Interactive PDF Forms to Conduct Online Examinations in University Education: Practical Experience and Lessons Learned

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Abstract—Due to the Corona Pandemic, paper-based examinations had to be transferred to an online format on short notice. At the Lucerne University of Applied Sciences and Arts we conducted three online examinations with a total of 816 students using an interactive PDF form. We faced two major challenges redesigning our examinations: 1) avoiding unnecessary stress to students' working memory by choosing a simple examination design and 2) minimizing the possibility of cheating. In our paper we explain how we addressed these challenges working with an interactive PDF form in combination with the learning management system Ilias. Our results show that using an interactive PDF form lowers the extraneous cognitive load on our students, increases our efficiency in correcting, reduces error rates in grading and further allows for faster feedback to our students.

Keywords—online assessment, interactive PDF forms, cognitive load theory, cheating

1 Background

The Corona pandemic has fundamentally changed university life. At short notice, all teaching activities had to be switched to online in the spring of 2020, while still maintaining the same quality of teaching. In Switzerland the Federal Council cancelled all face-to-face classes on the 13th of March 2020. In response to this, our university, the Lucerne University of Applied Sciences and Arts, started distance teaching on the 23rd of March 2020. Although our university managed the transition to online teaching smoothly, the biggest challenge we faced in the Department of Mathematics and Statistics was properly designing and conducting the remote assessment.

In general, the forms of assessment can be classified along three spectrums: invigilation, location and format [6]. These range from traditional on-site paper-based exams with in-person proctoring to online exams in which students participate under remote proctoring by using their own devices from another location. Based on this typology, our traditional exams in mathematics and statistics could be classified as paper-based, conducted on campus and proctored in person. All of this became impossible due to the

Corona crisis and the requirement for social distancing. Moreover, depending on the program, our modules have a large number of students which limits the available options for conducting assessment. While oral examinations and written assignments are suitable options for classes with few students, these options are very time-consuming with larger classes. In these larger classes, adopting traditional paper-based exams to the online setting would be a more favorable alternative.

However, redesigning the written paper-based exams to an online format is not without obstacles. First, since online exams are new to students, who have previously been taught and tested on-site, they can lead to more uncertainties and increase students' anxiety, that is often associated with anticipated technical failures [16], [25]. Additionally, online exams often require the use of learning platforms or other software, which increases the complexity of the exam design compared to paper-and-pencil assessment. This adds unnecessary stress to the students' working memory [6] and may even encourage academic dishonesty [18]. Second, in an online environment, students have numerous opportunities to cheat [5], [11], [17]. To ensure the reliability and validity of the exam results, the possibility of cheating must be taken into account when choosing the examination design [18].

In our paper we show how we addressed these theoretical challenges when adopting traditional paper-based examinations to the online setting. In particular, we explain how we are using the learning management system Ilias - in combination with an interactive PDF form - for our online assessments. We provide a detailed description on how we have designed and conducted three exams at the Lucerne University of Applied Sciences and Arts for a total of 816 students. Our paper contributes to the existing literature by providing a practical solution for online assessment, which is based on a solid theoretical background and has been tested at our university.

The following section describes the major challenges involved when designing online exams and explains how we delt with those challenges. In the following section we present the interactive PDF form in detail and share our experience. The last section concludes.

2 Literature review: Major challenges of online exams

In this section we present the theoretical challenges which arise when designing an online examination. These challenges lead to a set of recommendations which help us to find a proper solution when adopting traditional paper-based exams to the online setting.

2.1 Optimizing cognitive load

In general, the Cognitive Load Theory states that the working memory, which is responsible for problem solving and concentration, can only hold a limited amount of information at a time [24]. A distinction is made between intrinsic and extraneous cog-

nitive load. While the intrinsic cognitive load is determined by the amount of information and complexity of the learning material itself, the extraneous cognitive load is defined by the presentation of the material and the required learning activities [1], [19].

Thus, for exams, the intrinsic cognitive load is set by the difficulty of the subjects and the learning objectives. Since this does not depend on the exam type, the intrinsic load should be the same for paper-based and online examinations. The intrinsic load is predetermined by the learning content [20]. In contrast, the extraneous cognitive load is generated by the complexity of the exam design. It unnecessarily stresses students' working memory and should be reduced as much as possible. Comparing paper-based and online examinations in this context, the latter require the use of learning platforms or software, and add further technological challenges, which all increase the extraneous cognitive load.

Because online examinations are new to our students, who are normally taught and tested on-site, they are therefore associated with many uncertainties and anxieties. The results from surveys show that students' anxieties are often related to the fear of possible technical glitches [16], [25]. In an online environment, technical issues can be related to the system itself, e.g. malfunction of a learning platform, but can also occur on the student side, e.g. due to a poor internet connection. Recent surveys discussing online assessments during the Corona crisis have revealed that most students considered infrastructure problems to be a major challenge with online examinations [3], [10]. Results also indicate that university students, accustomed to paper-based exams, find online exams particularly stressful when they are unfamiliar with the online setting [16], [26]. Authors in [6] further note that students often face problems during online examinations due to their lack of preparation and knowledge of the technical requirements.

All of the above-mentioned issues unnecessarily increase students' cognitive load. Therefore, when creating online exams, special care must be taken to minimize any additional extraneous load related to the exam design [6], [14]. In addition to this, the provision of a mock exam and very clear instructions about the requirements and technological prerequisites are necessary [6], [8], [10]. In fact, students consider clear instructions about the rules and procedures of online examinations to be extremely important for a successful online assessment [3], [15]. Finally, as technical issues cannot be completely avoided in an online environment, a clear contingency plan should be in place in case of possible technical problems [10].

2.2 Reducing cheating

Cheating poses a threat to the quality of an assessment by decreasing its reliability and validity [18]. In an online environment, students have numerous opportunities to obtain unauthorized assistance [5], [11], [17]. Therefore, the nature of cheating threats must be understood and carefully considered when choosing or designing online examinations [18].

Authors in [18] suggest that academic dishonesty can be broadly explained by two main forces: cognitive offloading and motivation to cheat coupled with the possibility to cheat. Cognitive offloading means seeking external help in order to reduce cognitive

demand [21]. According to [18], students engage in cognitive offloading if the cognitive demand of the exam is too high and offloading is considered effective, i.e. unauthorized assistance is readily available. In turn, the motivation to cheat is usually more pronounced in exams that hold a heavy weight in determining the final grade. The motivation to cheat also increases if students feel unfairly treated, e.g. the time pressure during the exam is too strong. Finally, the possibility to cheat arises in exams that are not unique, i.e. when old exams are reused or when the same test is conducted asynchronously. Opportunities to cheat also increase with the absence of proctoring.

Existing literature presents multiple recommendations to minimize cheating through appropriate examination design or by influencing the environment in which the examination is conducted. These recommendations can be connected to the framework [18] described above. First, given that unnecessary cognitive load might encourage cheating [18], it is important to take the cognitive load theory into account when designing an online exam [6]. Second, to reduce the effectiveness of offloading, exam questions should require the application of the learning content [4]: critical thinking rather than simple computations. Answers should not be readily available in textbooks, on the internet or through peers [10]. Third, numerous papers state the importance of time constraints to reduce cheating opportunities [17], [18], [22]. However, time pressure must be reasonable, as motivation to cheat can increase if time constraints are unrealistic [18]. The final set of recommendations aims at reducing the possibility to cheat. According to [5] it is important to run the exam simultaneously for all candidates. Authors in [17] suggest allowing students to view only one question at a time and preventing them from going back to finished tasks. Randomization of questions is an additional tool that can increase the uniqueness of the examination [10], [12], [18]. Another related and very effective option to deter cheating is to create different exam versions [12].

Finally, one common way to reduce the possibility of cheating is by implementing proctoring technology [18]. To monitor students during an online exam, the actual student can be transmitted via a video and audio connection, or the student's desktop can be monitored [6]. In doing so, it is possible to record the connection and store it for later analysis. Additionally, the use of a special browser, such as the Lockdown Browser or the Safe Exam Browser, can increase the level of security in online examinations by limiting students' access to their own computers [9]. For example, the Safe Exam Browser only allows students to use certain applications during an exam and can also temporarily disable access to the internet [23].

Nevertheless, proctored online exams are associated with difficulties. First, proctoring may be problematic for data protection reasons as video surveillance represents an encroachment on personal rights. Students may therefore refuse and not consent to video surveillance [10]. Second, proctored online exams are subject to failures of software or internet connection and require a well-established infrastructure on the student side [10]. Finally, online surveillance involves additional licensing costs for the required software [5], [17]. Some studies that compare supervised and unsupervised online tests find no significant differences in exam results, indicating no increased cheating in an unsupervised setting [17]. Therefore, when properly designed, unsupervised exams can be a viable tool for online assessment [17].

3 Our examination design

3.1 Methodology

Based on the findings of existing literature, we were looking for a suitable solution for our online examinations. Our main goals were to optimize the cognitive load of our exams and to prevent students from cheating.

In our paper, we report on our experience with the interactive PDF form. Our research design is a two-stage triangulation. First, we qualitatively describe our procedure for creating the interactive PDF form. We explain how we designed and built our exams considering the relevant theory. Second, we apply a quantitative approach using the interactive PDF form in three of our examinations with a total of 816 students. We evaluate how the students handle the PDF form, provide the relevant statistics, and describe possible limitations and improvements.

3.2 General approach

To reduce the extraneous cognitive load, we ruled out the introduction of new software for the execution of our assessments. Instead, we decided to run the exams using our learning platform Ilias as our students were familiar with Ilias from their regular classes. At the beginning of the examination time, the students could download the exam from the platform and save it on their computers. This way, students had the exam available locally and could edit it offline in case of a network interruption. After finishing the examination, students had to upload their answers back to Ilias. As a backup, we also prepared an e-mail delivery for submission of the exams. Moreover, students could contact the lecturers by phone if they needed assistance.

All of our students received an instruction sheet, containing detailed information on preparing for and taking the exam. In addition, we provided optional mock exams, which were identical to the actual exams in terms of both procedure and design.

Based on the literature, we have implemented several measures to minimize the possibility of cheating in our exams. First, to limit the effectiveness of cognitive offloading, we decided to work with open book exams. The exercises focused on the application of the learning content. We made sure that the answers could not be easily found on the internet and that computational operations could not be performed via programs nor web pages. Second, to reduce the possibility of cheating, we created three different exam versions. We made all three versions as similar as possible by leaving the order and the content of the exercises unchanged. The students were not aware of which version they received or how many versions existed. To prevent students from finding out about the three different versions, we applied strict but adequate time constraints to the exam, i.e. the allocated time was sufficient to complete the exam but not to seek assistance from peers.

Moreover, in addition to working with different exam versions, we implemented another hurdle to prevent cheating. For the examination, we worked with two documents: an assignment document, which contained the exam questions, and an answer sheet, which presented the corresponding answer options, which had to be submitted to Ilias

at the end of the exam. For each exam version, we created a different assignment document. However, the answer sheets for all three versions were made identical. Therefore, students could not simply copy the answers from peers or use an answer sheet from a third party.

For reasons of data protection, the students were not monitored, neither by video transmission nor by monitoring their desktops. Special security browsers, such as Safe Exam Browser, were also not used. Instead, the students had to sign a declaration, in which they confirmed that they were taking their exams alone and independently.

3.3 Interactive PDF form as a tool for online examinations

Importantly, in our approach, reducing extraneous cognitive load is not limited to minimizing technical issues but also implies adapting a traditional paper-based exam to an online format, without unnecessarily complicating and changing the design. In this section we show how we created an examination with a simple design using an interactive PDF form.

As mentioned in the previous section, we worked with an assignment document and an answer sheet for our examinations. The assignment document is a normal PDF and contains the exercises, but not the answer options (see Figure 1). Its design is identical to a paper-based setting and is therefore familiar to our students. Each exercise on the assignment document is presented on only one page. This provides the students with all the information they need to solve the exercise without having to scroll through the document [14]. The students can deal with the assignment document first by solving the respective exercises, as in a standard paper-based setting.

Exercise 1: Health Insurance **Points: 3**

The Swiss health insurance system is based on a cost sharing between the insurant and the insurance. In case of a franchise of CHF 300, for example, this means that:

- The insurant pays the annual treatment cost not exceeding CHF 300 (=franchise);
- The insurant pays 10% (= patient's contribution) of the annual treatment cost exceeding CHF 300, provided the sum of franchise and patient's contribution does not exceed CHF 1,000.

Let x be the amount of the annual treatment cost attributed to an insurant, and let B the cost to be paid by that insurant. Then $B(x)$ defines a function for $x \geq 0$ that can be stated with three assignment equations.

a) Specify the assignment equation for $B(x)$ in the first interval, that is for annual treatment cost not exceeding CHF 300. *(1P)*

b) Specify the assignment equation for $B(x)$ in the second interval, that is for annual treatment cost exceeding CHF 300, but for which the sum of franchise and patient's contribution does not exceed 1,000. *(1P)*

c) Determine the treatment cost from which on the insurant has to pay the maximal amount of CHF 1,000. *(1P)*

Fig. 1. Excerpt from the assignment document of the mock examination introduction to mathematics for business and economics

The assignment document has a corresponding answer sheet. It displays the answer options but does not repeat the exam questions (see Figure 2). The students have to transfer their solutions to their answer sheets and submit them to Ilias. The answer sheets are a novelty that we specifically designed for the online setting.

Answer Sheet **AT 2020**

Candidate Information		
Last name		points
First name		
Learning group	Please select	

Exercise 1: Health Insurance				**3 Points**
a) (1P)				
☐ $B(x)=x$	☐ $B(x)=30x$	☐ $B(x)=300x$	☐ $B(x)=30$	points:
☐ $B(x)=x+30$	☐ $B(x)=x+300$	☐ $B(x)=-x$	☐ $B(x)=-30x$	
☐ $B(x)=-300x$	☐ $B(x)=-30$	☐ $B(x)=x-30$	☐ $B(x)=x-300$	
b) (1P)				
☐ $B(x)=0.1x-300$	☐ $B(x)=0.1x-120$	☐ $B(x)=0.1x$	☐ $B(x)=0.1x+90$	points:
☐ $B(x)=0.1x+270$	☐ $B(x)=x+300$	☐ $B(x)=0.1x+300$	☐ $B(x)=0.1x+120$	
☐ $B(x)=0.1x-90$	☐ $B(x)=0.1x-270$	☐ $B(x)=x-300$	☐ $B(x)=0.1x-30$	
c) (1P)				
☐1,000	☐1,600	☐3,100	☐5,100	points:
☐7,300	☐7,900	☐8,700	☐9,500	
☐10,000	☐10,500	☐12,500	☐13,200	

Fig. 2. Excerpt from the answer sheet of the mock examination introduction to mathematics for business and economics

We wanted to create an answer sheet with a fixed, unchangeable and simple design that could easily be completed by students directly on their computers. A Word file was out of the question because unlike a PDF, it can be changed, and would therefore be susceptible to manipulation by the students. We also ruled out a normal PDF because of the various options to fill it in (print and scan, filling in on the tablet, inserting text fields, etc.). The different formats would make the evaluation of the exam more difficult. In addition, students without a tablet would be at a disadvantage. We therefore chose an interactive PDF form for our online examination, which clearly and precisely specifies where and how entries are to be made.

The interactive PDF form can be filled in using Adobe Acrobat Reader, which is available free of charge. Adobe Acrobat Reader is widely used and already familiar to most of our students. All students were informed by their lecturers in class, and also on the instruction sheet, that they had to install Adobe Acrobat Reader before the exam and save the interactive PDF form on their computer before opening it with Adobe Acrobat Reader. Otherwise, when using an internet browser to edit the interactive PDF forms, solutions could get lost.

Since our university works with a specific Word template for exams, we decided to base our interactive PDF form on a Word file. Unfortunately, it is not possible to transfer interactive form fields from a Word file directly to a PDF form, because the form fields get lost in the conversion. Therefore, we developed the complete answer sheet in Word and saved it as a PDF. Adobe Acrobat can be used to convert any PDF into an interactive form. Therefore, once the PDF is converted, the interactive fields for the answers can be inserted. The simple menu navigation in Adobe Acrobat offers a large selection of buttons and text fields that can be included in the document, depending on each type of the question. For example, it can be specified whether only one or multiple answers are to be selected for an exercise. For open text fields, Adobe Acrobat allows to specify the maximum number of characters permitted. In addition, visual design options are also available, which provide the opportunity to test the students' knowledge in a similar way to a paper-based examination, as different question types (e.g. single choice, multiple choice, and open questions) can be included in the PDF form.

In order to evaluate the data from the completed interactive PDF forms in a spreadsheet program such as Excel, the data must first be imported. This is achieved by using the "Merge data files into table function" in Adobe Acrobat. If Excel is used, the imported text has to be transferred into columns. Once the imported text has been transferred, a separate column is created for each form field (see Figure 3). If a question is left unanswered, an Off is shown in the corresponding field. PDF submissions, where the interactive PDF form function has been removed, will not be transferred into the spreadsheet program (see student_1.pdf in Figure 3). Once the master solution is inserted, the respective answers can be automatically corrected and evaluated using simple Excel functions.

	A	B	C	D	E	F	G	H
1	**document**	**name**	**class**	**Ex. 1A**	**Ex. 1B**	**Ex. 1C**	**Ex. 2A**	**Ex. 2B**
2	**master solution**			1	2	2	2	1
3	**student_1.pdf**							
4	**student_2.pdf**	student_2	H2006	10	7	Off	Off	Off
5	**student_3.pdf**	student_3	H2032	1	8	2	8	1
6	**student_4.pdf**	student_4	H2034	1	7	2	8	1
7	**student_5.pdf**	student_5	H2034	1	2	2	2	4

Fig. 3. Importing the form data into the Excel spreadsheet program

3.4 Our experience with an interactive PDF form

In the autumn semester 2020, we conducted three math and statistics exams in the Bachelor of Science in Business Administration and the Master of Science in International Financial Management using the interactive PDF form with 816 students (see Table 1). Ninety-three percent of the students saved their answer sheets correctly and uploaded an interactive PDF form. These answer sheets were then imported and evaluated automatically in the spreadsheet program. Five percent of the students did not save their answer sheets correctly, and uploaded a normal PDF, which no longer contained the interactive form function. Nevertheless, these students' answers were recognizable and could be assessed manually. Despite receiving clear instructions, one percent of the

students submitted answer sheets that could not be evaluated. These files were damaged, and we were unable to extract the answers. Six out of these eleven students had fortunately documented their answers using screenshots, and we were able to acknowledge and grade their results. For the remaining five students, their answers could not be reconstructed, and the answer sheets were scored with zero points. One student accidentally uploaded the assignment document instead of the answer sheet and failed accordingly (no submission).

Table 1. Form of the returned answer sheets (percentages rounded)

	Introduction to Mathematics for Business and Economics	**Risk Models and Optimization**	**Business Analytics**	**Total**
Study program	Bachelor	Bachelor	Master	
Semester	1	3	1	
Number of students	438	355	23	816
Interactive PDF form submission	389 (89%)	354 (100%)	19 (83%)	762 (93%)
Normal PDF submission	38 (9%)	0	4 (17%)	42 (5%)
Damaged file submission	10 (2%)	1 (0%)	0	11 (1%)
No submission	1 (0%)	0	0	1 (0%)

When comparing first-semester-students to third-semester-students, it is notable that all but one student in the third semester correctly saved and submitted the interactive PDF form. The students who submitted a normal PDF or a corrupt file instead of the interactive PDF form were, except for one student, in their first semester. However, the general conditions in the first and third semester were identical: All students had received the same instruction sheet and were given the opportunity to take a mock exam in preparation. We attribute the different submission behavior to the fact that the third-semester students had already taken prior exams at our university and were therefore aware of how important it is to follow the instructions carefully. Furthermore, the third-semester students had already experienced writing online exams in the spring semester of 2020, although not using an interactive PDF form. This may have had a positive effect on lowering both extraneous cognitive load and perceived stress level.

All answer sheets submitted as an interactive PDF form were aggregated and exported into Excel and assessed automatically. All answers to multiple choice and single choice questions were transferred to the spreadsheet program without any issues. Of course, the answers in open text fields had to be corrected by hand. Nevertheless, it was helpful that all students' answers to each corresponding question were listed below each other in one column. This way, the answers could be compared directly and thus assessed more easily and objectively.

4 Summary and discussion

Although the efficiency of online examinations brings major benefits, especially for classes with a large number of students [8], redesigning paper-based exams into an online format is not a straightforward task. To meet the challenges, we were looking for a suitable solution for our online examinations. First, our goal was to take advantage of an examination platform that students were familiar with, without being solely dependent on it. At the beginning of the assessment time, the students were able to download the exam from the platform and work on it offline in the event of a network interruption. The downloading and uploading process using the Ilias exam platform was quick and without any problems. We did not receive any complaints from students in regard to poor connections or any other issues with the internet. This way we reduced the vulnerability to technical problems. At the same time, the entire examination process with student access was recorded by the learning platform and could be evaluated in the event of discrepancies.

Second, we incorporated the recommendations from existing literature to minimize cheating with our exam design by creating several exam versions and also implementing strict time constraints. As the grades from our unsupervised online exams were not substantially different from their supervised paper-based counterparts, we consider the implemented measures to be effective in preventing cheating.

Finally, to reduce the extraneous cognitive load, we created an examination with a simple design using an interactive PDF form. Our overall experience with the form was positive. First of all, similarly to conducting exams directly through learning platforms, our PDF form allowed for multiple test options, including single choice, multiple choice, open questions etc. [15]. We also found it advantageous that the design of the interactive PDF form was fixed and could not be changed by the students. This made accidental deletion of exercises, or any kind of alteration, impossible. Allowing only one answer option to be checked in the interactive PDF form prevented ambiguous results and simplified the assessment.

Furthermore, the interactive form could easily be completed by students directly on their computers using Adobe Acrobat Reader, which is a free tool known to most of our students. 93% of submitted answer sheets were correctly returned to us as an interactive PDF form and could be graded automatically. Automizing evaluation and grading provided numerous benefits compared to manual correction [1]. The effort required for the correction of these exams was much lower when compared to paper-based exams [9], which was particularly important in classes with a large number of students [8]. In the case of open questions, the typewritten answers improved readability and thus also reduced the correction time when compared to handwritten answers [8]. The automatic correction was error-free and thus reliable. Finally, due to increased efficiency and error-free correction, we were able to submit the exam results earlier when compared to previous years. Therefore, using the interactive form lowered extraneous cognitive load on our students [6], increased efficiency in correction [9], reduced error rates in grading, and further allowed for faster feedback to our students [13].

Naturally, a new format of examination using the interactive PDF form was not completely without issues. Not all students saved their answer sheets as instructed. As a

result, the interactive PDF form function was lost, and these documents could not be transferred to the spreadsheet program for automatic scoring. Nevertheless, a manual correction and an assessment of the results was still possible. The answer sheets of ten first-semester students and one third-semester student, who failed to follow the instructions, were damaged and were no longer readable. To prevent this from happening in the future, we will slightly modify our approach by making the mock exam mandatory for all students, as suggested by [6]. We believe that this will help to reduce the number of non-evaluable submissions in the future. Finally, for small classes, the time and effort required to create an interactive PDF form can exceed the total time required for an exam in normal PDF format. Therefore, in the future we will only continue to use an interactive PDF form for online examination with large classes.

For us, the simple technical implementation, the possibility to continue working in the event of a network interruption, and the fast and error-free correction were decisive in choosing the interactive PDF form for our online examination. Our approach received good feedback from our fellow lecturers. However, our proposed solution lacks feedback from students. In future studies, we are planning to conduct an extensive survey among our students to evaluate our approach from their perspective. Based on the survey results we would be able to compare our approach to other forms of online examination known to our students and improve our current solution.

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