Serious Game for Immersion in Embedded Software Development: An Approach Focusing on Smart Homes

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Abstract. *The serious game proposed aims to provide an overview of some problems and solutions in embedded software development for smart homes. The game seeks to spark students' interest in the subject, spreading the idea and motivating them to work in the development area. The game was implemented according to the Learning Mechanics – Game Mechanics (LM-GM) specification model. In order to investigate the educational impact provided by the experience of using the game, besides the questionnaires on usage and technical knowledge, the MEEGA+ questionnaire was used to evaluate the game. The results allow concluding that the game was able to introduce students to the Internet of Things area and motivate them to further their knowledge on the subject. The evaluation of the game by the students presented a positive overall result, as well as approval in seven of the eight dimensions used in the analysis.*

1. Introduction

Internet of Things (IoT) is a term that is just over two decades old. In 1999, Kevin Ashton, executive director of the Auto-ID laboratory at the Massachusetts Institute of Technology (MIT), first used the concept to describe the ability of sensors to connect to new services on the Internet [Ashton 2009]. Emphasizing the field of IoT in smart cities, Kim *et al*. (2017) exposes the impact of population growth in cities such as São Paulo and Tokyo, emphasizing that the most viable solution to face this problem is the development of techniques to reduce resource consumption in cities in an intelligent way. Technology and services such as smart homes are pointed out by the authors as part of the solution to problems in overpopulated centers.

Marikyan *et al*. (2019) conducted a systematic literature review that pointed out that the main characteristics used to define smart homes are the application of technology, the execution of services, and the ability to satisfy user needs. A smart home represents devices and sensors integrated into a smart system, offering management, monitoring, support, and responsiveness, as well as providing economic, social, emotional, health, sustainability, and security benefits. According to the report by Statista (2022), by 2026, the smart home market is estimated to reach US$195.20 billion globally. In Brazil, for example, the estimate is US$2.4 billion. IoT is present in all areas, and its growing evolution is remarkable. The demand for qualified professionals increases proportionally to the technological evolution of IoT. The professional market lacks qualified professionals in emerging technologies such as IoT [Heltzel 2018]. The lack of professionals in the field of IoT still starts in the training environment, where there is little publicity to kindle students' interest in pursuing a profession in this area. The integration of theory and practice in the classroom when teaching IoT is especially important. However, the practical part is sometimes left out due to the lack of hardware components to develop an IoT solution. Using a serious game is a way to promote interaction with hardware in the classroom. Students can thus acquire knowledge by playing outside of class hours.

The future professional in embedded software development can benefit from teaching tools to accelerate their learning, such as serious games, which go beyond entertainment. Its main objective is to provide learning, whether of curricular educational content or mastery of a professional skill [Clua; Rodrigues 2020], as in the case of this research. Serious games can be used to immerse the player in the scenario of creating applications that solve IoT problems. Compared to traditional teaching methods, they can provide more motivation and engagement, thus building knowledge about IoT and encouraging future professionals to enter the field. There is, therefore, the opportunity to design and evaluate a game that promotes a first contact with IoT development, in the context of smart homes, addressing some skills that can be of great value for the job market of the area.

This research proposes to develop and evaluate a serious game that promotes an overview of some problems and solutions in embedded software development in IoT for smart homes to anyone interested in the subject, especially students. Additionally, the research evaluated the perception of using the game, evidencing the participants' opinions about the experience through questionnaires. As a direct contribution of this research, the free availability of the serious game developed can be highlighted, to serve users who wish to continue its implementation or even modify some of its features. In addition to a serious scope, the game proposed seeks to awaken students' interest in the subject, disseminating the idea and motivating them to work in the development area, since IoT applications can have an impact on everyday life. Due to market growth, this research can present contributions to any interested party who aims to enter the field of IoT, having only basic programming knowledge. The research also targets audience students of disciplines related to digital electronics, as well as recent graduates and interns in embedded software development in IoT applications.

The paper is structured as follows: Section 2 presents the background. Section 3 details the serious game developed, and the research methodology used. Section 4 provides and discusses the results. Finally, Section 5 presents the final considerations.

2. Background

The purpose of IoT is to optimize and improve processes in several areas. In the context of home automation, smart homes are expected to save time by automating everyday tasks, being able to control alarms, cameras, air conditioning, and lighting via a mobile application [Camacho-Guerrero and Macedo 2013]. Smart homes are those equipped with connected sensors, communications network, household appliances, and devices remotely monitored, accessed, or controlled, providing services according to the needs of residents [Balta-Ozkan *et al*. 2014]. These houses have lighting, heating, air conditioning, televisions, computers, washing machines, refrigerators, and a security system capable of communicating with each other [Ismail 2019].

McKinsey and Company (2019) pointed out the applications/devices developed for smart homes with the greatest presence in the market, using a classification with five main segments, namely (i) security and protection – security and protection sensors ensure the interior and surroundings of the house, providing monitoring to prevent potential hazards such as flooding and fire; (ii) utility management – the monitoring system in a smart home is used to optimize energy, gas, and water consumption; (iii) wellness monitoring – accessories that provide details about the wearer's health and monitor chronic conditions; (iv) smart home appliances – connected equipment, such as washing machine, stove/oven, refrigerator, and vacuum cleaner; (v) smart entertainment – smart video and music playback tuned to individual preferences. The benefits of adopting smart homes can be divided into four groups [Marikyan *et al*. 2019; Nascimento and Fettermann 2021]: (i) health – user safety, accessibility and availability of care, well-being of aging and vulnerable people, social connectivity and communication; (ii) environmental – the adoption of smart homes can reduce environmental impacts by reducing energy use, feedback on consumption and environmental sustainability; (iii) financial – better costs in virtual consultations, accessibility to health care and sustainable consumption; (iv) psychological – well-being and comfort, entertainment and social inclusion.

2.1. Serious Games

In the literature, several authors seek to define the concept of games. Huizinga (2019) states that games are activities practiced by humans and animals to have fun and improve their skills. The game is a voluntary and free activity, not a task. When games bring learning about a specific subject, develop skills, or reinforce concepts already learned by the player, they are called educational games or serious games. They are used as didactic support for learning [Azevedo *et al*. 2022]. Serious games can provide rehabilitation, training, simulation, and learning [Wilkinson 2016]. The basis for building knowledge comes from the process of executions, discoveries, errors, and successes. Within the context of the game, with task simulations, the player can assume the responsibility for acquiring skills [Barros 2020].

Games can be classified based on the mechanics employed and their gameplay, in the following categories [Sato and Cardoso 2008]: RPG (Role Playing Game), action, adventure, strategy, emulation, simulation, and puzzle. The latter category covers games characterized by the solution of problems and enigmas through observation and reasoning. They are generally composed of a sequence of challenges with progressive difficulty. Some games combine the characteristics of more than one of the listed categories, with varied mechanics and gameplay. The literature review conducted by Feichas *et al*. (2021) showed that the use of games in learning had a positive impact on 22 out of 28 publications analyzed in the period between 2015 and 2020. The main benefits observed in these works were engagement and motivation on the part of the students participating in the research.

2.2. Related Works

Since the emergence of the term serious games, their scope and availability have expanded, and numerous games have been created in the world. The works with greater affinity with teaching in IoT applications are presented in this subsection.

Mavroudi *et al*. (2018) present a learning development pattern for Game-Based Learning in IoT. In addition, it uses a card game for IoT learning as an example of applying the proposed pattern. Nima *et al*. (2018) developed a serious 2D game to present IoT concepts in smart cities, such as information sharing, mobility, security, device networking, interoperability, and connectivity. The game was used by 19 computer science students, who, after experimenting, evaluated the game using a form. Of the five criteria investigated, flexibility had a result of less than 40% and the other criteria were above 70%. Oliveira and Shin-Ting (2019) developed a game in a 3D environment, seeking to bring knowledge of IoT in Industry 4.0, with a superficial choice of components and solutions. The game was evaluated with four participants; therefore, the authors state that the study does not bring conclusive results on the performance of the tool. Chochiang *et al*. (2019) developed a platform for IoT teaching, called ArViz, compatible with Arduino programming. Programming is block-based, making it unnecessary for the player to have experience with C/C++ languages. The tool showed improvement in IoT knowledge of 95% of participants, and overall satisfaction with ArViz was 80%. Dolinay *et al*. (2011) presented a set of components for teaching embedded systems programming, a workbench, composed of a microcontroller, software panel and I/O modules, enabling students to produce applications in real-time. González *et al*. (2013) proposed the programming of embedded video game systems as a motivation for improving learning. The embedded systems course was taught using portable video game consoles and open-source tools. The results portrayed good acceptance by the students in relation to the teaching method, in addition to improvements in the participants' grades. The work by Cristóvão (2018) presented a prototype of a serious game in smart cities with a 3D scenario, developed with Unity. The game performance was analyzed by a questionnaire and the test was conducted with nine unknown volunteers, with positive performance in the learning process of most players.

No tool was found regarding the development of embedded software in open C language in the context of smart homes, a little explored topic. The game proposed in our research seeks to encourage people to enter the area and provide some experience in developing IoT solutions, thus being unprecedented.

3. Method

This section is designed to present the mechanics of the proposed game, including the model used in its development, and the description of the case study conducted with volunteer participants.

3.1. Desafio IoT

The focus of the serious game proposed herein is to present the development of applications in sensor and actuator devices, not addressing other components of an IoT solution, for example, network management and data presentation via a dashboard. Therefore, the IoT applications addressed in the game have hardware and software components for devices that collect information, drive loads, and home automation. The game smart home applications fall into the segments of smart home appliances and utility management. The Desafio IoT is an online puzzle-style web game, aimed at training and improving skills; its challenges are of increasing difficulty, with clear objectives for the player. The challenges have a time limit and are solved through puzzles, with an inventory of items, a combination of tools, and programming snippets. The game was developed using the Unity engine in the C# language, with pixel art style. The LM-GM (Learning Mechanics – Game Mechanics) model [Arnab 2015] was used its development, allowing to highlight the educational and entertainment aspects contained in the game and their relationships. The map shown in Figure 1 shows the stages of the game and the mechanics present in each of them.

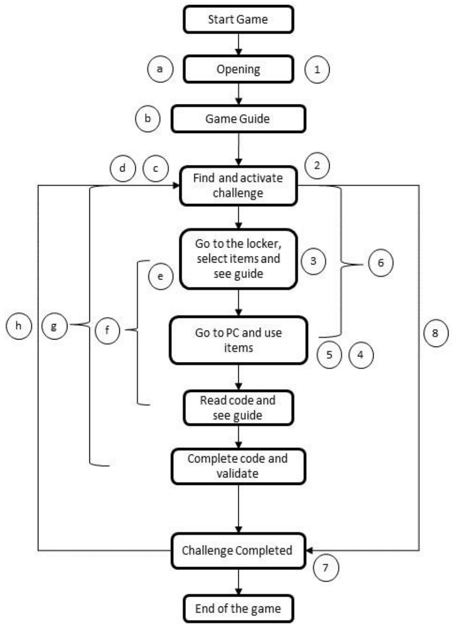

Figure 1. Map of game mechanics. Captions in Tables 1 and 2. Source: The authors.

The analysis identified eight game mechanics represented by numbers, and eight learning mechanics, represented by letters. The game mechanics listed by the LM-GM model used in the proposed game are shown in Table 1. The second column describes how they were applied. Likewise, Table 2 lists the learning mechanics explored and describes how they work in the game. As the final step in the LM-GM model, the relationship between the mechanics and learning components in the game was defined as follows: (1 – a); (2, 7 – c, d); (3, 4, 5 – f, e, b); (6 – g); (8 – h).

Table 1. Game mechanics. Source: The authors.

Game mechanics	Description
1 – History	Story of the game featured in the opening video
2 – Level	Projects have different levels
3 – Selection	Select the proper hardware
4 – Limited time	Decreasing time to choose items and go to the computer
5 – Appointment	Having to go to the computer to complete the challenge
6 – Movement	The player moves around the map to reach key points
7 – Elimination	After completing the challenge, it is eliminated from the map
8 – Behavioral moment	Repetition of steps in different challenges encourages the player to complete the game

Table 2. Learning mechanics (continued). Source: The authors.

Learning mechanics	Description
a – Instructional	The opening video shows the purpose of the game
b – Guide	The manual guides the player, providing the necessary information
c – Goal	The objective is completed when the player finishes the challenge
d – Discovery	The player must find out where the point that enables the next challenge is on the map
e – Planning	The player needs to plan the hardware items to be used in the project

f – Analyze	The player must analyze the problem to complete the challenge
g – Responsibility	The game provides freedom and responsibility for the player to perform all actions within the game
h - Repetition	The repetition of the steps in the challenges helps to fix the concepts shown

As a basis for the subjects addressed during the game, that is, the IoT concepts presented, research on the Brazilian market for embedded systems development and IoT was used, carried out by the Embarcados Portal (2019; 2021) in 2019 and 2021. The research purposed to identify and trace trends in the Brazilian market in embedded systems development and IoT, since the study in question was carried out in Brazil. The surveys carried out relied on information provided by 974 and 577 professionals who work directly with embedded systems development and IoT. Based on the results, we highlight that wireless communication, battery power, and real-time response were the resources most used in the projects developed. Among the wireless technologies in projects, the most used are wi-fi and Bluetooth. The most used real-time operating system was FreeRTOS. The most used coding tool is Visual Studio Code and the C programming language. The kit provided by the manufacturer is the most used, followed by ESP32. The game addresses these issues in the smart home environment, but the skills acquired can be applied to other IoT areas.

The game scenario is set inside a house (Figure 2 – left), with several equal and/or similar rooms, and the player only has a view of a part of the house while playing. Moving around this scenario is an important game mechanic necessary to complete the challenges since some stages have limited time. The player is free to follow any path and can start any of the projects by the activation points available on the map.

Figure 2. Game scenario and game inventory. Source: The authors.

The game was divided into five different residential IoT projects and each has a maximum of five versions, totaling 13 challenges (Table 3). Once the game is booted, five activation points for challenges are available on the map, the first version (V0) being all five blueprints. Each challenge consists of four stages (Table 4).

Table 3. Game projects (continued). Source: The authors.

Project	Version
1	Version V0: Monitor the presence of rain in the house by Wi-Fi; V1: Close the windows when it rains. Content addressed: ESP32 + Wi-Fi + FreeRTOS + Sensor + Engine.
2	Version V0: Monitor flower soil moisture by Bluetooth; V1: With the help of the irrigation pump, water the plants when necessary; V2: Plants are dry, change watering to when soil moisture is below 70%.

	Content addressed: ESP32 + Classic Bluetooth + FreeRTOS + Sensor + Irrigation pump.
3	Version V0: Monitor the electric current of the air conditioner by Bluetooth; V1: Monitor home temperature and humidity via Bluetooth; V2: Turn off the air conditioning when it is on unnecessarily. Content addressed: ESP32 + Classic Bluetooth + FreeRTOS + Sensor + Relay.
4	Version V0: Turn on the dog feeder at 8am and 5pm, prompting via Wi-Fi; V1: Make coffee at 7 am by turning on the coffee maker. Notify by Wi-Fi; V2: Schedule an audible alert, for 5 minutes, at 7:30 am. Notify by Wi-Fi; V3: Change project power to battery and switch connectivity to Bluetooth. Content addressed: ESP32 + Wi-Fi + BLE + FreeRTOS + External RTC + Relay.
5	Using voice control, turn the lamps on and off, prompting via Wi-Fi. Content addressed: ESP32 + Wi-Fi + FreeRTOS + Microphone + Relay.

Table 4. Challenges stages. Source: The authors.

Stage	Description
Activate challenge	When there is no challenge on the screen, the player must find an exclamation mark on the map to start the challenge. Initially, the map has only the V0 challenges of the projects. As soon as the V0 challenge of the project is solved, it is eliminated from the map and the V1 of the same project appears, so that it can be activated.
Pick up components	With the challenge defined and if necessary to solve it, the player must choose (with the help of information in the manual), the components to be used in the IoT solution in the closet. Up to three components are used per challenge and the player's backpack has three spaces to carry them. Figure 2b shows the game inventory and, in the lower left corner, the player's backpack.
Take to the computer	With the items chosen, the player must go to the computer and click on them to add to the project. The steps "Pick up components" and "Take to the computer" must be performed within a specific time; if the player does not reach the computer in time, the items and the challenge are reset. If the items chosen are not correct to solve the challenge, the player must look for the correct items in the closet again. Once the player has got all the right hardware components, he/she moves on to the next programming step.
Program IoT solution	The computer screen opens automatically once the hardware components are correct. The project is programmed in the C language and the codes presented correspond to those used in real development practice as far as possible. Using the computer screen during in-game programming has features such as Visual Studio programming software with the ESP-IDF extension (an extension for programming the ESP-32 through Visual Studio). The documentation needed to solve the problem is available in the manual.

The challenge in the programming step is presented with empty spaces that must be filled in according to the manual, with names of functions, variables, variable types, function parameters, and time variables. If the fields are filled in correctly, the challenge is completed, and its activation point no longer appears on the map. If there are more versions, the activation point of the next version is placed on the map. The game ends when all the versions of blueprints are completed. The current situation of the player in relation to the challenges is indicated in the upper left corner of the game scenario (Figure 2 – right). When the challenge has not yet been discovered, the situation is represented by the yellow question mark; when discovered and not resolved, it is indicated by the red exclamation point; when the challenge has been solved, it is marked by a green tick. Fixing each challenge includes two sequential steps – hardware and software/programming – the programming step can only be played if the hardware chosen (if necessary to solve the problem) is correct. The combination of correct hardware components for each challenge is only one and validated by equality comparison. The programming step is also corrected by equality since each field filled in has only one correct answer. The Desafio IoT game can be accessed at the following link: https://cleidiana.itch.io/desafio-iot

3.2. Participants and Method Description

After the development of the game, a study was conducted with 31 students enrolled in the Embedded Systems Programming discipline for 42 days, in the second semester of

2022 at the Federal University of Itajubá (UNIFEI). Participants could use the game for as long as they wanted during that period. The students were informed about the game experimentation, the main purpose of the research. A Free and Informed Consent Term was given to the students who agreed to participate in the research, highlighting the initial purpose of the study in question, as well as the anonymity and use of the data collected only for research purposes. This research followed the ethical precepts determined by Resolution No. 510 [Brasil 2016], of April 7, 2016.

Before using the game, students were instructed to answer a technical knowledge questionnaire (pre-test). After the test period, the students finished evaluating the game using three questionnaires in the post-test stage: a technical knowledge questionnaire (the same as in the pre-test), a questionnaire about using the game, and the MEEGA+ evaluation questionnaire (Model for the Evaluation of Educational GAmes), proposed by Petri *et al*. (2019). The Technical Knowledge Questionnaire has 11 questions[1] to cover the contents presented in the game, aiming at verifying whether the participants have improved their knowledge in the field of IoT, and validating the objective of the tool. The Questionnaire on the Use of the Game[2] has five questions for measuring the perception of each student after trying out the game. The questions deal with interest in games, time played, and motivation during the game. The MEEGA+ Questionnaire has 31 questions[3] that use a five-point Likert scale, divided into eight dimensions: usability, confidence, challenge, satisfaction, fun, focused attention, relevance, and perceived learning. Regarding the original questionnaire, four questions were not investigated, in addition to the "social interaction" dimension, as they do not apply to the game proposed in this research. For analyzing the results of the technical questionnaire, the participants' responses in the pre- and post-test were compared. The experience obtained playing Desafio IoT can be related to the possible change in the answers of the participants who indicated greater knowledge in the area. The answers to the form about the use of the game showed trends in the discussion of results. The post-test was held on the same day the game testing period ended.

4. Results and Discussion

Regarding the age range of the 31 students, only one participant was younger than 18 years old (3.2%). 23 participants were between 18 and 20 years old (74.2%). The age group between 21 and 23 years comprised six students (19.4%) and only one participant was older than 24 years of age (3.2%). The 'C' programming language was known by 30 participants and only one student knew 'C++', therefore, all participating students knew some programming language, indicating that they would be able to read the codes present in the game.

By applying the same Technical Knowledge Questionnaire to the participants before and after using the game, it was possible to analyze the possible effects of the game on the students' perception of the topic. Figure 3 shows the answers (%) to questions Q1 to Q7 in the pre- and post-test, as well as the average for each question in both tests. The average score for the questions was obtained by assigning values from 1

[1] https://drive.google.com/file/d/1qRU6FuQ5hPx7xbEqFqUf649Sq9JS6GYT/view?usp=drive_link
[2] https://drive.google.com/file/d/1we6fDy_9jMfKrMyI7GdxdsggdQnwMJ9U/view?usp=drive_link
[3] https://drive.google.com/file/d/1Hxg6zt-vHt_uMGudfa1_63gzhjh5_MsJ/view?usp=drive_link

to 5 to the levels of agreement on the Likert scale, with an average of 3 indicating equivalent agreement and disagreement for the total number of participants. The questions that had the greatest increase indicate that the game was successful in providing participants with experience in projects that use microcontrollers, sensors, actuators, and firmware programming. The increase of at least one participant choosing the options 'totally agree' or 'partially agree' in all questions and the average of answers pointed to a positive effect of the experience on the knowledge of the participants. However, the responses to Q5 showed that the game was not effective in increasing the participants' interest in working with firmware development for IoT.

Pre-test participant responses

	Mean (SD)	Totally disagree	Partially disagree	Neither agree nor disagree	Partially agree	Totally agree
Q7	2.97 (1.28)	12.9%	32.3%	9.7%	35.5%	9.7%
Q6	4.00 (1.03)	3.2%	9.7%	3.2%	51.6%	32.3%
Q5	3.26 (0.82)	3.2%	6.5%	58.1%	25.8%	6.5%
Q4	1.58 (0.99)	64.5%	22.6%	6.5%	3.2%	3.2%
Q3	2.32 (1.08)	29.0%	25.8%	29.0%	16.1%	0.0%
Q2	3.58 (0.99)	3.2%	16.1%	9.7%	61.3%	9.7%
Q1	3.71 (1.22)	9.7%	3.2%	22.6%	35.5%	29.0%

Post-test participant responses

	Mean (SD)	Totally disagree	Partially disagree	Neither agree nor disagree	Partially agree	Totally agree
Q7	3.47 (1.04)	3.3%	13.3%	33.3%	33.3%	16.7%
Q6	4.10 (0.65)	0.0%	3.2%	6.5%	67.7%	22.6%
Q5	3.23 (0.92)	6.5%	6.5%	51.6%	29.0%	6.5%
Q4	2.61 (1.26)	22.6%	29.0%	19.4%	22.6%	6.5%
Q3	3.10 (0.94)	3.2%	22.6%	41.9%	25.8%	6.5%
Q2	4.16 (0.58)	0.0%	0.0%	9.7%	64.5%	25.8%
Q1	4.00 (0.77)	0.0%	3.2%	19.4%	51.6%	25.8%

Figure 3. Answers to questions Q1 to Q7 in the pre- and post-test. Source: The authors.

The answers to the question about how many IoT applications the participants knew (Q8) pointed out that after experiencing the Desafio IoT game, the option that they did not know any application reduced by 25%, and the option that they knew more than three applications increased by 15%. The answers “two” and “three” applications varied from 13% to 20% and 6% to 10%, respectively, and the answer “one” remained at 6%. In question Q9, after using the game, the number of participants who said they knew the FreeRTOS system increased from 23% to 35%, and those who did not know any real-time operating system (RTOS) dropped from 55% to 52%. The answers to the question about which microcontrollers they knew (Q10) showed that, after using the game, the number of participants who knew ESP32 increased from 19% to 39%. The percentage of participants’ responses that they knew Arduino ranged from 97% to 90%. The answers to questions Q8, Q9, and Q10 showed that the game experience increased the number of IoT applications known to the participants, as well as the number of participants who knew the real-time operating system (FreeRTOS) and the ESP32 microcontroller used in the game. In all the questions, except for Q5, there was an improvement in knowledge, according to the participants’ opinions. This result pointed to a possible learning about the utility of IoT, microcontrollers, firmware programming, solving problems with IoT, use of libraries, sensors/actuators, ESP32, and FreeRTOS, these being the contents covered in the Desafio IoT game.

The Questionnaire on the Use of the Game was answered after the experience of using Desafio IoT and allowed analyzing how the participants interacted with the game. In this context, only one participant responded to liking games (Q1). When asked if they studied to play Desafio IoT (Q2), most (17 students) answered 'no' and 14 students answered 'yes'. In the third question, the participants were asked if they were interested in further knowledge on some concept learned in the game; the majority answered they are interested (22 'yes' and nine 'no' answers), indicating that the game achieved one of its objectives, that of encouraging players to have more contact with the IoT area. In the fourth question, participants answered how much time they spent playing Desafio IoT. The most chosen option was 'one to two hours' (14 participants) and then 'two to three hours' (nine participants). Six participants stated that they had played for 'less than an hour' and two stated 'three to four hours'. In the last question, the students informed how long ago they had played for the last time before filling out the form, and the predominant answer was 'one to two weeks', with 15 answers. Seven participants answered 'less than a week' and six participants answered 'more than two weeks'.

When analyzing the responses in the post-test, divided between the usage questionnaire and the technical knowledge questionnaire, the students were observed not to show greater interest in working with firmware development for IoT after playing the game but reported an interest in deepening some concept learned in the game. The content presented can be concluded to have successfully taught to the players, as the questionnaires demonstrated their greater perception regarding knowledge in the field of IoT after playing Desafio IoT. Regarding the MEEGA+ Questionnaire, approval was greater than 60% in three of the eight dimensions evaluated, namely “satisfaction”, “relevance” and “challenge”, with 72%, 69%, and 62% of answers 'totally agree' or 'partially agree', respectively. These three dimensions were considered the most positive aspects of the game. Four other dimensions reached more than 50% of ‘totally agree’ or ‘partially agree’ answers, namely: “trust” had 56%; “usability”, “perceived learning” had 53%; and “fun” had 52%. These dimensions were considered the good aspects of the game. The dimension that presented the worst result was that of 'focused attention', in which only 34% of the answers agreed with the statements, being the most criticized aspect of the game. This data indicates that one of the points that could be improved the most in the game is related to attracting the player’s attention, which would possibly increase their involvement with the game and learning. Considering the 31 questions, 16.6% of the answers were 'totally agree' and 40.1% 'partially agree', while 22.7% were 'neither agree nor disagree', 15.2% 'partially disagree' and 5.4% 'strongly disagree'. The general average of the eight dimensions was 3.48, pointing to a good evaluation of the game. The dimensions “satisfaction”, “relevance” and “challenge” had the highest means, with 3.84, 3.78, 3.66, respectively. The dimensions that received an intermediate evaluation were “fun”, with 3.45, “trust”, with 3.42, and “usability” and “perceived learning” had an average of 3.34. Only the 'focused attention' dimension had an average of less than 3, with 2.99. The dimensions that stood out for having the best evaluations were: (i) **Relevance**: indicated that the content and educational proposal of the game are in accordance with the needs and objectives of the students; (ii) **Challenge**: troubleshooting tasks with IoT applications made the game suitably challenging for players; (iii) **Satisfaction**: game progress and learning succeed in rewarding the player's effort.

The main limitations of this research are sample size, as the validity and representativeness of the results could be improved by testing the game in other case studies; and monitoring the use of the game, as there was no monitoring of the participants’ possible difficulties during the experience or any guarantee of using the game for a minimum period.

5. Final Considerations

The main motivation of this research can be justified by the demand for qualified professionals that increases with the technological evolution of IoT and the low interest of students in this area. Aiming to increase students' interest through a more motivating learning method, this work proposed the Desafio IoT serious game as a tool to assist in the first contact with IoT environments and applications. The game promotes an overview of some problems and solutions in embedded software development for smart homes, aimed at students, recent graduates, or interns with basic knowledge in programming. Some of the differentials of the Desafio IoT are the immersion in the development of IoT solutions in the context of smart homes, being a serious game and the use of the C language for programming embedded software.

The objective of developing a problem-solving serious game with IoT applications was met; it was tested by a group of computing students and made available as a final game on a website. The game was well evaluated by the students in the analyzed criteria and was successful in presenting the concepts for developing IoT applications and for encouraging students to further the content presented in the game. As future work, we propose to increase the Desafio IoT to other areas, such as smart cities, in addition to smart homes, which was the focus of this approach. It is also necessary to make improvements, especially in terms of intensifying the player's attention, considering the evaluation carried out. In addition, the hardware and software components used in the game can be expanded, as well as the number of challenges proposed.

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