the examination, surely comes with a lot of overhead. Of course, it is possible to circumvent any security measure implemented into a software. Especially if that software is executed on an untrusted device, as which the students' devices have to be considered for sure. However, the overhead introduced by reverse engineering and modifying the software is surely higher than for other ways of cheating. To keep that overhead high, it is important to design the security measures in the examination software in a way that it is not possible to circumvent those automatically, because that would allow for a single anti-security program which has to be developed only once and can then be used by several students. This is the main reason why we introduced the concept of *Remote Attestation* to the examination software, because this allows for a live inspection of the integrity of the examination software. This alone, however, does not solve the security threat complete, because a live integrity check, which happens always in the same manner, would be easily hackable. Therefore, the *Remote Attestation* has to utilize a certain degree of randomness in the integrity check. This way, it is not possible to work out an anti-security tool in advance, because the specific workings of the security measure this tool has to work against are not known. Keeping these prerequisites in mind, it is easy to conclude that "traditional" ways of cheating, e.g. cribs or using a smartphone on the, toilet is by far easier and less likely to be noticed by an invigilator. Therefore, we consider the possibility that students use the newly introduced possibilities for cheating instead of the traditional ones as negligible.

6. DISCUSSION

As discussed previously, we argue that changing the mode of an examination from analogous to digital does not affect the cheating behavior of the students. Even if a digital examination in theory offers more possibilities for cheating than an analogous examination, the ways that invigilators can use to get to know of cheating students enhance in the same way (Opgen-Rhein, 2019). With that in mind, we think that the introduction of digital exams should not be hindered by security concerns, but should even be boosted by the advantages this kind of examination offers. Beyond the advantages discussed in this paper, which are purely of formal nature, there are a lot of study programs nowadays, such as the study program "Applied Mathematics and Computer Science", which would pedagogically benefit from digital examinations, because for this study programs the computer is a tool which is already present in the learning processes and later working life. By switching to digital examinations, a media disruption between the learning process, which is mostly digital nowadays (Hochschulforum, 2016), and examination can be avoided.

7. SUMMARY AND OUTLOOK

In our analysis we compare security issues and threats between e-Assessment and traditional paper exams. In particular we show that many of those threats exist similarly in both exam forms. With the postulate that digital examinations should be at least as secure as a traditional on – but does not need to solve every issue that exists since long – we see e-Assessment as a chance to use all its benefits over analog exams.

8. REFERENCES

Dawson, P. (2015). Five ways to hack and cheat with bring-your-own-device electronic examinations. *British Journal of Educational Technology, 47(4)*, doi: 10.1111/ bjet.1 2246

Dick, M., Sheard, J., Bareiss, C., Carter, J., Joyce, D., Harding, T., Laxer, C. (2002). Addressing student cheating: definitions and solutions. *In:* Working group reports from ITiCSE on Innovation and technology in computer science education *(ITiCSE-WGR '02). ACM, New York, NY, USA, 172-184.* doi: 10.1145/782941.783000

Garay, J.A., Huelsbergen, L. (2006) Software integrity protection using timed executable agents. *In: Proceedings of the 2006 ACM Symposium on Information, computer and communications security (ASIACCS '06). ACM, New York, NY, USA, 189-200*, doi: 10.1145/1128817.1128847

Hochschulforum Digitalisierung (2016). The Digital Turn – Hochschulbildung im digitalen Zeitalter. *Arbeitspapier Nr. 27. Berlin: Hochschulforum Digitalisierung.*

Jara, N., Madrid, M. M. (2015). Bewertungsschema für eine abgestufte Bewertung von Programmieraufgaben in E-Klausuren. *In: Pongratz, H. & Keil, R. (Hrsg.), DeLFI 2015 -- Die 13. E-Learning Fachtagung Informatik. Bonn: Gesellschaft für Informatik e.V.. (S. 233-239)*

Küppers B., Politze M., Zameitat R., Kerber F., Schroeder U. (2019). Practical Security for Electronic Examinations on Students' Devices. *In: Arai K., Kapoor S., Bhatia R. (eds) Intelligent Computing. SAI 2018. Advances in Intelligent Systems and Computing, vol 857. Springer, Cham,* doi: 10.1007/978-3-030-01177-2_21

Opgen-Rhein, J., Küppers, B., Schroeder, U. (2018). An Application to Discover Cheating in Digital Exams. *In: Proceedings of the 18th Koli Calling International Conference on Computing Education Research (Koli Calling '18). ACM, New York, NY, USA, Article 20, 5 pages.* doi: 10.1145/3279720.3279740

Striewe, M., Balz, M., Goedicke, M. (2009). A Flexible and Modular Software Architecture for Computer Aided Assessments and Automated Marking. *In: Proceedings of the First International Conference on Computer Supported Education - Volume 2: CSEDU, ISBN 978-989-8111-82-1, pages 54-61*, doi: 10.5220/0001966900540061

9. AUTHORS' BIOGRAPHIES

Bastian Küppers, M.Sc. is research associate at the IT Center of RWTH Aachen University. His research focusses on e-Learning and e-Assessment technologies. He received his M.Sc. cum laude in Artificial Intelligence from Maastricht University in 2012. Since 2010 he works at the IT Center as a software developer and later as a teacher for parallel programming, robotics and other topics in computer science for the study program "Applied Mathematics and Computer Science" at FH Aachen University of Applied Sciences.

Dr. rer. nat. Thomas Eifert is Chief Technology Officer of the IT Center of RWTH Aachen University and as such responsible for the strategy for technological development and the corresponding third-party funding of the IT Center. The focus in this function includes concepts for research-oriented storage infrastructures. He is also a lecturer for Calculus in the study program "Applied Mathematics and Computer Science" at the FH Aachen University of Applied Sciences, where he is involved in the processing and digitalization of traditional teaching content.

Prof. Dr-Ing. Ulrik Schroeder received his Diploma degree as well as his PhD in Computer Science from Technische Universität (TU) Darmstadt. Since 2002 he heads the Learning Technologies Research Group in the computer science department at RWTH Aachen University. His research interests include assessment and intelligent feedback with a focus on learning processes, Web 2.0 applications and social software in education, mobile Internet and learning, gender mainstreaming in education, and Computer Science didactics.