Educational escape room for teaching Mathematical Logic in computer courses

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***Abstract*—In recent years, escape room has attracted the academic community for its ability to develop teamwork, problem solving, creative thinking and communication, in addition to motivating students. For this reason, educational escape rooms have emerged as a disruptive activity with the promise of improving learning in a creative and engaging way for students. The activities consist of escape rooms that mobilize knowledge on the study subjects of the course in their puzzles, and for students to be able to unveil them, they need to demonstrate their mastery in the contents to be successful in the task. In the literature we can find several studies that report the use of escape rooms in several disciplines, especially in the health area, but few reports the use of educational escapes in computer courses. This article reports on the use of an educational escape room in the discipline of Mathematical Logic, in Software Engineering and Information Systems, courses at a higher education institution and provides information on the instructional effectiveness of using the educational escape room for teaching of logical reasoning, one of the most valuable skills of the 21st century. The results of this article show that the proper use of an educational escape room can have significantly positive impacts on the commitment, motivation and mobilization of students' learning in the discipline of Mathematical Logic. These results also suggest that students prefer these activities to traditional classroom exercise sessions.**

***Index Terms*—escape room, game-based learning, math logic, escape game**

I. INTRODUCTION

In education, student commitment is an important factor for learning and if he is not involved in solving the problems presented, the probability of learning is reduced [1]. Mathematical Logic is an important foundation for students of computing and future Software Engineers [2]. Educators try to find ways to involve first graders in learning propositional logic and predicates, because many do not realize the importance of mathematical logic in their future profession.

In computing, one of the main objectives is to develop programs that solve problems in different domains. Mathematical foundations, more precisely logic and reasoning, help professionals in the area of software development to abstract and understand different problems. We can simply say that this professional will be able to abstract the problem and translate the solution into a programming language [3]. There is harsh criticism in the way of teaching concepts of mathematical logic in the training of future software engineering professionals [4], as for example, the fact that educators do not relate the practice to the concepts presented to students and therefore they tend to become unmotivated and consequently present difficulties in this discipline.

Mathematical logic is still taught in a traditional way, where the teacher is a transmitter of content and the student takes on the passive role of receiver [5], this teacher-centered approach to learning prevents the educational growth of students [6], does not achieve cognitive goals higher [7] and according to some authors [8] [9] [10] [11] are not in line with the requirements of the 21st century, which foresees, in addition to technical knowledge, the development of soft skills, such as the ability to solve complex problems, communication, teamwork and creativity.

Educational games, or serious games, have become popular for software engineering education, as they can increase learning effectiveness, student engagement [12] and can be considered an effective instructional strategy [13] provided they have defined learning outcomes [14] [15]. Games can be digital or non-digital, and are designed to teach students about a specific technical subject, reinforce learning themes and assist in the development of soft skills [16]. Computer courses in higher education are inclined to use games, especially for teaching software engineering [17], programming fundamentals [18], computer network [19], algorithms and complexity and information security [20] [21]. But the literature points out few works related to educational games for the course of Mathematical Logic.

Escape Room is an activity in which participants are confined to a room and have 60 minutes to solve a series of puzzles and escape the room [22] [23]. Several companies have used this method to develop soft skills among employees and have been attracting the interest of educators from different areas of knowledge, due to their ability to develop teamwork, problem solving, creative thinking and communication, in addition to motivating students [24]. When it comes to student

motivation and engagement, several academic escapes have had positive feedback and concluded that students are more active and motivated to work as a team [25], reported an increase in learning, said to have aroused greater interest in the subject addressed [26] [27] and indicates escape room as an interesting learning method to be used in class [28]. Non-digital games have a positive effect on the teaching of computing by promoting social interaction among students, providing a fun environment for learning, stimulating cooperation, and having less effort in their development when compared to digital games [29].

In terms of benefits obtained by students who participate in educational escape rooms, we can highlight the promotion of communication, group dynamics, increased commitment, development of problem solving skills [30], motivation [31] and improvement in learning [32] [33] [34].

This article presents the stages of development of an educational escape room and the results of a pilot experience of an educational escape room carried out in the Mathematical Logic discipline at a higher education institution. The educational escape room presents a variety of puzzles and combines physical and digital resources, creating a hybrid experience. After the activity, a survey was carried out to collect the students' perceptions regarding the learning method, learning topics, necessary skills, positive and negative aspects of the escape room. The results of this research provide information on the instructional effectiveness of using educational escape rooms in the Mathematical Logic course.

II. BACKGROUND

A. Computer Education

In recent years, there has been a great effort by the community of educators to propose new teaching-learning approaches and improve the motivation and engagement of students in the field of computing [35]. Some interesting proposals, develop new methodologies capable of improving student performance using new teaching tools, such as cooperative and technology-enhanced tools, group projects, conceptual questions and new uses of traditional tools.

There are several variables that contribute to student involvement. The teacher has control over factors that involve the type of activity, pace of activity, how to approach a topic, the charismatic of the presenter and the composition of groups. On the other hand, there are factors that are poorly controlled by teachers, such as the motivation to learn [36].

The Swebok [3], an initiative by the IEEE (Institute of Electrical and Electronics Engineers), it describes a set of areas of knowledge necessary to work with software development, from coding to project management. One of the areas of knowledge is Mathematical Foundations, where logic and reasoning are the essence of mathematics that a software engineer must master. They must be able to use mathematical methods to describe and analyze their products, so a solid understanding of logic is essential for these professionals [37]. Discrete mathematics can be seen as software engineering mathematics and its application to the software development problem has been the subject of research [38]. In general, this discipline is offered in the first year of the course and causes a negative perception in students, who feel that mathematics is not essential to their learning experience mainly because several of them arrive with rather weak mathematical skills [39]. Studies [40], [1] indicate that the negative attitudes of students towards mathematics are reflected by poor sults and can generate dropout or evasion.

Several initiatives to improve the teaching-learning of mathematical logic have been proposed. Herman and Loiu [41] discussed the development of pedagogical evaluation tools; Guha [42] made a proposal on how to teach logical rules and make students realize their importance; Bakó [43] suggests computer games and puzzles; Mbale [44] proposed an automated tool that simplifies and assists in the calculation of the propositional logic; Li et *al*. [45] described the use of practical projects to add value about student's learning.

B. Escape Room Educational

Escape room is a relatively new concept but has become really popular recently. In 2007, this type of game has grown quickly initially in Japan and now in all around world [46]. Games, specially non-digital ones, has been used by professors as a form of learning, considering the teamwork and communication improvement between students [29] [47]. Escape room is a multiplayer game with live action where which player needs to find clues, solve puzzles, ending tasks and achieving specifics goals in a limited time. The main objective can includes solve a criminal or mystery case regarding a fictional character or literary escape the room [23]. In games we can enjoy for learning with family or friends or only for fun as well. Academically, escape room is being considered a great opportunity to interaction and learning improvement, from the pedagogical view [48].

Escape room is based on social-constructivist approach by Vygotski, where individuals can interact and share information, experiences and objectives, consists of the learning process [48]. Educational escape room is focused on knowledge, facing challenges solving problems and interacting with other members and having fun. The class escape room is designed to feature activities involving a series of locked boxes in which the students must solve puzzles to be able to open them. In this configuration adapted to education, some commercial designs features are lost, but it still provides a motivating and great experience when well-designed [27].

López-Pernas et *al*. [49] describe an educational escape room for programming teaching and propose a workflow composed of 9 stages. Warmelink et *al*. [50] created the AMELIO escape room that combines virtual reality technology with a strong sense of physical presence and complex social interaction, as results they point to a positive and significant increase in team cohesion. Ho [51] created an escape room for the teaching of cryptography, its results show that students reported greater engagement and an increase in learning.

III. STUDY DESIGN

A. Goals

The aim of this study is to evaluate the students' perceptions about the educational escape room held. Learning effectiveness was assessed qualitatively, using a questionnaire. To achieve this objective, we propose the following Research Questions (RQ):

RQ1. How do students perceive the escape room's contribution to the development of logical reasoning in Software Engineering education?

RQ2. What skills can be developed in an escape room activity, in the students' perception?

RQ3. What are the positive aspects observed by students in an escape room activity?

RQ4. What are the negative aspects observed by students in an escape room activity?

The escape room was attended by students from the Bachelor of Software Engineering and Information Systems courses at a higher education institution.

B. Method

The approach of this research is qualitative, and its nature can be considered applied. The objectives of the research are classified as descriptive and the procedures, considered as field research. Regarding the data collection process, an anonymous questionnaire was used, distributed to the escape room participants at the end of the session. The research was selected because it is systematic, impartial, representative, theory-based and applicable. Several discussions were held between the teachers and monitors of the discipline of Mathematical Logic, to decide which type of puzzle would be more appropriate to meet the objective of mobilizing the knowledge of propositional logic of predicates. The educational escape room proposed in this article has three phases: conception, execution and evaluation (Fig. 1).

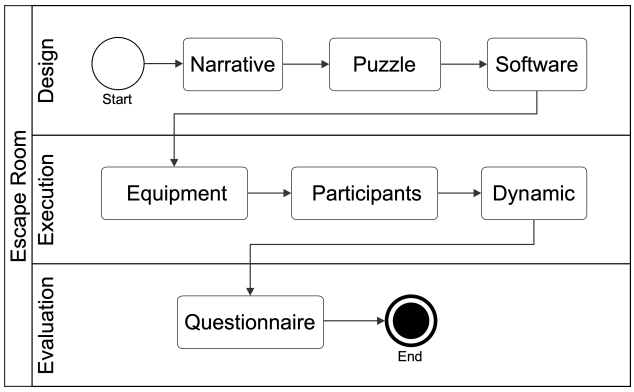

Fig. 1. Proposed process for the educational escape room.

1) Design: **NARRATIVE**: Telling a story is a means of engaging students in the game [52], has the role of contextualization and motivation, with the objective of leaving students immersed in the mystery, so that they are attracted to solve the problems presented. To make this more realistic, there was the participation of two course coordinators, the actresses. The narrative revolves around the "kidnapping of the coordinator", each of them recorded on video, a cry for help to the students, it is up to them to investigate the room from which the coordinator disappeared, investigate clues, solve puzzles, find out who the kidnapper was and find the place of captivity.

CHALLENGES (PUZZLE): The challenges that students should solve were puzzles of propositional logic and predicates (subjects of study of the discipline). Its objectives were aligned with the elements of competence defined in the Pedagogical Project of the Courses, being: i) To identify the logical sequence of steps for problem solving from software specifications in various areas of application; ii) apply mathematical concepts in computational problem solving.

SOFT SKILL: Interactive live action games can help in the development of social skills. In this context, some skills are developed throughout the game - students are expected to develop the cooperation (from the teamwork that is required to solve the puzzles), strategy (knowing when to use the tips and how to join the parts of the puzzles found), autonomy (offering to solve a problem and solve it), communication (some puzzles need two or more people to be solved and communication is a determining factor for this and need to communicate to know the what they found, what they lack and how they will leave the room). For the challenge questions, they were divided into 3 difficulty levels, being 3 easy level, 4 medium and 4 difficult (Fig. 2). The last module was composed of the solution of the kidnapping, that is, the insertion of the name of the supposed kidnapper would be the key to disarm the module, and the software informed the correct answer or not.

It is noteworthy that the puzzles were necessary to align with the narrative, integrate the appropriate course materials to achieve their corresponding learning goal and imply a reasonable difficulty to achieve an adequate balance between boredom and frustration. To meet this last requirement, it was essential to take into account the effect of difficulty, not only of the mechanics of the puzzle, but also of the learning objectives. As suggested by Groh [53], the puzzles were designed to be of increasing complexity, the latter being the most difficult. In fact, despite following a sequential path to the entire escape room, the last puzzle had an open structure to increase complexity. This puzzle was composed of three sub-puzzles that students needed to solve in no particular order to finally succeed in the escape room. After the elaboration of the puzzles, each of them was tested individually to ensure correction. Then, the entire educational escape room was tested through a simulation with a faculty member (knowledgeable of the course materials) who offered to participate. Finally, some minor improvements were made in the escape room based on lessons learned from the simulation and participant feedback.

AUXILIARY SOFTWARE: as part of the dynamic, a software (Fig. 3) was used to assist students during the activity. The software was developed in the C Sharp (C#) programming language, authored by a student monitor, and is available for consultation at the link:

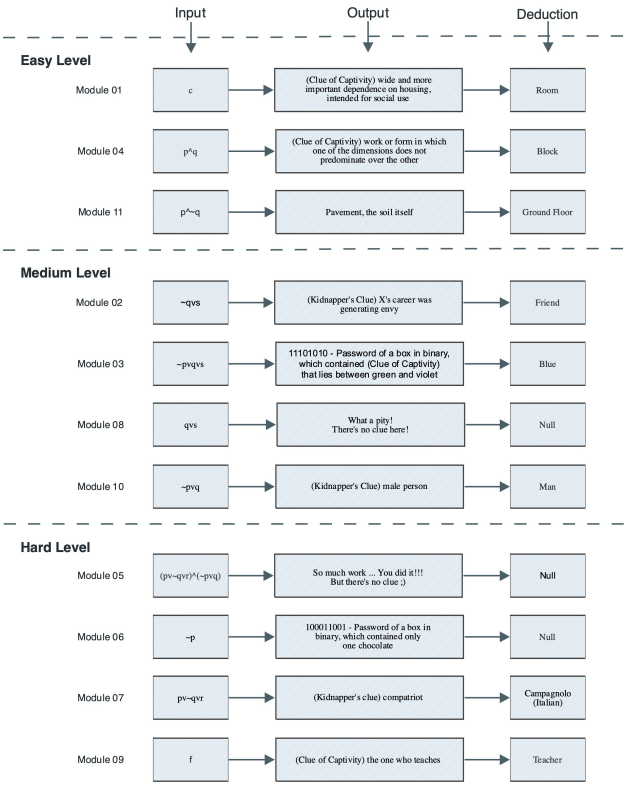

Fig. 2. Flow of puzzles used in the educational escape room learning of Mathematical Logic.

https://github.com/paulogusstavo/escapeRoom.

This software was intended to simulate an explosive bomb, composed of 12 armed modules. Each module should be disarmed with the answer of the questions passed to the students. There was no penalty in case of insertion of an invalid response, thus being possible multiple attempts. When entering a valid answer, the respective module was automatically disarmed, and similarly, a clue was released. As part of the game, the clues did not follow an order to unravel the mystery, and yet, null clues could be offered as a way to maximize the complexity of solving the problem. Upon arriving at half the activity (30 minutes), the software simulated receiving a new video message recorded with the prisoner, which asked the students to be faster and more agile in the resolution because she needed help to escape.

It is worth noting that it was not necessary to complete the activity for the prisoner to be found and released. If the students could deduce the location of the safe house, they could leave the room looking for the prisoner.

2) EXECUTION : **EQUIPMENT**: This step was used to bring animation to the game experience in terms of providing a realistic and amazing scenario for players to interact with. i) Location/space design: one classroom was used for every 27 students to ensure adequate space for the game experience and comfort to move around; ii) Physical props: wooden boxes, padlocks and envelopes were used. The students were made

Fig. 3. Screenshot of support software used in the educational escape room

available to the blackboard, pens and papers to solve the activity. iii) Technical props: a computer with monitor was used to allow interaction with the software and a projector for better visualization of all players. iv) Actors: there was the participation of two actresses (coordinators of the courses), who were willing to record videos to make experience more realistic.

PARTICIPANTS: this activity was optional, and thus, not all enrolled students participated. The courses had 69 students enrolled, and 62 participated in the escape room. For each course, the class was randomly divided into two groups, which disputed each other who would complete the game first. In addition to the students, the game had the participation of 4 monitors (each group was assisted by a discipline monitor) and the teacher responsible. The role of the monitors was to assist in doubts about the process.

DYNAMIC: at the beginning of the activity, the narrative was explained, and the software was started. When started it, the first video of the kidnapping was displayed, and the regressive counter started. From this moment, students began searching for clues hidden in the classroom. The clues were hidden and scattered throughout the room, such as: under the desk, behind the curtain, below the blackboard, etc. Once all the clues were found, the students organized the tasks in the division (Fig. 4), to expedite the resolution of the puzzles.

From the beginning to the end of the dynamic, the monitors and the teacher were watching the whole movement. In some moments, there was a need to intervene in solving the problems passed to the students. This occurred because a great difficulty was perceived on the part of the students in solving some puzzles.

Arriving at the end of the activity, when identifying the place of captivity, the students left the room looking for the prisoner, and ended up finding the coordinator trapped in the teachers' room. Thus, everyone celebrated their freedom and the activity was closed. The team that arrived first at the venue was considered the winner.

Fig. 4. Students during the escape room solving the logical puzzles.

3) EVALUATION: After the end of the activity, it was requested to complete a qualitative analysis of the students perception, in order to verify how much the activity influenced the students. The questionnaire (Table I) consists of demographic questions (Q1-Q4), a set of questions about the Educational Escape Room (Q4-Q13), where students had to agree or disagree using a 5-point Likert scale (1=totally disagree and 5=totally agree). Open questions had the proposal of capturing the students' perception of technical learning topics (Q14), skills to succeed in an escape room (Q15), positive aspects (Q16) and aspects to be improved (Q17).

IV. RESULTS AND DISCUSSION

The research results are presented in this section. Of the 62 students who participated in the escape room, 53 (85%) answered the questionnaire. For the statistical analysis of the data, IBM SPSS® software was used. To assess the reliability of the instrument and ensure internal validity, the Cronbach Alpha test was used [54] on Likert scale questions (Q4-Q13). The result found (Table II) is higher than the limit of 0.7, which indicates a reliable measure. If we analyze the Alpha test separated by gender, we have 0.61 for male and 0.82 for female, these data indicate that the responses of women are more consistent, as our sample is predominantly male, the value of Alpha was 0.71.

The Kolmogorov-Smirnov test was used to verify whether the data had a normal distribution or not and in Table III it can be verified that the data in this study do not have a normal distribution, the significance of the p-value <0.005 in all variables. Therefore, we used the Mann-Whitney U non-parametric test to compare central sample trends

In Table IV, we can see that two variables have a p-value< 0.050 (Q6 and Q9), which means that we must reject the null hypothesis (H_0), that is, the variables Q6 and Q9 do not have an equal distribution in the female and male gender. This issue is discussed in section 4.1.

A. Participant history

Questions Q1-Q3 were used to map the students who participated in the assessment. The sample is characterized

TABLE I
EVALUATION QUESTIONNAIRE STRUCTURE

Section	ID	Question	Type answer
Participant information	Q1	Graduate program	Open
	Q2	Genre	Female/Male
	Q3	Age	Open
Learning method	Q4	What is your general opinion about Escape Room?	Likert
	Q5	Evaluate the statement: "Overall, I liked this game."	Likert
	Q6	Evaluate the statement: "Solving the logic problems was easy for me."	Likert
	Q7	Evaluate the statement: "The Space Room was a lot of fun for me."	Likert
	Q8	Evaluate the statement: "The Escape Room was very difficult for me."	Likert
	Q9	Evaluate the statement: "I liked the Escape Room more than a traditional class session."	Likert
	Q10	Evaluate the statement: "I learned more from the Escape Room than from the exercises developed in the classroom."	Likert
	Q11	Evaluate the statement: "I would recommend the Escape Room to other students."	Likert
	Q12	Evaluate the statement: "The Cape Room could be used in other subjects in my course."	Likert
Learning topics	Q13	"Assess how much the escape room has contributed to the development of learning the following topics: a. Propositional logic b. Predicate logic "	Likert
Skills	Q14	In your perception, what skills do you think were essential to develop the activity?	Open
Positive aspects	Q15	In your perception, what were the main positive aspects of the escape room?	Open
Negative aspects	Q16	In your perception, what were the main negative aspects of the escape room?	Open

TABLE II
ASSESSMENT OF QUESTIONNAIRE RELIABILITY, NUMBER OF ITEMS ASSESSED (N=11)

Alpha Cronbach	Alpha Cronbach based on standardized items	Genre
0.71	0.81	Mixed
0.61	0.75	Male
0.72	0.86	Female

TABLE III
NORMALITY TEST ACCORDING TO KOLMOGOROV-SMIRNOV (LILLIEFORS SIGNIFICANCE CORRELATION), N=53.

Var	Statistics	p-value
Q4	0.470	0.000
Q5	0.484	0.000
Q6	0.290	0.000
Q7	0.484	0.000
Q8	0.218	0.000
Q9	0.388	0.000
Q10	0.149	0.005
Q11	0.485	0.000
Q12	0.509	0.000
Q13a	0.314	0.000
Q13b	0.228	0.000

TABLE IV
MANN-WHITNEY U TEST WITH ASYMPTOTIC SIGNIFICANCE.

Null hypothesis (H_0)	p-value	Decision
Q4 distribution is the same in the gender categories.	0.282	Retain null hypothesis
Q5 distribution is the same in the gender categories.	0.598	Retain null hypothesis
Q6 distribution is the same in the gender categories.	0.043	Reject null hypothesis
Q7 distribution is the same in the gender categories.	0.511	Retain null hypothesis
Q8 distribution is the same in the gender categories.	0.478	Retain null hypothesis
Q9 distribution is the same in the gender categories.	0.003	Reject null hypothesis
Q10 distribution is the same in the gender categories.	0.294	Retain null hypothesis
Q11 distribution is the same in the gender categories.	0.545	Retain null hypothesis
Q12 distribution is the same in the gender categories.	0.447	Retain null hypothesis
Q13.a distribution is the same in the gender categories.	0.107	Retain null hypothesis
Q13.b distribution is the same in the gender categories.	0.081	Retain null hypothesis

by students in the program of Software Engineering (49.1%) and Information Systems (50.9%), who took the Mathematical Logic course during the second semester of 2019, with 82.8% being male and 13.2% of the female gender. The majority of students are in the 17-19 age group (62.3%), while 22.6% are between 20-22 years old, 7.55% are between 23-25 years old and 7.55% are over 25 years, that is, a young profile, all in the 2nd course period.

B. Learning method evaluation (RQ1)

To answer RQ1, questions Q4-Q13.b were used. The Fig. 5 presents the results from the Likert scale, illustrating the students' perceptions.

The results of the research conducted in this study show that students had a very positive general opinion (Q4) about the educational escape room (M=4.75 and SD=0.48) and considered the experience to be fun (Q7) with an average of M=4.77 and SD=0.51. When questioned in relation to the experience with the game (Q5) the average is 4.77 and the standard deviation of 0.51, numbers that indicate appreciation by the students. The Tabel V presents the amplitude, the mean

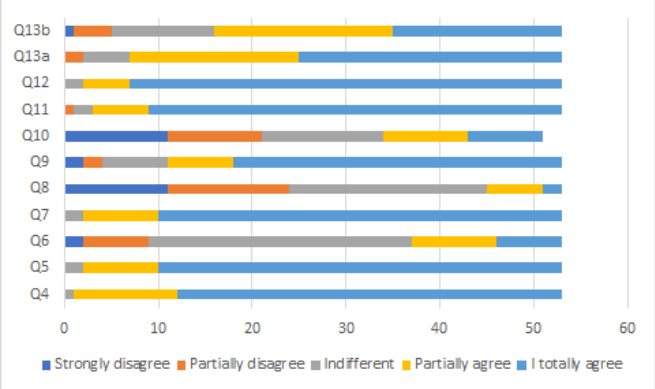

Fig. 5. Likert scale responses of student perceptions of the applied learning method.

and the standard deviation for each variable. It is evident that this experience would not work as a teaching activity, but as a knowledge-mobilizing activity, it proved to be attractive, encouraged and motivated students in solving problems. In a next round we will consider explaining the escape room in the week before the activity and encourage students to review the content, so that they refine their knowledge.

TABLE V
DESCRIPTIVE STATISTICS: RESULTS OF THE SURVEY CARRIED OUT AMONG STUDENTS N=53 WITH AMPLITUDE (A), MEAN (M) AND STANDARD DEVIATION (SD) RESPONSES.

Var	A	M	SD
Q4	2.0	4.75	0.48
Q5	2.0	4.77	0.51
Q6	4.0	3.23	0.97
Q7	2.0	4.77	0.51
Q8	4.0	2.53	1.07
Q9	4.0	4.34	1.09
Q10	4.0	2.79	1.39
Q11	3.0	4.75	0.62
Q12	2.0	4.83	0.47
Q13a	3.0	4.36	0.81
Q13b	4.0	3.92	1.02

The literature points out that students consider problems of mathematical logic difficult to solve [55]. In our results, according to the Mann-Whitney U Test (Table 4), a gender bias was detected in the answers to questions Q6 and Q9. When asked whether it is difficult to solve the logical puzzles (Q6) the average of students is 3.23 and SD=0.97. Women show an inclination to have greater difficulty in solving questions of logic (M=2.57 and SD=0.53) while men (M=3.29 with SD=0.97) consider that they have a medium facility. In relation to Q9, the overall assessment was M=4.34 with SD=1.09 (women M=2.86 and SD=1.21; men M=4.58 and SD=0.87), that is, a strong gender bias that points out that men are more likely to solve exercises in an escape room and women are more likely to solve exercises in the classroom. It is strange for women to have this perception, because our observation during the game showed that women were more organized, were willing to help their colleagues and solved the enigmas

that were proposed, while several men were pacing from side to side without being able to cope. Time pressure, one of them took a puzzle and did not want help (it took almost 40 minutes to solve), while another was trying to open the password lock in brute force. Women have a tendency to be more demanding of you and this can be an important factor that influences your perceptions of being more demanding about your performance. Additional research can be conducted to identify different leadership behaviors between genders [56].

The Q8 "The Escape Room was very difficult for me." presents an overall average of M = 2.53 and SD = 1.07, which indicates that students considered escape to be not very difficult and would recommend (Q11) the activity to other students (M = 4.75 and SD = 0.62). An important factor to be taken into account was that when a puzzle proved to be too difficult for students (they spent more than 10 minutes trying to solve a problem) the monitors took action to give tips and help in the construction of knowledge. This measure was included in the escape room to mitigate the low success rates that lead students to feel frustrated for not having enough time to complete the activity, as reported by Ho (2018) [51] and Li et *al.* (2020) [45].

One of the most interesting points is in charge of Q12 (M=4.83 and SD=0.47), where students agree that Educational Escape should be used by other disciplines. Students who report that the escape should be expanded to other disciplines also liked the game and found it fun, as well as indicating the escape room for other students. Spearman correlations were found between Q12 and Q5 (r=0.432 and p-value<0.01); Q7 (r=0.560 and p-value<0.01); Q11 (r=0.589 and p-value<0.01). It would be interesting to use a hybrid educational escape room, which addressed various study topics and mobilized knowledge from related disciplines, for example: an escape room for Discrete Mathematics, Cryptography and Programming. Thus, the concepts of the subjects can be mixed and presented in a fun way to students.

C. Skills developed in Escape Room (RQ2)

To answer RQ2, the variable Q14 (learning topics) was used, where the student should point out on the Likert Scale how much he considers the Escape Room contributed to his learning in (a) Propositional Logic and (b) Predicate Logic and Q15 (skills) the student could point out which skills he conquered important for solving the Escape Room (Table VI). Regarding learning effectiveness, students agree that the escape room helped them to improve their knowledge in propositional logic (Q13a) with a mean of 4.36 and standard deviation of 0.81 and predicate logic (Q13b) with a mean of 3.92 and standard deviation of 1.02. These results are related to previous studies, which also found that educational escape rooms have the ability to improve students knowledge of a specific topic [13] [49].

As for the necessary skills (Q14) the students considered soft skills (communication, problem solving organization, leadership) at the top of the list followed by a hard skill (propositional logic). These findings point out that the escape room can be used not only to improve students' technical skills, but also to develop essential behavioral skills in the 21st century in Software Engineering. [57].

TABLE VI
STUDENTS' PERCEPTION OF THE SKILLS REQUIRED TO SOLVE PUZZLES IN THE LOGIC ESCAPE ROOM (Q15)

Skill	Frequency	Type
Communication	20	Soft
Organization	12	Soft
Problem solving	11	Soft
Leadership	9	Soft
Proposition	9	Hard
Collaboration	8	Soft
Companionship	8	Soft
Predicates	8	Hard
Logical reasoning	6	Hard
Inference rules	6	Hard
Act under pressure	3	Soft
Persistence	2	Soft
Simplification of logic circuits	2	Hard
Creativity	1	Soft
Patience	1	Soft
Proactivity	1	Soft

D. Positive aspects of the Escape Room (RQ3)

The Table VII shows the positive points observed by the students, Q16 was an open question and from the answers a grouping of the adjectives' frequencies was carried out. The sum of the frequencies is greater than the number of students because it was possible to write as many positive points as they wished. According to the students, competitiveness (24) is the most important factor in this game, followed by the fun (10) it provides, application of the concepts learned in class (9), satisfaction in reaching the final goal (9), cooperation between colleagues (8) and teamwork (8) top the list of positive aspects. These results are in line with those presented by [48], except for the competitiveness that was inserted based on Competition-Based Learning, which combined with games provides a strong motivation for students, helping to increase their performance [58], a fact that is evident in our results.

E. Negative aspects of the Escape Room (RQ4)

In Table VIII, student feedback were categorized when asked about the points for improvement in the activity developed. The biggest criticism was in relation to the puzzles, eight students reported that they could be better developed: be more difficult, more variety and one student thought that they could be easier. The concept of difficult / easy must be related to the complexity of the issues. In this game we created questions on three levels of difficulty, however, according to the perceptions described, we could have put a higher level of complexity. However, 21 students did not answer this question, which leads us to conclude that they considered that there were no negative points to be pointed out.

V. THREATS TO VALIDITY

Wohlin et *al.* [59] it classifies threats to validity into four types: completion, internal, construction and external.

TABLE VII
FREQUENCY OF POSITIVE POINTS IN THE PERCEPTION OF STUDENTS (Q16)

Positive points	Frequency
Competitiveness	24
Fun	10
Application of learned concepts	9
Satisfaction in reaching the final goal	9
Cooperation	9
Award	8
Teamwork	8
Well-designed puzzles	5
Challenger	4
Organization	4
Work under pressure	4
Companionship	3
Interaction	3
Communication	1
Innovation	1
Creativity	1
Puzzles difficulty	1
Leadership	1
Overcoming difficulties	1

TABLE VIII
STUDENT FEEDBACK ON POINTS TO BE IMPROVED (Q17).

Improvement class	Feedback
Puzzles (8)	"The questions."
	"Asking questions that depend on each other for us to suffer more."
	"Decrease the level of issues."
	"More complicated exercise in everyday skills."
	"So that difficult issues are related to logic that requires more of logical reasoning."
	"More difficult questions."
	"Perform shorter exercises and more complex goals."
	"Variety of challenges."
Tips (5)	"Give more tips during the Escape."
	"The amount of tracks and increase the time."
	"Easier tips."
	"The tracks could be better edited, and more organized."
	"Introduce the rules better."
Other courses (5)	"The activity could be carried out in conjunction with other disciplines."
	"Asking questions from other courses that we have taken previously."
	"We could have an Escape Room involving all courses. That way more people could contribute different skills."
	"I could do one with several courses involved."
	"Being programming and not just logic :D."
Location (4)	"The location, how to use the library, leave clues in specific books and pages."
	"An external environment would increase the difficulty and give a tone of gymkhana, allowing more interaction with the university and its dependencies."
	"The rooms are the same." (2 replies)
Groups (2)	"Be in smaller groups."
	"I could have more (smaller) teams."
Frequency (1)	"Do this activity more often."
Other (1)	"Knowing how to deal with nervousness."
Nothing (6)	"At first nothing, it was well organized."
	"Nothing." (4 replies)
	"Nothing, genius."

Internal validity: We recognize that there are threats related to internal validity, such as not having performed in before and after test for a quantitative measure of learning, however this intervention can have an impact on students' motivation, since filling out a questionnaire is perceived as a painful task for many of them. To mitigate this threat, we conducted a qualitative assessment at the end of the activity, at which time the students are still enthusiastic and willing to respond, so much so that 85% of the students who participated in the escape room responded to the survey. Although there is still no consensus, there is evidence that self-assessment provides reliable, valid and useful information for this type of study [60].

External validity: as an external threat, we carried out the experiment in a single educational institution with 53 participants. To mitigate this threat, we run the escape room with two different courses (Software Engineering and Information Systems), which have different student profiles. But we recognize that we cannot generalize the findings.

Construct validity: Regarding the validity of the adapted questionnaire by López-Pernas et *al.* [49] in our survey, we analyze reliability to ensure the internal validity of the survey. The values identified from the Cronbach's Alpha test showed that the results are reliable p-value=0.71.

Conclusion validity: Threats related to the validity of the conclusion concern the relationship between treatment and outcome. We try to mitigate it by analyzing the data to answer our research questions with static methods. First, we identified the non-normality of the data from the Kolmogorov-Smirnov test, which guided us to select the Mann-Whitney U non-parametric static tests (to validate the hypotheses) and the Spearman test to verify correlation between variables.

VI. CONCLUSION

This article described a research study to investigate the students perception of the use of the Educational Escape Room in the teaching of Mathematical Logic. The study counted on the participation of 53 undergraduate students, from the Bachelor courses in Software Engineering (49.1%) and in Information Systems (50.9%). Our results indicate that: **(i)** the students liked the Educational Room (M = 4.75 and SD = 0.48) and consider that the activity helped in their learning process (M = 4.36 and SD = 0.81); **(ii)** what skills required to solve the puzzles are both soft and hard. Top of the list are soft skill's communication (20), organization (12), problem solving (11), leadership (9) followed by propositional logic (9); **(iii)** Among the aspects that students consider positive in the activity, the following stand out: competitiveness (20), fun (10), application of learned concepts (9), satisfaction in reaching the final goal (9) and cooperation among colleagues (9); (iv) the main negative points in the students' perception are: puzzles (8), hints (5), not having other disciplines involved (5), location (4), formation of groups (2), frequency (1), others (1) - however, 6 students said they did not identify negative. Our results suggest that the educational escape room is a promising activity in software engineering education, which

motivates, engages students and promotes knowledge mobilization. Commercially, the escape room is used to develop soft skills, and, according to our results, the educational escape room can be used to jointly develop technical and behavioral skills. As a consequence of this study, we are currently working on a flexible structure to guide educators in adopting the Escape Room Educational principles in the area of Software Engineering, such as, for example, including character roles as they are attracted to games from the type RPG (Role-playing game) [61].

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