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Special Issue on Remote Learning and Work

Are remote educational escape rooms designed during the pandemic useful in a post-pandemic face-to-face setting?

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Abstract— Numerous initiatives were conducted online during the COVID-19 pandemic and today it is necessary to analyze whether it is better to continue conducting these initiatives online or should they be done face-to-face and even readapted to this format. This paper compares an educational escape room for learning software engineering conducted online during the confinement caused by the pandemic and later face-to-face. The research involves 241 students, and employs instruments to explore the knowledge acquisition attained by the students and their perceptions towards the activity. The results provide insights to consider in the future use of this technique. The digital elements used in a remote escape room are suitable for a face-to-face escape room since the educational efficacy of the activity was similar when conducted online and face-to-face. However, some students' perceptions related to enjoyment were worse in the face-to-face escape room, which could be improved by incorporating physical elements.

In recent years, education has changed due to the sanitary emergency resulting from the COVID-19 pandemic. This emergency forced for some time the conventional face-to-face teaching to become entirely remote. Many works have analyzed innovative initiatives that were carried out remotely and have provided indications for converting face-to-face activities into online activities [1]. Nowadays the sanitary crisis can be considered overcome and teaching can once again be carried out in class. The COVID-19 pandemic has undoubtedly opened up many challenges and opportunities that today, in a post-pandemic era, can be seized [2, 3, 4].

In this context, it is necessary to analyze which activities do benefit from a face-to-face implementation and which are equally or more effective when conducted remotely. Among the activities to be analyzed, educational escape rooms have brought the attention of teachers and researchers due to their possibilities for enhancing students' motivation and learning outcomes. Educational escape rooms are games in which students organized in teams work together to solve a series of puzzles in order to achieve a final objective and in which recreational and educational elements are blended together [5].

These activities began to be used in higher education around 2017 [6, 7, 8] and their realization, which initially was face-to-face, usually involves physical elements like printable documents, jigsaw puzzles, safes and padlocks, hidden messages visible under ultraviolet light, etc. The sanitary crisis forced to digitize all these elements in order to allow the implementation of escape rooms remotely like the ones presented in previous works [9, 10, 11, 12].

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Now that it is no longer mandatory to carry out educational escape rooms remotely, it would be interesting to know whether it is convenient to continue conducting them online, conducting them face-to-face using only digitized elements like those created during the pandemic, or conducting them face-to-face but de-digitizing the aforementioned elements and re-introducing physical elements. To conduct entirely digital escape rooms would eliminate the physical resources needed to conduct them, but will these digitized elements be as effective in face-to-face settings as the physical elements that were traditionally used before the sanitary crisis?

Prior research [13, 14, 15] comparing escape rooms conducted face-to-face with those conducted remotely shed some light on this issue. These works compared an escape room conducted face-to-face by using physical elements with a different version of the escape room adapted to remote learning in which the physical elements were replaced by digital elements.

The present article also compares an escape room conducted face-to-face with the same escape room conducted remotely, but using a different approach. In this case, the comparison is made between an escape room premiered remotely during the lockdown resulting from the COVID-19 sanitary crisis and the same escape room conducted later in the classroom with the same digital elements. Will the entirely digital escape room designed during the COVID-19 pandemic be equally useful for a post-pandemic face-to-face context?

THE ESCAPE ROOM

The learning topic addressed by the educational escape room was software modeling. Specifically, it was aimed at reinforcing the knowledge on understanding, interpreting and creating some of the most important UML diagrams used for modeling software.

The escape room was conducted remotely by using a web platform called Escapp [16]. The content of the escape room was comprised of several interconnected web-based applications, which communicated with the Escapp platform through its API. The students only needed a computer with an HTML5-compliant web browser for participating in the escape room.

The escape room was designed to have a duration of two hours and had a total of five virtual puzzles arranged sequentially, which combined educational contents with game mechanics that are common in ludic breakout games. A detailed description about the narrative and puzzles of the escape room can be found in a previous work [9].

RESEARCH METHODOLOGY

Context and sample

The research was conducted at the School of Computer Systems Engineering of the *Universidad Politécnica de Madrid* (UPM). Specifically, the research was conducted in a software engineering foundations course. This course is a fourth-semester course that lasts 16 weeks and accounts for 9 European Credit Transfer System (ECTS) credits. The course offers an introduction to the most common methodologies of software development and the most common phases thereof: requirements elicitation, design and modeling, implementation and testing.

From a temporal perspective, the research was performed through two experiences in the academic years 2019-20 and 2020-21, thus giving rise to a quasi-experimental research methodology. The first experience was conducted in April 2020 (during the lockdown caused by the COVID-19 sanitary crisis, which forced the teaching to be in a remote format) and the second one in March 2021 (once the sanitary crisis subsided and teaching was able to return to the face-to-face format). It is important to remark that in 2020 the activity took place in the week 12 of the course, while in 2021 the activity took place in the week 8 of the course. This meant that, despite in both years the same number of classes were delivered for teaching the topics that would later be addressed in the escape room, in 2020 the students had more time available to study these topics.

Regarding the sample, it was exclusively compromised of students who carried out the activity in teams and under the supervision of a teacher. It was made up of 241 students, which were divided into two groups. The first group was composed of 140 students (organized in 34 teams) that performed the escape room in the 2019-20 academic year in remote format during the lockdown (hereinafter, Remote group). The mean age of these 140 students was 20.6 (SD = 1.9) and the gender distribution was 114 men (81%) and 26 women (19%). The second group was composed of 101 students (organized in 33 teams) that performed the escape room in the 2020-21 academic year in face-to-face format (hereinafter, Face-to-Face group). The mean age of these 101 students was 20.5 (SD = 1.8) and the gender distribution was 82 men (81%) and 19 women (19%).

Procedure

Each of the two educational escape rooms was evaluated in a single session of about 120 minutes. The first step was to administer the pre-test to the students in order to assess their prior knowledge about the topics covered by

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the escape room. After that, the researchers enabled access to the activity in the Escapp platform. Then, the students played the escape room until completion, surrender or, in the case of the face-to-face group, time ran out. The students of the remote group could complete the activity once the two hours of time scheduled for the activity had been used up, but the students of the face-to-face group did not because they had to physically leave the classroom after two hours. The students in the remote group communicated with each other and with the teachers using a videoconferencing tool, while the students in the face-to-face group communicated in person. Once the students finished playing the escape room, a post-test was administered to assess students' acquired knowledge, along with a questionnaire to collect their perceptions about the escape room.

Methods and instruments

The virtual campus of the course allowed us to gather electronically the information related to the tests and questionnaire. The questions in the pre-test and the post-test were the same ten multiple-choice questions about the course topics covered by the escape room. The students could obtain a score from 0 to 10 in the tests, and they had 10 minutes to take each one. The questionnaire employed to gather the student's perceptions was composed by 24 items. Of these items, 22 were on a Likert scale from 1 (strongly disagree) to 5 (strongly agree) and 2 were on a yes/no scale. Furthermore, the Escapp platform [16] allowed us to gather the time each team played the escape room.

Data analysis

The data were analyzed using mean (M) and standard deviation (SD). Moreover, inferential statistical analyses were also utilized to check the statistical significance and the effect size of the differences under study. Since the Kolmogorov-Smirnov test results confirmed that all the gathered data were non-normally distributed, non-parametric tests were employed. A Wilcoxon Signed-Rank test for paired samples was used to verify whether the difference between pre-test and post-test scores in each group was statistically significant. Moreover, Mann-Whitney tests for independent samples were used to determine if the differences between both groups in the following variables were statistically significant: pre-test, post-test, learning performance, student's perceptions, and team performance. The correlation coefficient (r) was used to determine the effect size of comparisons carried out. Following Cohen's guidelines [17], a value of r between 0.1 and 0.3 represents a small effect size, an r between 0.3 and 0.5 represents a medium effect size, and if r is larger than 0.5, it represents a large effect size.

The learning performance (LP) is calculated as the difference between the post-test scores and the pre-test scores and considering the time invested by the students to complete the escape room as a normalizing variable (see Equation (1)). This way, the learning performance of both groups can be properly compared by eliminating the influence that the invested time may have had on the learning performance.

$$LP = \frac{(posttest\ score - pretest\ score) * 120\ mins}{time\ spent} \quad (1)$$

RESULTS

Knowledge acquisition

Table 1 shows, for each group, the results of the tests performed prior to the activity (pre-test) and afterwards (post-test), as well as the resultant learning performance. First, it can be observed in both groups that the difference between the post-test and the pre-test is statistically significant and has a medium to large effect size. Second, it can be observed that there are statistically significant differences in the pre-test and post-test obtained by both groups, but not in their learning performance.

TABLE 1. KNOWLEDGE ACQUISITION RESULTS

		Remote Group (N=140)	Face-to-Face Group (N=101)	Mann-Whitney Test	
				p-value	Effect Size (r)
Pre-test	**M**	6.8	6.0	< 0.01	0.22
	SD	1.7	1.7		
Post-test	**M**	8.5	7.4	< 0.01	0.32
	SD	1.5	1.7		
Learning performance	**M**	1.8	1.9	0.96	0.02
	SD	1.9	2.2		
Wilcoxon Signed-Rank Test	**p-value**	< 0.01	< 0.01		
	Effect Size (r)	0.47	0.38		

Student perceptions

Table 2 shows, for each group, the results of the questionnaire completed by the students after the escape room. It can be observed that the results are quite positive in both groups and that there are certain differences, some of them statistically significant, between the perceptions of the two groups under study.

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TABLE 2. QUESTIONNARIE RESULTS

	Item	Remote Group (N=140)		Face2Face Group (N=101)		Mann-Whitney Test for Independent Samples	
		M	SD	M	SD	p-value	Effect Size (r)
	General evaluation						
1	My general opinion about the escape room is positive	4.6	0.7	4.6	0.5	0.99	0.00
2	The escape room allowed me to improve my knowledge on software modeling	3.9	0.9	4.5	0.6	< 0.01	0.36
3	The narrative of the escape room was attractive	4.7	0.6	4.5	0.7	0.05	0.15
4	The escape room was an immersive experience	4.4	0.8	4.2	1.1	0.2	0.10
5	The escape room was a fun experience	4.6	0.7	3.9	0.9	< 0.01	0.40
6	The escape room was a stressful experience	2.5	1.2	2.0	1.2	< 0.01	0.20
7	I liked the fact that the escape room used digital puzzles	4.6	0.6	4.5	0.7	0.45	0.07
	Evaluation of organization and difficulty						
8	The escape room was well organized	4.3	1.0	4.6	0.6	0.2	0.17
9	The duration of the escape room was adequate	4.3	0.9	4.6	0.6	< 0.01	0.19
10	The escape room was too difficult	2.7	0.9	2.4	0.8	0.02	0.18
11	The main difficulty of solving the puzzles lied in mastering the course materials	2.9	1.0	3.1	0.9	0.3	0.10
12	The main difficulty of solving the puzzles lied in the game mechanics	3.5	0.9	3.4	0.9	0.6	0.06
	Evaluation of guidance and supervision						
13	I think I was prepared enough to succeed in the escape room	4.2	0.9	3.7	1.0	< 0.01	0.25
14	The initial guidance provided was enough	4.1	0.9	4.1	0.9	0.8	0.00
15	The supervision of the activity was adequate	4.4	0.8	4.5	0.7	0.5	0.06
16	I would have liked more help during the escape room	2.2	1.2	1.9	1.0	0.06	0.13
	Evaluation of teamwork						
17	I liked participating in the escape room in a team	4.8	0.6	4.5	0.9	< 0.01	0.19
18	I would have preferred to do the activity alone rather than in a team	4.6	0.7	4.5	0.8	0.08	0.06
19	I would have preferred to do the activity in a team with more members	2.0	1.1	1.8	1.0	0.43	0.09
20	All members of my team contributed equally in solving the puzzles	4.2	0.9	3.7	1.2	< 0.01	0.22
	Evaluation of remote experience conditions (only in remote group)						
21	The fact that the escape room was held remotely caused communication problems in my team.	1.9	1.0	-	-	-	-
22	I would have preferred that the escape room had been conducted face-to-face instead of remotely	3.5	1.2	-	-	-	-
	Evaluation of the willingness of future use	Yes (%)		Yes (%)			
23	Would you like other courses to include activities like this escape room?	98%		100%		-	-
24	Would you recommend other students to participate in the escape room?	99%		100%		-	-

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Team performance

The 34 teams of the remote group spent, on average, 116 minutes playing the escape room (SD = 23), while the 33 teams of the face-to-face group spent 91 minutes (SD = 11). This difference is statistically significant ($p<0.01$) and has a large effect size ($r = 0.58$)

DISCUSSION

Learning effectiveness

The first finding is that, regardless of the format in which the escape room was carried out, the activity was clearly effective from the knowledge acquisition perspective. In both groups, the disparity between post-test and pre-test scores was statistically significant ($p<0.01$) and has a medium effect size, resulting in a positive learning performance in both cases.

Before delving in the comparison of both groups, it is worth mentioning that despite the fact that the conducted escape room in both formats was exactly the same (i.e., the students faced exactly the same challenges and did so virtually), some conditions were different. As explained before, beyond the format in which the activity was conducted, the main differences were the available time in both groups to complete the activity and the moment of the course at which the activity was carried out.

First, as the format was different, so were the communication methods. In the remote group, the students could solve doubts with the teachers by videoconference and could communicate with their teammates using a videoconferencing tool that allowed screen sharing. In the face-to-face group, the students would physically gather around the screen of one of the team members and communicate with each other and the teachers in person.

Second, the students of the remote group could complete the activity once the two hours of time scheduled for the activity had been used up, but the students of the face-to-face group did not because they should physically leave the classroom after two hours. This influenced the time invested by the students to carry out the activity. Indeed, the students of the remote group spent, on average, 116 minutes to complete the activity, while the students of the face-to-face group spent 91 minutes, being this a statistically significant difference ($p<0.01$) with a large effect size ($r=0.58$). However, this difference in time spent does not affect the comparison of the learning performance between both groups because of the way the learning performance is calculated (see Equation (1)).

Third, the remote escape room took place in week 12 and the face-to-face escape room in week 8, so the students of the remote group had more time available to study autonomously the topics covered by the escape room. This explains the differences in the pre-test, where it can be appreciated that the remote students obtained a score of 6.8, while the face-to-face students obtained a score of 6.0, this being a statistically significant difference ($p<0.01$) with a small effect size ($r=0.22$). In the same vein, the moment of the course in which the escape room was conducted probably influenced the scores obtained by both groups in the post-test, where again it is observed that there is a statistically significant difference ($p<0.01$) with medium effect size ($r=0.32$) between the scores obtained by students in the remote group (8.5) and those in the face-to-face group (7.4).

However, it can be also observed that the learning performance in both groups is similar (1.8 in the remote group, 1.9 in the face-to-face group) ($p=0.96$, $r=0.02$). So, despite the starting level of the students in both groups being different, the effectiveness of the escape room in terms of knowledge acquisition was quite similar. This result suggests that the format in which this escape room was conducted did not affect its instructional effectiveness. This seems reasonable, since both the students in the remote and face-to-face groups performed exactly the same five puzzles and did so virtually (for a detailed explanation of the puzzles comprising the escape room, please refer to [9]). Consequently, this indicates that the digital elements used to perform the escape room remotely are fully usable in the escape room performed face-to-face without undermining the instructional effectiveness of the activity and saving time and economic costs associated with the preparation of physical elements.

Student's perceptions

The first finding regarding the students' perceptions towards the escape room is that in both groups, the general evaluation of activity is very positive (item 1, 4.6 out of 5) and that the majority of the elements evaluated garnered very positive ratings that are generally above 4 out of 5. Both groups considered that the activity was useful for learning (item 2), had an attractive narrative (item 3), was an immersive (item 4) and fun (item 5) experience that was well organized (item 8), and had an adequate duration (item 9) and level of difficulty (item 10), and a proper initial guidance (item 14) and supervision (item 15). In addition, the vast majority of the students of both groups stated that they would like to do in other courses educational escape rooms like the performed (item 23) and that they would recommend the activity to other students (item 24).

Nevertheless, it seems that the students in the face-to-face group experienced the escape room as a more educational

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experience, while those in the remote group experienced it as a more playful experience. This can be appreciated in the scores obtained in the items related to the usefulness of the activity to learn about software modeling (item 2), aspect that the face-to-face group rated with a 4.5 and the remote group with a 3.9, as well as in the fun provided by the activity (item 5), which was rated by 3.9 by the face-to-face group and 4.6 by the remote group. In both cases, the differences between these items are statistically significant ($p<0.01$) and have a medium effect size ($0.3 \leq r < 0.5$).

These perceptions can be caused by two reasons. First, it is expected for students who were physically at the university and had the professor at their side to experience the escape room as a more academic (and therefore, for many students, less fun) activity than those students who were doing the activity at home. Second, it is also natural that the students who did the activity face-to-face expected an escape room that was not completely virtual and had some physical elements such as those usually used in recreational escape rooms, while the students who did the escape room remotely could not expect in any case that the activity would involve physical elements. Anyhow, the perception of enjoyment experienced by the students who perform the escape room face-to-face could improve if some physical elements (e.g., jigsaw puzzles, safes and padlocks, ultraviolet light decipherable codes, etc.) had been incorporated. After all, it is reasonable to think that getting a code using an ultraviolet light can be more fun than getting it using a web form.

It can be concluded that the approach and digital elements used to perform the escape room remotely are suitable for the face-to-face version of the activity since the students who performed the escape room in person had a good general appreciation of the activity. This is a very positive result because, as mentioned before, the remote approach using digital elements of an escape room in a face-to-face setting saves time and economic costs associated with the preparation of physical elements needed to conduct non-virtual face-to-face escape rooms. Nevertheless, we deem that the inclusion of physical elements in the face-to-face escape room could improve the students' perception of the activity and could enhance some critical elements of the experience such as fun and immersion.

Contrast of findings with related work

Finally, the obtained findings should be contrasted with those obtained in related studies [13, 14, 15]. In contrast to our contribution, which compare two identical escape rooms based on the same digital elements, these works compared a face-to-face escape room based on physical elements with a different version of the escape room conducted online in which the physical elements were replaced by digital elements. The research reported by Ang et al. [13] compared an escape room designed to learn chemistry conducted face-to-face and online. It concluded that both approaches were useful to learn, but the students preferred the escape room conducted face-to-face because of the presence of physical elements that enabled an immersive environment. These conclusions are partially consistent with ours, since they point to the effectiveness of both formats. However, it must be considered that the authors [13] did not use instruments to measure learning objectively and based its conclusions only on a perception's questionnaire. The research reported by Bright and Ulmen [14] compared an escape room in nursing education conducted face-to-face and online. It concluded that escape rooms can improve academic achievement regardless of remote or face-to-face format. These conclusions are in line with ours regarding learning performance, but the authors did not compare students' perceptions between the two delivery methods. Lastly, the research reported by López-Pernas et al. [15] is the closest to our contribution since it evaluates learning dimensions similar to our research and it is framed in the field of computer science. Contrary to our study, the cited work [15] found that the students who performed the escape room face-to-face learned somewhat more than those who performed it online and perceptions about the activity like fun or immersion were very similar or even slightly higher in the case of the face-to-face group. However, it should be borne in mind that in this case the escape room conducted face-to-face was not exactly the same as the conducted online because it included some physical elements. This fact reinforces the idea suggested in our work about the positive effect that the incorporation of certain physical elements could have in a face-to-face educational escape room.

CONCLUSION

This contribution has presented, evaluated and compared two learning experiences based on the same virtual educational escape room, one conducted remotely and one face-to-face. The research involves 241 students and several instruments to measure knowledge acquisition and students' perceptions. The research is based on a quasi-experimental design, and here lies the main limitation of this contribution since the students performed the activity in different academic years under different conditions.

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Anyhow, the obtained results allow us to reach the following conclusions.

The mere fact that the educational escape room is conducted either face-to-face or online seem to have no effect on its instructional effectiveness. So, the digital elements used to perform a remote escape room are fully suitable for a face-to-face escape room since they do not undermine its instructional effectiveness. This approach saves time and economic costs associated with the preparation of physical elements needed to conduct a face-to-face non-virtual escape room. However, certain students' perceptions towards the activity, such as the experienced fun, were worse in the face-to-face group. We deem that this not-so-positive perception of these aspects could be improved by incorporating in the face-to-face escape room physical elements that would energize the activity.

Consequently, future work involves the incorporation of physical elements like jigsaw puzzles, printable documents, safes and padlocks, or code-cracking ultraviolet lights to the face-to-face escape room presented in this article. This will allow us to study through quantitative and qualitative methods this new version of the activity, examine the effect of the introduced physical elements and compare them with their equivalent digital elements.

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