Towards a Functional and Technical Architecture for e-Exams

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Abstract: In the context of lifelong learning, student learning is online or computer-mediated. However, schools and universities are still using the traditional style of paper-based evaluations even if technological environments and learning management systems are used during lectures and exercises. This paper proposes a functional and technical e-exam solution in order to allow learners and students to do e-exam in universities' classrooms and dedicated centres. We evaluate our approach in an object-oriented programming and databases course. The experimental study involved students from the first and second year of a Master degree in an engineering school. The results show that (1) Students' knowledge is better assessed during the e-exam, (2) the technical environment is easier to master than the paper environment, and (3) students are able to apply the competencies developed during the lessons in the e-exam. This research work is dedicated to Education and Computer Science active communities and more specifically to directors of learning centres / Universities' departments, and the service of information technology and communication for education (pedagogical engineers) who meet difficulties in evaluating students' in a secure environment.

1 INTRODUCTION

Lifelong learning is an important asset, subject of educational policies in Europe, including development of Key competencies (Council of the European Union 2006). In order to support lifelong learning, assessment needs to be seen as an indispensable aspect of lifelong learning (Boud, 2000). This includes formative and summative learning in order to enable learners to support their own learnings. Whereas, Boud proposes the principle of sustainable assessment, where formative assessment should be central as key enabler, he also acknowledges the need for assessment for certification purposes.

In the meanwhile certification opportunities have become more accessible, notably because of MOOCs development. More than 100 million students have now signed for at least one MOOC (Class Central 2018). Certification is now an available opportunity for lifelong learners, especially in an employability perspective.

However, the development of effective certification models is hardly considered. Fluck (2019) acknowledges that literature on e-exams is very scarce. Peer assessment is more adequate as formative than summative assessment (Falchikov and Goldfinch, 2000). Proctoring (Morgan and Millin, 2011) is only one of the many solutions that can be proposed to ensure fair assessment. Across the key subjects with e-exams, one can notice learner authentication (Smiley, 2003), and controlling fairness of exam environment.

(Rytkönen and Myyry, 2014) identify four main types of e-exams: When the time and place of the exam situation are defined by the organization, the electronic exams are either called computer classroom exams or Bring Your Own Device (BYOD) exams. If the time is restricted but not the place, the exams are online exams. When the exam room is always the same but the students can select when to take the exam, the exams are called electronic exam room exams. Finally, if the time and place are both free within a time period, then you can call the exams online exam periods or online assignments. In our context, the e-exam is related the computer classroom exams with the idea that the classroom is not only the university's classroom. It can be in an exam center room outside the campus.

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In this contribution, we propose an original architecture, hybrid between online assessment and more classical exams rooms in universities, enabling a dissemination of e-exams opportunities in third places.

The paper is organized as follows. Section 2 presents some research work done in the area of online environment and e-exams. Section 3 presents existing solutions to insure e-exams. Section 4 details our functional and technical architecture for e-exams. Section 5 introduces our case study. Section 6 presents the results of the case study. Section 7 summarizes the conclusion of this paper and presents its perspectives.

2 RELATED WORK

In this section, we present important features that need to be in an e-exam solution.

(Casey et al., 2005) identify three type of activities that must be handled to ensure academic integrity in the online environment, namely (i) improper access to resources during assessment (ii) plagiarism and (iii) contract cheating, meaning using a paid or unpaid surrogate for course assessment. The authors propose a review of techniques to deter academic dishonesty, concluding that for formative exams all techniques should be used.

Along these techniques, online proctoring like ProctorU (Morgan and Millin, 2011) are the most advanced solution, including detection techniques against improper use of external resources and learner authentication to counter contract cheating. This kind of solution provide a flexible schedule for the student. However, the candidate must be able to isolate himself in a quiet room, with an effective network connection, which is not possible in all cases.

The process of authentication is commonly completed through the use of logon user identification and passwords, and the knowledge of the password is assumed to guarantee that the user is authentic (Ramzan, 2007). However, authentication cannot be viewed as an effective mechanism for verifying user identity because a password can be shared between users. That is why Bailie and Jortberg (2019) outline the importance of the learner's identity verification in e-exams.

According to (Baron and Crooks, 2005), requiring students to complete exams in a proctored testing center is probably the best way to avoid the possibility of cheating. Some universities provide exam rooms, ensuring authentication, and a similar environment to paper exams, but this solution cannot scale up to a broader access, and are available only for specific sessions with specific schedule and where all candidates must pass the same exam.

Fluck (2019) recently proposed a review of e-exams solutions. As a result, he also notices that assessment integrity is a very sensitive issue, proposing a similar list of software techniques. Other features acknowledged are (i) accessibility to provide equitable access for students with disabilities, and (ii) architecture and affordance for higher order thinking. Concerning accessibility, he observes that accessibility have been tackled by allowing students with disabilities to use a computer, sometimes with an additional time allowance. This practice continues to be relevant in e-exams context.

In order to achieve higher order thinking assessment, Fluck notices that using quizzes generally conduct to lower order thinking assessments and advocates for the use of rich media documents and professional software. In the domain of software development, (Wyer and Eisenbach, 1999) provide an extensive solution that aims to ensure assessment integrity, while providing the same software environment during practice and exams.

(Dawson, 2016) confirms that in an e-exam, students must have prohibited internet access or controlled access to the internet based on the context. Students must not have access to any file, resource via the network / Universal Serial Bus, or via a prohibited program such as screen sharing or chat tools. (Pagram et al., 2018) clarify the importance of the auto-saving feature in an e-exam. The e-exam solution can have an auto-save or save to the cloud. This leads to improvements in the exam efficiency and would also address student problems with the PC and protect student data in the event of a crash.

Table 1: Important features for an e-exam solution.

Feature code	Feature label
F1	control the access to the internet / local resources
F2	authentication
F3	learner's identity verification
F4	regular backup of learners' answers
F5	same software environment during practice

The previous existing works enable us to define important features for an e-exam solution (see Table 1). The solution must control the access to the internet / local resources. It must ensure authentication and learner's identity verification. It must also enable regular backup of learners' answers in case of a technical problem during the e-exam. The solution must allow the use of rich media documents and professional software providing the same software environment during practice and exams.

3 EXISTING e-EXAM SOLUTIONS

In this section, we consider existing e-exam solutions.

He (2006) presents a web-based educational assessment system by applying Bloom's taxonomy to evaluate student learning outcomes and teacher instructional practices in real time. In the Test Module, the instructor can design a new test or query existing tests. The system performance is rather encouraging with experimentation in science and mathematics courses of two high schools.

Guzmán and Conejo (2005) proposed an online examination system called System of Intelligent Evaluation using Tests for Tele-education (SIETTE). SIETTE is a web-based environment to generate and construct adaptive tests. It can include different types of items: true/false, multiple choice, multiple response, fill-in-the-blank, etc. It can be used for instructional objectives, via combining adaptive student self-assessment test questions with hints and feedback. SIETTE incorporates several security mechanisms, such as test access restrictions by groups, Internet protocol (IP) addresses, or users.

Exam (Rytkönen, 2015) is a web-based system used by a consortium of 20 universities in Finland where the teacher and students get different types of webpage. Also, the exams in the Exam system are constructed so as to be managed on the server. Exam is composed of an examining system and an exam video monitoring system. All the classrooms and computers have their individual IP addresses. When the student enters the exam room, the video monitoring turns automatically on, and the building janitors are able to see the live stream. The exam situation is also recorded so that the teacher is able to watch the exam situation afterwards, if there is a reason to suspect cheating or other issues.

Another example of e-exam systems is the Educational Testing Service (ETS) (Stricker, 2004) that is used to run the International English Language Testing System (IELTS), the Graduate Record Examination (GRE) and the Test of English as a Foreign Language (TOEFL). These tests evaluate every year the ability to use and understand English of millions of people from hundreds of different countries. Formerly deployed as traditional paper-based supervised tests, they have been reengineered to be computer-based.

Learning Management Systems (LMSs) like Moodle provide an environment where teachers can maintain course materials and assignments (Kuikka et al., 2014). These LMSs support features for examination purposes, but they are not actually intended for e-exams. For example, Moodle has no separate exam feature, but does contain tasks and objects that could be used for e-assessment such as assignment and test activities.

For the sake of clarity, S1 refers to the web-based educational assessment system by applying Bloom's taxonomy, S2 to SIETTE, S3 to Exam, S4 to ETS, and S5 to LMSs.

Table 2: Comparison between existing e-exam solutions and our required features.

	F1	F2	F3	F4	F5
S1	-	✓	-	-	-
S2	✓	✓	-	-	-
S3	✓	✓	✓	-	-
S4	-	✓	-	✓	-
S5	-	✓	-	-	-

Across the table 2, we found that no existing solutions for e-exams meets our needed features detailed in table 1. This led us to think deeply about a functional and technical solution of e-exams. To highlight all these ideas we are going to detail in the next section our approach that includes all these features and provides innovative solutions in this domain.

4 OUR SOLUTION

Our aim is to propose an hybrid solution, giving the opportunity to provide flexible access to proctored e-exams in third places like libraries, town halls, Fabrication Laboratories (FabLabs), … by providing a mobile system, that ensure learner authentication, assessment integrity, access to any available exam, in various dedicated environments, that enables higher order thinking assessment. Local authorized persons will ensure a classical face-to-face proctoring.

The system is composed of a box, namely the classroom Server that hosts a web-server, ensures a gateway role, provides an authentication facility and allows regular backup of learners' answers. Candidates connect their device to this classroom server in order to be allowed to participate. This two side client/server architecture gives the opportunity to propose a modular architecture with different options depending on examination needs.

4.1 Our Functional Architecture

As (Casey et al., 2005) noted all parts of the architecture must integrate mechanisms in order to ensure academic integrity. Our functional architecture is depicted in figure 1.

Teachers can provide course and elaborate exams on a reference Learning Management System (LMS) environment, and the Classroom Server will synchronize itself to this environment in order to locally provide courses and exams when deployed.

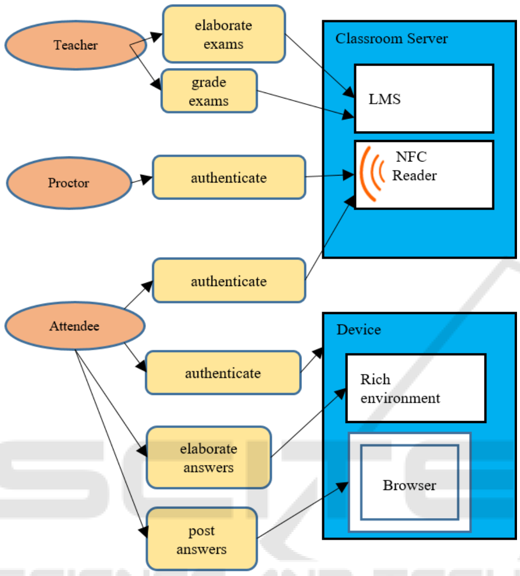

Figure 1: Our functional architecture.

In order to start an exam session, an authorized proctor will authenticate itself to the Classroom Server, thanks to a secure authentication system. After this initialization, attendees are authorized to enter the session. They will first provide an ID proof to the secure authentication system (a NFC reader) in order to be acknowledged as candidate. Secondly, they will be able to choose an available exam on their device and connect themselves. Using the device, they are allowed to use the software environment needed to elaborate answers for the exam, to access relevant resources on the Classroom Server LMS. They can post their answers to the LMS via a standard browser. Attendee's data in the software environment and posted answers are regularly saved on a separate storage in the Classroom Server.

Access to resources is controlled on the classroom server side, by giving access to relevant documentation and by controlling access to the web. If necessary, candidates' devices may run a controlled environment in order to avoid local resources access. Cheating by communicating to others is technically avoided by controlling connections as the classroom server is the gateway of the classroom. In addition proctors are able to directly monitor screens. Where appropriate, the classroom server can work offline, preventing all external connections.

The Classroom Server provides an authentication system ensuring surrogate avoidance at a similar or better level than paper exams.

As the system is hosted in a public place, the attendee doesn't need to provide facilities such as quiet room and effective network connection. Moreover, he is allowed to pass any exam he is subscribed for.

Finally, the device is standard, meaning that it provides standard accessibility features, rich media interactions, and possibly professional software access similar than those provided during practice.

4.2 Our Technical Architecture

We have designed a proof of concept architecture based on the MOOCTAB results (El Mawas et al., 2018). Technically, the Classroom Server solution is based on the MOOCTAB box system that permit local offline access to MOOCs and further synchronization to online MOOCs.

The authentication is based on visual verification by local proctors. Additionally, a RFID reader is provided that can check an ID card, and verify that the candidate applied to an e-exam. This authentication enables e-exam access to the attendee for a specified time.

The MOOCTAB box hosts a MOOC LMS server, namely edX. The attendee can then connect to this server to access the examination instruction and all necessary resources (documents, simulators, editors, results upload, etc.).

If the Classroom Server is offline, this will be the only resources available to the attendee. Otherwise the Classroom Server serve as a gateway filtering available external resources.

The edX server can be synchronized with external edX server. This means that any interaction in a MOOC session can be further synchronized with an online edX server. This enables a seamless e-exam exploitation on an edX server providing all necessary facilities for correction, and marks' exploitation.

A synchronization service may be provided to guarantee that the attendee may not lose information during examination if he works on his own device.

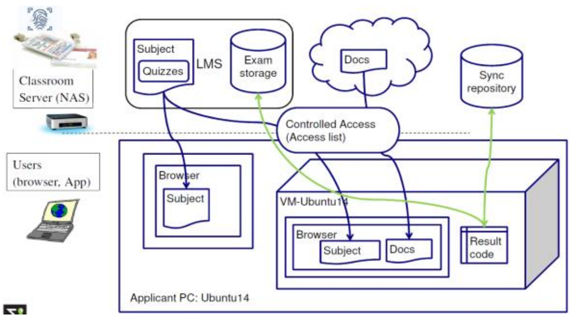

Figure 2: Our technical architecture.

The attendee device can be anyone relevant for the assessment. The MOOCTAB project was specifically dedicated to tablets, meaning that preferred device was a tablet. This enables local authentication that has to be compliant with the server side, for example fingerprint recognition corresponding to the ID card.

In our experiment, we aimed to adapt a professional software environment. Thus the attendee's device was a PC, with a professional IDE (Eclipse). In this case, we chose that the PC will boot on a specific Linux distribution in order to control the environment, similar to those provided during practice. This solution is similar to the one proposed by (Wyer and Eisenbach, 1999). As the management of the attendees is done by the Classroom Server, our solution is more flexible as neither specific room preparation nor attendee's assignment to specific PC is required. In order to be identified the attendee has to connect to the LMS server in order to access to his assessment.

Providing two different environments, tablet and software development PCs demonstrate the modularity of the proposed solution.

Table 3: Correspondence between our solution and the required features.

	Our solution
F1	Classroom Server (online and offline modes)
F2	Logon user identification and password
F3	Fingerprint recognition + ID card with NFC reader
F4	Classroom Server Separate storage
F5	Any software environment

Table 3 shows the correspondence between our solution and the required features. The access control to internet / local resources is ensured thanks to the online and offline mode of the Classroom Server. Attendees are authenticated via the logon user identification and the password. Fingerprint recognition and ID card with a NFC reader allow learner's identity verification. The Classroom Server Separate storage provides regular backup of learners' answers. In our proposed solution, we can use any software environment that is why the teacher can choose the use of the same software environment during practice in the e-exam.

5 CASE STUDY

5.1 Overview of Our Case Study

We have used and evaluated the MOOCTAB platform to manage the exam of an 84 hours, object-oriented programming and databases course. The course is followed by students in the first and second year of a Master degree in an Engineering School.

The course considers two aspects when developing object-oriented (OO) applications that access a database: analysis and design (of the OO program and the database) and programming and database utilization.

Since the course took place the first time, its evaluation mainly consisted on a traditional paper-based, proctored exam. Questions always include a MCQ (Multiple Choice Questions) to evaluate knowledge, and exercises to evaluate a subset of skills developed during the course: problem analysis, solution design, and programming and database utilization. Evaluating paper-based MCQs can be error-prone but can be easily automated. Exercises to evaluate skills are very different in nature.

On one hand, answers to problem analysis and solution design exercises are expected to be graphical diagrams; and no particular tool is recommended to be used to create them during the course. Evaluating them on a paper-based, proctored exam seems to be "aligned with skills" developed during the course.

On the other hand, programming and database use exercises are expected to be lines of code or issues encountered when programming (mainly resolving bugs and compilation errors) and students are provided with special tools that help on such tasks during the course. Evaluating them on a paper-based, proctored exam raises two important issues:

1. Alignment with skills is not guaranteed as students are not provided with the same tools as during the course,
2. Very frequently, students are not rigorous enough to properly write code making its evaluation difficult and error-prone.

We decided to tackle these issues by evolving the exam and in particular exercises to evaluate skills.

Problem analysis and design exercises are decided to remain unchanged. Programming exercises are designed so that students use computer to do them.

5.2 Design of e-Exam Content

Three types of exercises were chosen for the e-exam. They are presented below.

Type 1: Exercises to Write Code from a Program Design: Students were given a UML class diagram and a UML sequence diagram (well-known, spreadly used standards to describe the structure and dynamics of a program) and they had to write (part of) the corresponding code. These exercises evaluate students on their understanding of the used standards and their skills to write a code that conforms to a specification.

These exercises were not different from the ones on the paper-based exam. Expectations relate to the better-written lines of code thanks to the use of the computer.

Type 2: Exercises to Give a Solution for a Particular Compilation Error: These are two-steps exercises: we ask students to give her interpretation of the error (why the error occurs?) and a solution. These exercises evaluate students' skills on solving such errors while understanding them. Indeed, tools used to write programs help on solving compilation errors.

Even if these exercises were not different form the ones on the paper-based exam, error interpretation is much more important in an e-exam. Indeed, the programming tool used by students (as all programming tools) already proposes a solution to a compilation error. Therefore, students are able to give a solution (the one proposed by the tool) without understanding why they give them.

Type 3: Exercises to Write Code to Access a Relational Database: Relational databases are the most common type of databases used by programs. The language used to access them is the SQL language and is an ANSI and ISO standard since mid-80's. For such exercises, we intend to evaluate students' skills to write SQL requests that are correct and minimal (the simplest request among all the possible ones).

5.3 Case Study Settings

The evaluation included a group of four voluntary students who were assessed by using the MOOCTAB exam environment. The examination took place in class, outside the normal hours of study. Once the e-exam was taken, the researchers wanted to assess the affordance, acceptability and overall experience of the students as they prepared and took the exam. To do so, the researchers prepared an online questionnaire and received the students who volunteered for an interview to explain their answers to the questionnaire.

The questions are presented in Table 4 and are organized to evaluate three important criteria: the students' knowledge in the e-exam, the e-exam technical environment, and the applied competencies in the e-exam.

Questions 1 to 5 were related to the first evaluation criterion, they were specifically testing the overall opinion of the students about e-exams and the self-efficacy estimations on how they dealt with the exam itself. Questions 6 to 9 to the second evaluation criterion and were more specifically testing aspects like how the students generally perceived their performance during the exam. Finally, questions 10 to 12 were related to the third evaluation criterion and were evaluating more generally how the students felt about generalizing the dispositive of e-exams.

Table 4: Survey questions.

Question	Answer scale
Q1. What's your general opinion about e-exam?	- Not favorable - Neutral - Favorable
Q2. What's your level of competencies in computational sciences?	- Bad - average - Good
Q3. Do you think you managed to mobilize the necessary knowledge to pass this exam?	- Disagree - Not really - Agree
Q4. Do you think the e-exam allows you to show better that you master the knowledge of the course than in the paper examination?	- No - a bit - Yes
Q5. If you had to compare a classical paper examination and this e-exam would you say that you are:	- Not favorable - Neutral - Favorable
Q6. When you found out that you'll have to take an e-exam, you were:	- Anxious - Neutral - Enthusiastic
Q7. Take an exam in similar conditions to those experienced in class was for you:	- An element of difficulty - Had no effect on my answers - An element of facilitation

Table 4: Survey questions (Cont.).

Q8. During the e-exam, would you say you were:	- Less at ease than with paper exams - Neither less nor more at ease than with paper exams - More at ease than with paper exams
Q9. The developing environment (Eclipse) seemed to you:	- Hard to work with - A bit hard to work with - Neither hard nor easy to work with - A bit easy to work with - Easy to work with
Q10. Have you encountered difficulties to upload your file on EdX?	- Not at all - Some difficulties - Yes - I was unable to upload my file
Q11. Why did you accept to take an e-exam?	(Free text)
Q12. Was the e-exam meeting your expectations?	- No - A bit - Yes
Q13. Would you like for every exam to be organized this way	- No - A bit - Yes

6 CASE STUDY RESUTS ANALYSIS

All participants have a positive overall view of e-exam (Q.1). Three of them identify they have a good skill level in computational sciences and one of them considers his skill level as “average” (Q.2). They all believe that they have been successful in mobilizing the necessary skills to succeed (Q.3). Two of them estimated that the digital environment helped them “a bit” to better show their skill in computational sciences than the traditional examination. And the two others did not perceive any differences in that aspect (Q.4). Three of them were favorable in their e-exam comparison to a traditional examination, one participant was neutral (Q.5). Three of them were excited to have a digital exam. But it should be noted that one of the participants stated that he was worried about the examination (Q.6). Two of them said that the digital test was a facilitating factor in their examinations, the other two felt that it had no effect on their answers (Q.7 and Q.8). All have also found the Eclipse environment easy to use (Q.9). Technically speaking, two of them declared no difficulty to upload their document on EdX, one found it difficult, and another was unable to do it (Q. 10). The interview highlighted the fact that the instructions were not clearly given and so at least one of the participant misused the digital environment. All agreed to participate in order to further develop these kinds of initiatives and to generalize the use of screens. For one of them: "That's the way computer science exams should be done." (Q.11). Regarding their expectations, it seems that the digital examination has answered either "a little" for one of them or "quite" for the other three (Q.12). And all would like to see the device extended to all computer exams (Q.13). These generally positive remarks are reflected in oral interviews, where the students reiterate their appreciation of the care taken to reproduce environments that are closer to the conditions of exercises in the practical work. They also reiterate their desire to see the device extended to all exams in computer courses. Based on our evaluation criteria (see Section 5.3), we analyze below the results of our case study.

6.1 Students’ Knowledge in the e-Exam

Based on these results, it seems that we have some evidence that students' knowledge is better assessed (Q.1 to 5) during the digital exam than with a traditional exam. In fact, most of the students' responses were favorable in terms of greater ease of mobilizing their knowledge, so it seems that it can be said that this better alignment is conducive to better quality evaluation at least from the point of view of the students. Indeed, during the interviews, all expressed their general appreciation of a device that allowed them to better account for their knowledge: "for sure I was more comfortable than if it had been on paper, on paper, it's longer ... well, it's simpler and then it's also more logical ", " When you think about it, what's the point of doing a digital exam on paper? ". This result supports Biggs (1996) who think that students’ knowledge is better assessed during the e-exam because this type of exam is more aligned with the way lessons are organized.

6.2 The e-Exam Technical Environment

Overall, the technical environment does not at all represent a factor of difficulty for students. On the contrary, apart from the elements related to the clarification of instructions (see next section), they tended to say that the digital evaluation environment was a facilitating element for their delivery. The fact that it is the same environment as the one used in class, of course, played, and most of the time during the interviews, the students underlined that they were comfortable with the tools: "This is the environment we know, we just had to authenticate, it was clear and we used to work like that. " When asked if they were comfortable during the exam, they gave evasive answers that make their feedback difficult to interpret: "Yes ... It was not that complicated", "I felt rather at the comfortable what... ". This difficulty in answering the question could come from the fact that no clear difficulty has been identified and that the computer work has a natural character in them and that therefore the situation was not exceptional. We can deduce that this habit of the digital environment is really a point on which we must rely to put students in optimal examination situations and that do not add additional difficulties.

6.3 Applied Competencies in the e-Exam

In terms of the interviews and the results of the questionnaires, it seems that the participants were more able to use the skills developed by the courses during the digital exam than if they had to go through a paper exam. Indeed, during the interview, one of the participants stressed the importance of: "developing solutions like this for other courses that do practical work on machines", and this, to end up in an examination situation more "close to the courses", and thus pedagogically relevant. One of the participants even showed a particular appetite for innovative evaluation devices: "I loved the peer review at a MOOC I followed, I thought it was great [...] it would be necessary for the teachers to test more things like that!". We find the same kind of remarks in the questionnaire when one of the participants specified: "That's the way computer science exams should be done.", "Because it could be interesting for the future students of info and practice for the MOOC"(Q. 11).

It should be noted, however, that it is important to clearly specify and give the instructions since this was deplored by the students and negatively impacted the experience and the rendering quality of one of them (Q.10). During the interview, the main problem identified by three of the participants was precisely related to the need to clarify the instructions verbally and not to rest on the fact that the instructions are already written in the document of the review: "The biggest problem is the distinction of the question from the statement. Speak orally to read the instructions. It would be nice for the teachers to be more explicit about the expectations of the exam. "One of the participants even remarked to us:" I did not think about reading the instructions, it was not clear that 'it was necessary to use the digital environment'. These verbatim highlight the fact that the human relationship remains important in the context of digital examination. The students encountered difficulties in understanding the expectations and would have liked the teacher to be clearer about what to do. In conclusion, it can be noted that students are better able to apply the skills developed during the lessons when they are exposed to a situation of evaluation similar to those experienced during the lessons. However, these results must be weighted in light of the need to clearly explain the expectations and the technical aspects of the exercise.

To conclude, we can say that it would be wise to generalize the experiment to a larger class group, because the acceptability, the affordance and the feeling of success of the participants are globally very encouraging.

7 CONCLUSIONS

This study addresses the problem of the use of e-exams to evaluate students. The main questions of the study are how to control the access to the internet / local resources, how to authenticate and verify learner's identity, what are the approach allow regular backup of learners' answers, and how to promote the use of the same software environment during practice in the e-exam.

We investigate the problem from its theoretical background, and we consider existing e-exam solutions in order to see if any existing approach can meet our requirements. Unfortunately, no one can respond to our needs. To achieve this, our approach is proposed as a functional and technical solution to our problem. Thanks to this solution, the access to the internet / local resources is controlled via the classroom server. Authentication is ensured thanks to the logon user identification and the password. Identity verification are provided by the use of fingerprint recognition and ID card with a NFC reader. Regular backup of learners' answers are made by the Classroom Server Separate storage. In our proposed solution, we have no constraint about the software environment that is why the teacher use the same software environment during practice in the e-exam. Our solution provide a flexible way to pass proctored exams, enabling subject diversity like online systems, and face-to-face facilities of exam rooms (isolation and access control). From a technical point of view, this approach is lighter than online proctoring systems.

Our solution was tested on students from the first and second year of a Master degree in an engineering school. The results show that students' knowledge is better assessed during the digital exam than with a traditional exam. Moreover, students' didn't find any difficulties related to the e-exam environment. In addition, students were more able to use the skills developed by the courses during the digital exam than if they had to go through a paper exam.

Now we will deploy our solution in different universities and engineering schools in order to evaluate our approach on large scale. This research work has broad impacts because the proposed e-exam solution can be easily adapted to support different programs and disciplines. We want also to collect traces about student results in the e-exam in order to better understand the learning process and improve the method of teaching and the evaluation process in a lifelong learning perspective.

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