IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received December 13, 2020, accepted January 4, 2021, date of publication January 6, 2021, date of current version January 22, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3049690

Using an Online Serious Game to Teach Basic Programming Concepts and Facilitate Gameful Experiences for High School Students

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This work was supported in part by the Spanish Ministry of Science, Innovation and Universities under Project TIN 2015-66731-C2-1-R, in part by the Madrid Regional Government through the project e-Madrid-CM under Project P2018/TCS-4307, and in part by the e-Madrid-CM Project through the European Structural Funds (FSE and FEDER).

ABSTRACT Teaching programming to pre-university students has attracted a great deal of attention in the last years. The benefits of teaching programming before University have been investigated by taking several approaches to improve the students' learning scores, motivation and satisfaction levels. Serious Games (SGs) are also gaining an increasing research interest for education. SGs can be defined as games designed for a primary goal other for than pure entertainment. In the case of this paper, the DFD-C serious game has been created to investigate whether High School students will improve their learning of programming fundamentals and, if there are gender differences in the improvement. Moreover, it is explored the perception of the gameful experience by the students when using a serious game such as DFD-C, and if this perception is different in the case of boys or girls. An experiment with 38 K-10 High School students has been carried out during the 2019-2020 academic year. All students took a pre-test at the beginning of the experiment. After that, they were randomly split into a control group (no use of DFD-C) and a test group (use of DFD-C). Finally, all of them took the same test (post-test) to measure their learning gains. The test group also completed the Gamefulquest questionnaire to evaluate their perception of the gameful experience. A significant improvement in the scores of the test students was registered, with no gender differences. Moreover, the answers to the Gamefulquest reveal that students had a positive gameful experience, being the ratings of the girls slightly higher than boys. It is concluded that using SGs to teach learning programming fundamentals to High School students increased their learning scores and students perceived the sense of playfulness, guidance and social experience of the SG without having significant differences between girls and boys.

INDEX TERMS Serious games, programming basics, gameful experience, data flow diagrams, C language.

I. INTRODUCTION

Learning to program has attracted a great deal of research in the last decades in pre-university levels [1], [2]. It is not clear if traditional University programming teaching can be replicated in High School or Primary Education because children of younger ages have lower attention levels and probably are less motivated to learning how to program because they did not choose it. Many approaches have been tried such as [3]: textual programming, block-based programming, and unplugged activities.

Textual programming dates to the 60s with the LOGO programming language (a dialect of Lisp) [4]. LOGO was not a compiled language. At the beginning, it was an interpreted language with immediate feedback on individual instructions. That way, children could give instructions in LOGO to move a turtle. The core idea of this approach is that writing is a powerful medium for students to think and reason, and thus to learn programming [5].

The current trend seems to be more visual, based on the use of block-based programming, to engage and motivate

The associate editor coordinating the review of this manuscript and approving it for publication was Mark Lee.

students by creating games in multimedia environments using languages such as Scratch [6]–[9]. In the case of not having technological devices to program, the alternative is to use unplugged activities [10]. For instance, students could fill in exercises downloaded from Code.org and think to solve them. However, the efficacy of this approach has still not been proved [11].

Much research has also been devoted to the use of Serious Games (SGs) for education. A SG can be defined as ''a mental contest, played with a computer according to specific rules that uses entertainment to further government or business training, education, health, public policy and strategic communication objectives'' [12]. SGs have been used in different courses as tools to increase the students' learning and helping students' focusing [13]. Among the main benefits of SGs, it can be cited that they help motivation, improve logical reasoning, and encourage learning through interactivity [14], [15]. In addition, there are recent studies on the particular benefits of using serious games to teach computer education [16], [17].

Given that many High School students have difficulty in relating the abstraction required to design an algorithm in pseudocode and to obtain the expected results [18], and also the need of teachers to have powerful resources to foster students' learning and motivation. The DFD-C serious game has been created to investigate and measure whether students will improve their learning and if there is a gender component in improvement. Moreover, the perception of the gameful experience by the students is explored when using a serious game such as DFD-C, and if this perception is different in the case of boys or girls.

This paper has six sections: Section II presents the related work; Section III describes the serious game DFD-C to teach programming to High School students; Section IV describes the experiment conducted; Section V presents the results gathered; Section VI discusses the results; and Section VII ends the paper with the main conclusions and lines of future work.

II. RELATED WORK

Serious Games (SGs) are gaining an increasing interest for education by taking advantage of the latest simulation and visualization technologies, SGs are able to contextualize the player's experience in motivating learning environments [19]. SGs engage students to ''convey ideas, values, and sometimes at persuading the players'' [20]. These games have the purpose of influencing the players' thoughts and actions, so they can help them in their real life. This is particularly relevant in the area of teaching programming as one of the goals of teaching programming is to allow students to use computer resources to solve their real life problems [21].

In order to develop effective SGs for education it is necessary to take into account three kernels of SG design (see Fig. 1): theory, contents and game design. The instructional goal is key and SGs should provide quality contents based on proper educational foundations [20].

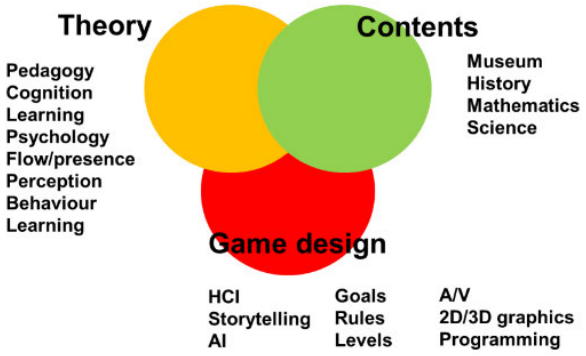

FIGURE 1. The three kernels of SG design (source: [19]).

Principles from pedagogy, cognition, learning, psychology, flow, perception, behaviour and learning should be taken into account. For instance, when designing a SG to teach programming to children between 10-12 years old, it should be taken into account their particular features as pre-adolescent children, what they like, their preferences and their cognitive development. More research is needed on methods and tools for infusing pedagogy and instruction inside SGs [19].

The elements of game design: storytelling, goals, rules, levels, graphics and the programming of the game should also be factored in. Advances in related areas such as Human-Computer Interaction (HCI) and Artificial Intelligence (AI) help to produce more motivating SGs for students, with interfaces adapted to the needs detected (theory kernel) and even with the ability of adapting to their game patterns or dialogue in natural language with non-character players by applying modern AI techniques.

Another key design point is the contents kernel. The SG for education is focused on a certain domain such as Mathematics, Science or Language. High quality contents should be created by experts in the domain according to the pedagogy and instruction kernel for the SG to achieve its educational purposes. In particular, to teach programming -that is the focus of this paper- there are several SGs available, such as the approaches described in the following paragraphs.

Wu's Castle [23] allows students to program changes in loops and matrices in an interactive and visual way. An experiment carried out with a randomized stratified sample with a crossover experimental design showed that the game Wu's Castle is more effective than a traditional programming task to learn how to solve problems in loops, matrices and nested loops.

A pilot study at Aalto University during the spring semester of 2011 on the use of serious games in the field of data structures and algorithms explored the benefits of four SGs: SortingGame, SortingCasino, Secret rule and Draw and guess. The results indicated that using such card games can be useful in teaching data structures and algorithms [24].

It was also found that students have shown great motivation to play educational scaffolding games compared to the original games [25]. In addition, they have successfully

integrated their problem-solving skills into the games using their knowledge of programming concepts.

Prog & Play [26] is based on an open source real-time strategy game, in which four criteria are assessed: improvement of programming skills, system usability, entertainment, and teacher evaluation. The result was a functional and motivating SG. One of its key elements can be the interaction with real-time strategy (RTS) because it motivates the players by making them protagonists of the story. Another key element is how the pedagogical contents are introduced in the SG.

Capital Tycoon [27] was implemented and evaluated as a supplementary instruction method in a computer programming course. Students were randomly divided into a test group and a control group. The control group used an electronic test program, and the test group used Capital Tycoon. After the instructional treatments were implemented, the students' intrinsic motivation and final results were measured and analyzed. The result of the study indicated an improvement of the interest/enjoyment dependent measures, perceived competence and overall Intrinsic Motivation Inventory scores in the test group.

HIT Typing (Typing game), Serious Cube (Multiple choice game) or 3D action game [28] were proposed and evaluated with the core idea of ''Learning programming through games''. This approach is geared towards students who have no previous knowledge of programming. From their results, they concluded not only that it is possible to obtain a basic knowledge of programming while having fun through these games, but that to achieve a deeper understanding of the programming processes executed within the game.

An educational computer game for teaching the concept of variable with the ''semantic method'' is also another approach [29]. This method forces the student to concentrate only on understanding the problem and finding the right solution using the logic behind the programming concepts. Thus, the student learns the concept of variable in an intuitive and motivating educational computer game environment. The results indicated that the game actively promotes interactivity and deeper learning.

ProGames [30] is a system for learning programming skills through different levels of visually engaging and interactive programming games in Greenfoot [31]. The games were categorized according to the students' tastes. The evaluation was done with students enrolled in the Computer Science, Computer Science & Mathematics, and Computer Science & Business Administration and Management degrees of the Universidad Rey Juan Carlos of Madrid. Firstly, the usability of the game in the 2012-2013 academic year. Next, in the 2013-2014 academic year, its attractiveness to the students was evaluated according to the organization in game categories. The results of the first evaluation showed that the use of the ProGames game influenced more positively in the students' learning, generating significant differences in the score that evaluates the knowledge before and after its use in the test group. The magnitude of this improvement was outstanding. The results of the second evaluation corroborated the results obtained in the first evaluation.

The Odyssey of Phoenix [32] is a learning tool to improve the student's understanding of object-oriented programming such as encapsulation, abstraction, inheritance and polymorphism. The study was conducted with 20 randomly selected sophomore computer science students. Students were split into a control group and a test group. The two groups completed a 70-questions pre-test. Next, the test group used the game for one month in addition to their daily lessons, whereas the control group only performed their daily lessons. Finally, both groups completed a post-test, which was the same as the pre-test. The results proved that the test group obtained a higher significant improvement in the learning process and the understanding of object-oriented programming with the game proposed as a support learning tool than the control group.

ProLounge (Programming Lounge) [33] is a SG covering topics considered difficult in C programming. An experiment was carried out at the university with 47 students of the computer applications subject, in which the use of the game was proposed. Each one of the students had access to the game from their cell phone or from their computer to the website where the game was online. Students were asked to pass all levels of the game, once the evaluation process was completed. ProLounge proved to be a great source of fun learning for the general student community.

TIS-Q-SP [18] is an online game-based formative assessment in a flowchart-based Intelligent tutoring System to improve problem-solving skills. It benefits from Bayesian networks for the process of decision making for learning computer programming. The game combines tic-tac-toe with online assessment and revises the rule of tic-tac-toe for stimulating students to use online formative assessment. An empirical investigation carried out to evaluate its performance revealed considerable learning gains for the test group who used TIS-Q-SP with respect to the control group who did not use TIS-Q-SP.

Autothink [17] is an intelligent adaptive SG to develop Computational Thinking [21] for Primary and Secondary school students. It seeks to engage players through personalized and fun game play while offering hints, feedback and tutorials. Autothink is based on the use of icons instead of text, code or programming commands. The goal is to reduce the cognitive load of the students by minimizing the chances of syntactical errors. It covers the sequence, conditional and loop concepts, and four skills: problem identification and decomposition, algorithm building, debugging and simulation. Its interface is inspired by the classic Pac-Man game and it has also proven useful for students reinforcing not only theoretical knowledge but applied knowledge and developing skills.

Finally, regarding the assessment of the design of serious games in the literature, the main trend is to focus on the quality of the SG's content, rather than on the SG's intention-based design. However, it seems important to

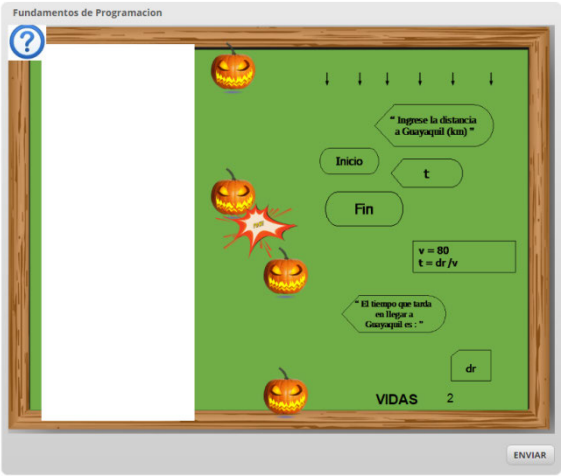

FIGURE 2. Game "Avoid the Pumpkins" the player must arm the DFD for the sequential algorithm. By dragging the DFD piece (right) and dropping onto the board (left), a collision with the pumpkin occurs.

FIGURE 3. Narrative for an activity on the arm the DFD game for a conditional algorithm.

analyze the game's formal conceptual design, its elements, and their relation to each other based on the game's purpose [34]. In fact, the lack of assessment tools to analyze serious games and insufficient knowledge on their impact on players is a general criticism in the field. If SGs aspire to be validated as useful tools to foster learning their impact on players has to be studied [34], [35].

III. DFD-C

The fundamental part of serious games is to integrate the learning objectives into the game, through which the educational objective is achieved [13]. So, serious game DFD-C is based on the Learning Mechanics-Game Mechanics (LM-GM) model since it supports the analysis and design of educational games [36].

For the elaboration of the serious game DFD-C, first an instructive script was developed. The instructional script allows to place all the necessary resources for the development of the educational resource [37]; then it was taken as reference the elements indicated by [38].

A. GAME MECHANICS

As the game mechanics represents the behavior assessment activity in the game, they set the actions to be executed when the player clicks on a certain area. For example: In the "Avoid the Pumpkins" Game, in the "develops Flow chart" activity, when the player selects an element from the flowchart and places it outside the area (board) the element must return to where it was, or if the element hits a pumpkin it loses a life as shown in Fig. 2. In the "Round of Penalties" game (Fig. 4), the player must score a goal by answering the question. If the answer is correct, s/he scores a goal; otherwise s/he does not.

B. VISUAL AESTHETIC DESIGN

The visual design is the one that determines how the tools and the functions of the game mechanics are visualized, that is to say, it allows having a cognitive function and another aesthetic one. In the game DFD-C the screen that is presented with the flowchart elements is a green board, the elements of the flowchart are transparent objects, the obstacles are pumpkins that move for preventing the objects from passing to the white left area, which is the area to assemble the DFD as shown in Fig. 2.

C. NARRATIVE DESIGN

The narrative of a game is the story lines that are advanced through features such as cut scenes, game actions, dialogues and voiceovers. In the game DFD-C there is a narration in all the content, in each activity there is a detailed description of what the player must do written as dialogues as shown in Fig. 3.

D. INCENTIVE SYSTEM

The incentive system of a game shows elements of motivation that aim to encourage players to continue with their efforts. The feedback tries to properly modify their behavior. In DFD-C, for instance, in "On the way to school" game, students must answer questions, while advancing to school, if the answer is not correct they are given another opportunity (always trying to encourage them to continue revising). In the "Round of Penalties" game, if a student answers questions correctly, s/he accumulates points as shown in Fig. 4. For every 30 points, students get an extra life to be used in any of the DFD-C games.

E. MUSICAL SCORE

The musical score of a game is the background sounds that are usually used to direct the player's attention at important or specific moments of the game. In the game DFD-C, there are different background sounds in each activity. For example, in the "round of penalties" game there are various background sounds for different moments, such as: while getting ready to kick the ball, scoring the goal, missing the goal, winning or losing the penalty round.

F. CONTENT AND SKILLS

It is the content of the subject and the skills that the game is designed to teach. The game DFD-C took into account the contents of the annual planning 2019-2020 of the subject

FIGURE 4. Game "Round of Penalties", when the student answers correctly s/he adds up points that can get him/her extra life.

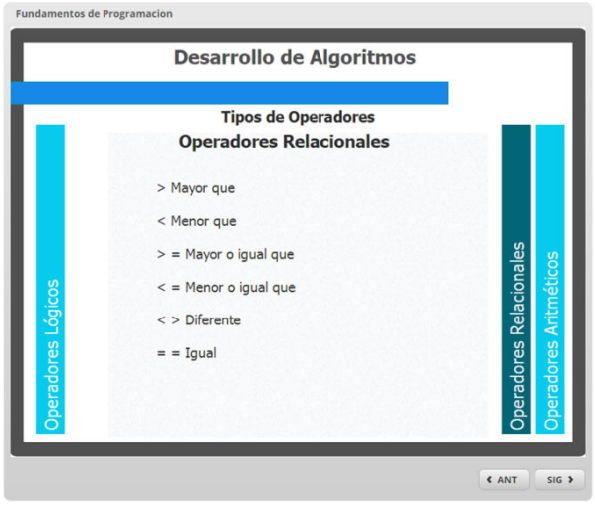

FIGURE 5. Example of a screen with contents, in this case "Types of operators."

of programming fundamentals, being the following: basic concepts of programming methodology, C a structured language, start of programming, static structures, sequential and conditional statements. These contents are presented before the games and activities that the player is asked to perform, as shown in Fig. 5.

Table 1 illustrates how DFD-C promotes programming skills.

IV. EXPERIMENT

A. GOAL

The first goal is to determine whether students improved significantly their understanding of programming fundamentals by using the serious game DFD-C; the second is to assess if using the serious games was a positive gameful experience. The research questions of the study are as follows:

RQ1: Will students improve their learning of programming fundamentals by using ad-hoc serious games?

TABLE 1. Games activities associated with programming skills.

Task	Programming skills	Game activity
Problem identification and decomposition	Problem solving (algorithmic thinking)	Helps the player to perform an analysis of the proposed problem. The DFD-C provides assistance for performing this activity.
Creating efficient and repeatable patterns	Building algorithms	The Player builds the DFD on the symbols learned. The DFD-C provides support for this activity.
Practicing runtime mode	Simulation	Checks the correctness of the DFD that student creates.
Sequence	Planning involving arranged actions in the order that produces accurate effects	Perform DFD, desktop testing and coding by dragging and dropping commands into the solution and check for correctness. The DFD-C provides support for this activity
Conditionals	The ability to make decisions based on certain conditions, supporting the expression of multiple outcomes	Perform DFD, desktop testing and coding by dragging and dropping commands into the solution and check for correctness. The DFD-C provides support for this activity

H1: Students who use the serious game DFD-C improve significantly their learning of programming fundamentals as compared to those who do not use it.

RQ2: If there is improvement, do girls improve the same as boys in their post-test?

H2: Gender does not influence the improvement of students who use the serious game DFD-C.

RQ3: Is there a positive perception of the gameful experience when using the serious game DFD-C?

RQ4: Does gender influence the gameful experience perception towards the game?

B. CONTEXT AND PARTICIPANTS

The experiment took place in the "Unidad Educativa Hermano Miguel" School in the city of Latacunga (Ecuador), from April 27, 2020 to June 9, 2020, with a total of 38 students from K-10 (15 and 16 years old) in the first year of the technical high school in the computer science specialty. The course was randomly divided into one test group of 19 students (68% men 32% women) using the DFD-C SG and one control group of 19 students (47% men and 53% women) using the conventional approach as in previous courses. An instructor with 10 years' experience of teaching the "Programming Fundamentals" course taught the 38 students. A test on Programming Fundamentals along with a questionnaire for assessing the 7 dimensions of gameful experience: accomplishment, challenge, competition, guidance, immersion, playfulness and social experience of the students comprised the research tools for this experiment.

C. INSTRUMENTS

Once the groups were formed, teachers proceeded to work as follows:

TABLE 2. Pre-test & post-test for programming fundamentals.

Part	Question/Concept/Problem	Type	Score (pts.)
Conceptual	Definition of Computer	Yes-or-no	0.5
	Problem analysis, coding, documentation, maintenance, testing & debugging	Matching definitions	0.5
	Methodology for computer-based problem solving	Ordering	0.5
	Priority of the operators	Multiple choice	0.5
Practical	Given a number of percentages for a student final grade on a course, define his/her final grade asking for the required inputs, then show the outputs	Design a sequential structure flowchart (DFD)	3
	Given a flowchart on the calculation of total amounts depending on given values	Perform the desktop test	3
	Given a code written in C with inputs, data operations and outputs	Correct syntax errors	2

TABLE 3. Gameful experience questionnaire (gamefulquest).

Dimension	Number of items	Scale
Accomplishment	8	7 point Likert
Challenge	7	
Competition	7	
Guided	7	
Immersion	9	
Playfulness	9	
Social Experience	8	

Eight computer science specialist (5 high school teachers and 3 university teachers) all of them computer science engineers designed and validate the Programming Fundamental test (to be used as pretest and posttest) based on the course curricula. The questions in the test were selected according to the competences that students must acquire once they finish each unit of the course; the test structure is explained on Table 2.

The student's previous knowledge was assessed with the pre-test (which was the same as the post-test) with a score scale from 1 to 10 points. The test has been in use at the High School "Hermano Miguel" in Ecuador since the 2016-17 academic year.

The gameful experience was evaluated by means of the validated questionnaire "Gamefulquest" [39], to assess the DFD-C SG, with a 7 point Likert scale detailed in Table 3.

The Crombatch's alpha value of 0.71 was obtained for the test used as pre-test and post-test. For the Gamefulquest questionnaire with a 7-point Likert scale, which includes 7 dimensions, the Crombatch alpha's values of 0.98, 0.81, 0.89, 0.98, 0.91, 0.91 and 0.96 were attained for its dimensions of accomplishment, challenge, competition, guidance, immersion, playfulness and social experience respectively.

D. EXPERIMENTAL PROCEDURE

The procedure of the experimental study is illustrated in Figure 6. It includes 5 weeks of 2 hour per week face-to-face classes on the learning of basic knowledge of programming, which is part of the Programming Fundamentals course. Due to the emergence of the global pandemic caused by COVID-19, classes in Ecuador were suspended on March 16, 2020, forcing educational institutions to seek technological means and resources to help continue the academic preparation of students. Thus, in the "Unidad Educativa Hermano Miguel" a virtual classroom was implemented for the institution, which became operational on March 30th. The virtual classroom was used by the teachers to upload resources about the topics to be discussed in online classes lasting one hour per week. It was also established that the virtual classroom was the means for the authorities and teachers to give the necessary indications so that they could advance with the established plans for the academic year. Thus, in the last week of April, the teachers were authorized to give classes by videoconference according to a schedule that was given by the Vice-Rector, so the experimentation could continue. The intervention began with a 1h 30' pre-test which was taken by all the first-year students of the computer science specialty in the virtual classroom https://server.uehm-latacunga.edu.ec/dfd/story_html5.html. Then, the one-hour-per-week videoconference classes began and lasted 6 weeks. The test group was given online the serious game DFD-C, with those directions: "you can enter as many times as you want and at any time", "the activities and score obtained do not influence the qualification of the programming fundamentals subject". Parallel to this, the control group was given a set of solved exercises covering the same topics as the test group, which they could work also on their own, as conventionally has been done in this course. Each group had 6 weeks. At the end of this period students took again the 1h 30' post-test, to assess and monitor any changes in Programming Fundamentals. Moreover, the test group completed the 20 minutes Gameful Experience questionnaire to assess their perception towards the use of the serious game DFD-C.

E. MATERIALS AND TASKS

In accordance with previous subsection, the theoretical part was uploaded as a resource, so that students could review and improve their knowledge about the basic concepts of the programming methodology, which are summarized in Table 4.

It must be stressed that although the topics about how to design a sequential flowchart and perform the test are explained, they are very difficult for students to understand in just one hour online class a week. The control group was given exercises and problems to revise on their own, whereas the test group had access to DFD-C, in which they

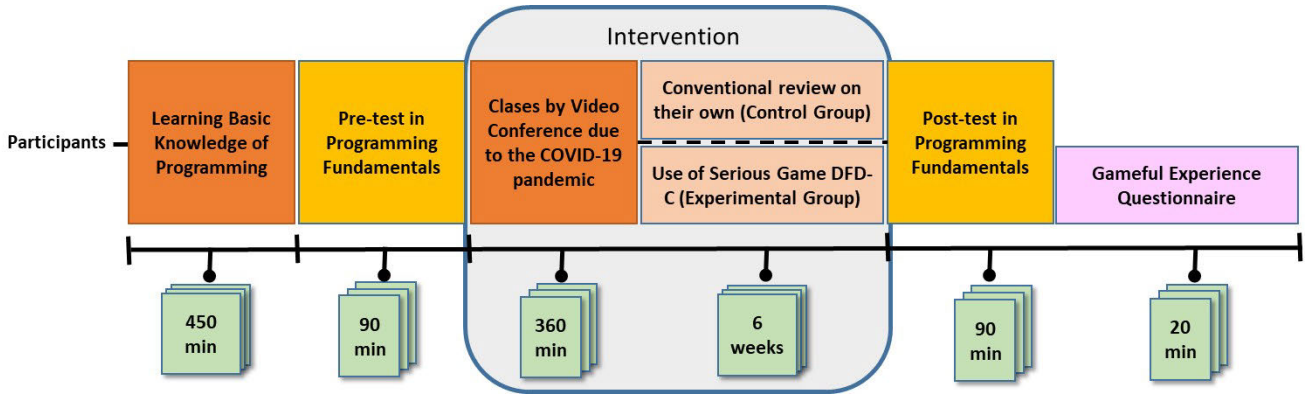

FIGURE 6. Diagram of the experimental design.

TABLE 4. DFD-C Serious Games Included and number of Exercises and Content for Learning Programming Fundamentals.

Part	Programming Fundamental	Content	Games on DFD-C	N. Ex.
1	Basic concepts and methodology for problem solving by means of (definition of the problem, analysis of the problem, design of the algorithm, codification, test and debugging)	Programming languages Types of algorithmic languages Methodology for solving computer-based problem Data types Expressions Operators and operands Structure of a C basic program	**"On the way to school",** here the player, on the way to school, must move through each street until s/he gets to the school, s/he must answer questions about programming concepts. **"Round of penalties"**, to kick the ball the player must answer a question, if s/he answers correctly he will score a goal, otherwise he will throw out the goal.	1 1
2	Sequential algorithms	Flow chart Desktop test C Language coding Running the program	**"Avoid the Pumpkins",** develops Flow chart, the player must arm the proposed DFD, avoiding being touched by the pumpkins that are moving from side to side. **"Avoid the Pumpkins"**, perform desktop test, the player must perform the desktop test of the proposed DFD, avoiding being touched by the pumpkins that are moving around. **"Avoid the Pumpkins",** program in C language, encodes de DFD to C language, avoiding being touched by the pumpkins that are moving everywhere.	2 2 2
3	Conditional algorithms	Flow chart Desktop test C Language coding Running the program	**"Avoid the Pumpkins",** develops Flow chart, the player must arm the proposed DFD, avoiding being touched by the pumpkins that are moving from side to side with conditional statements. **"Avoid the Pumpkins"**, perform desktop test, the player must perform the desktop test of the proposed DFD, avoiding being touched by the pumpkins that are moving around. **"Avoid the Pumpkins",** program in C language, encodes de DFD to C language, avoiding being touched by the pumpkins that are moving everywhere.	2 2 2

found the basic concepts of the methodology of programming, the explanation of how to make a sequential and conditional flowchart, desktop test of the flowchart, passing from a sequential DFD and conditional coding to C language. Table 4 also shows the games and number of exercises for each part of the course on Programming Fundamentals.

V. RESULTS

A. EXPERIMENTAL RESULTS IN THE LEARNING OF PROGRAMMING FUNDAMENTALS

As one of the primary objectives of this study, the efficiency of the proposed system was investigated considering its role in improving students' learning achievement. The analyses of results were oriented to perform a descriptive analysis of the data presented and then to deduce whether or not there had been a significant improvement between the control group and the test group of the variable evaluated in the first year of high school. The analysis was performed using the program RKWard [40].

Fig. 7 shows a boxplot for pre-test and post-test applied to both the control group and the test group on knowledge of programming fundamentals.

The boxes are delimited by the values Q1 (first quartile) and Q3 (third quartile). Each box contains 50% of the corresponding cases, highlighting the median. The minimum and maximum values at the ends of the diagram correspond to values that are not less than Q1-1.5 - (Q3-Q1) and not more than Q3 + 1.5 (Q3-Q1).

It is observed that the pre-test results of both the control and test groups maintain a central tendency around the same median value. With regard to the results of the post-test, a small increase in the median value is observed for the

TABLE 5. Pre-test and post-test results of the control and test group on programming knowledge.

Group	Median	Mean	Standard Deviation	Asymmetry coefficient
Control Pre-test	2	2.33	1.58	0.72
Control Post-test	4.2	4.15	2.40	0.19
Test Pre-test	1.5	2.5	1.75	0.92
Test Post-test	6	5.72	2.10	-0.26

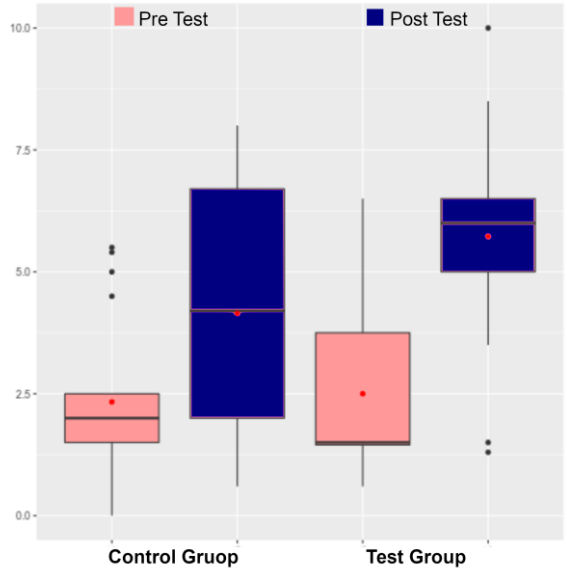

FIGURE 7. Boxplot for the control and test group in the pre- and post-phases of the programming fundamentals knowledge test.

control group, while in the results of the test group there is a considerable increase in the median value, and there is also a small dispersion of data. Table 5 shows the values of the median, mean, standard deviation and asymmetry coefficient for the control and test groups.

These values corroborate the previous statements referred to in Fig. 7, since in the control group the average shows a slight improvement (from 2.33 to 4.15) that is almost imperceptible in the case of the median. The standard deviation, slightly low, with respect to its asymmetry indicates that most of the ratings are close to the mean. On the contrary, the test group showed an evident improvement (from 2.5 to 5.72), with slightly scattered data, with respect to the standard deviation is considerably low; with respect to its asymmetry it indicates that there is an average percentage of grades below the mean.

The descriptive analysis gives a first idea of the distribution of the sample. The following is a more detailed study comparing the results of the pre-test and post-test phase in both groups to deduce whether there was any significant improvement.

First, it was studied the pre and post-test to determine whether there were differences between the test and control groups. The samples were found to be normal and homocedastic, therefore it was possible to carry out the t-test.

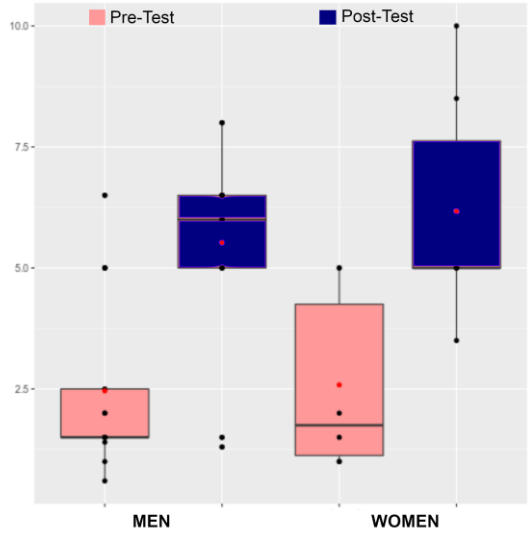

FIGURE 8. Boxplot for the men's and women's group in the pre- and post-test phases of the test group's programming fundamentals knowledge.

TABLE 6. Pre-test and post-test results of the men's and women's test group on basic knowledge of programming.

Group	Median	Mean	Standard Deviation	Asymmetry coefficient
Men Pre-test	1.5	2.46	1,76	1.06
Men Post-test	6	5.52	1.99	-0.92
Women Pre-test	1.75	2,58	1.74	0.45
Women Post-test	5	6.17	2.29	0.48

For this study the Student's t-test was used for independent samples, concluding that there were significant differences on the value that assess learning, with a significance of $p<0.05$, where $p = 0.04$ for the test group.

This indicates that there has been a significant improvement in the test group that used the serious game DFD-C in their course.

Analysis was extended to assess the differences in learning regarding the gender, as shown in Fig. 8.

It can be observed in the post-test that both men and women had a significant improvement, but in the case of women it seems that they had a greater improvement than men considering the median value. Table 6 shows the values of the median, mean, standard deviation and asymmetry coefficient of the test group.

These values corroborate the previous statements referred to in Fig. 8, as men show an improvement (from 2.46 to 5.52), the standard deviation, slightly low, with respect to their asymmetry it can be said that most of the ratings are close to the average. On the other hand, women showed an evident improvement (from 2.58 to 6.17), with slightly scattered data; with respect to the standard deviation is considerably low; with respect to its asymmetry indicates that there is an average percentage of grades above the average.

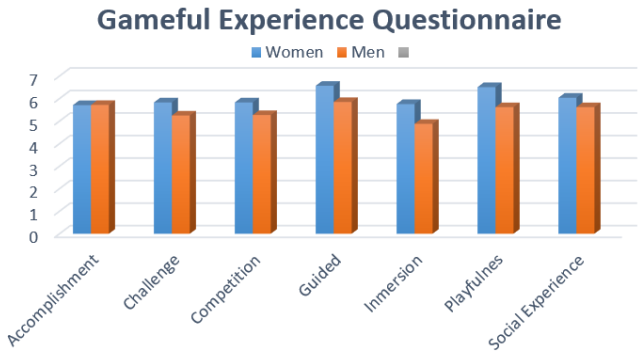

FIGURE 9. Bar chart of results of Gameful Experience Questionnaire on the 7 dimensions evaluated on a Likert scale from 1 to 7(for women & men).

The descriptive analysis gives a first idea of the distribution of the sample. Now, it offeres a more detailed study comparing the results of the pre-test and post-test phases in both groups to deduce whether there was any significant difference in improvement between men and woman.

First, there was a study of the pre-test phase to determine whether there were differences between men and women.

For this study it was used the Student's t-test for independent samples. It concluded that there were no significant differences between men and women, with a significance of $p<0.05$, where $p = 0.59$.

This indicates that there has been no significant difference on the improvement between men and women.

B. QUANTITATIVE RESULTS IN THE GAMEFUL EXPERIENCE

Another important concern of this study was to determine if students had had a positive attitude towards the use of the serious game DFD-C. Therefore, the gameful experience of using the Serious Game by the students in the test group was evaluated by means of the Gameful Experience Questionnaire [39] ''Gamefulquest'' conducted to measure the DFD-C gameful experience where seven dimensions were considered; Figure 9 shows the overall results by dimension and also divided by men and women.

It can be observed that all dimensions are rated rather positively in a scale from 1 to 7. The more valued dimensions were guided and playfulness, followed (in this order) by social experience and accomplishment. Competition, challenge and immersion were also very highly rated by students.

Accomplishment - Participants commonly described agreeing 31.6% and 31.6% agreeing strongly with having a sense of accomplishment, plus 31.6% agreeing and 36.8% agreeing strongly that it seemed to be part of a drive for progress and a willingness to always improve.

Challenge - 47.4% of participants indicated that they fully agreed, and 26.3% agreed that it takes a lot of effort to be successful in the activities, which in turn motivates them to do very demanding things and continuously improve.

Competition - 31.6% of participants mentioned that they feel totally in agreement as if it were a competition, 31.6 % agree that it makes them want to be in first place.

Guided - 52.6% of participants fully agreed that they felt guided and 47.4% fully agreed that they felt they had an instructor, in addition to receiving guided help and feedback.

Immersion - 26.3% of participants described that they agreed somewhat and 26.3% agreed that there was a change in their perceptions of the real world, such as the rapid passage of time or a directed behavior that became less difficult because the serious game acted as a distraction and caught the attention of each player.

Playfulness - 78.9% of the participants referred to the fact that they totally agreed that it was a playful experience, 42.1% that it gave the sensation of exploring things and wanting to know what comes next, and making them feel like they are discovering things.

Social experience - 42.1% of the participants indicated that they totally agreed that it felt like a social experience, 31.6 % of the participants indicated that it gave them the feeling of not being alone, they felt as if they were socially involved, and of being connected to others, as well as having the feeling of being noticed for what they have achieved.

Regarding the difference of perceptions among men and women, the values are very similar, but it is remarkable that women have had a slightly more positive attitude in all the dimensions except accomplishment, where they are almost equal. Therefore, women show a slightly more positive attitude towards using DFD-C serious game than men.

VI. DISCUSSION

A. EVALUATION OF RESULTS AND IMPLICATIONS

Using SGs for teaching programming to High School students has proven a beneficial approach according to the results gathered in the experiment carried out. The answers to the four research questions of the study will be discussed, deducing its practical implications for the design of SGs for teaching programming to High School students.

Regarding RQ1 whether students improve their learning about programming concepts by using DFD-C the results validated H1 as students who used DFD-C significantly improved their learning of programming fundamentals compared to those who did not use it. This result is similar to the ones found in the experiments with other SGs such as Wu's Castle [23], SortingGame, SortingCasino, Secret rule and Draw and guess [24], Capital Tycoon [27], HIT Typing, Serious Cube and 3D action game [28], ProGames [30], The Odyssey of Phoenix [32], TIS-Q-SP [18] and Autothink [17]. However, the use of games in formal educational environments is not always successful [41]. It must be taken into account that the three kernels (see Fig. 1) must be covered taking into account theory, game design and contents to create a successful SG for education. As a practical implication, in particular, for SGs used to teach programming to High School students, it is recommended first to create the instructional script [37] and next, to start with the development of the game following the Learning Mechanics - Game Mechanics (LM-GM) model [36]. It was possible to advance quickly in all phases of the LM-GM model because the

instructional script describes step by step the elements of the digital educational resource such as the target group, learning objectives and contents [42]. It is also necessary to bring together experts in the field with instructional designers and programmers in order to explore and develop good SGs for education [43].

Regarding RQ2 about the differences in the results between men and women in the improvement of learning by using DFD-C, the results have validated H2 as gender does not seem to influence the improvement of students who used DFD-C. Both, men and women, improved significantly in the post-test scores but no significant differences between them were found. This is a highly relevant result, as it contradicts social stereotypes that women could be worse for STEM subjects or that they do not enjoy using SGs as men. More research on this topic that corroborates the result found here are published in [44], [45]. All in all, the results should be explored together with more social and individual differences [46]. As practical implications, when designing SGs, it is important to focus more on the social and individual differences than in gender differences as both male and female will be able to play and learn with SGs in a similar way, while social and individual differences may create the gap.

Regarding RQ3 about the perception of the gameful experience using DFD-C by the students as reported in the Gamefulquest questionnaire [39], the results show that students seem to have had a positive experience using the SG according to its seven dimensions: accomplishment, challenge, competition, guidance, immersion, playfulness, and sociability. The dimension which students rated higher their gameful experience was playfulness. More than 78% of the students felt the ludic component of the SG. It was followed by their feeling of guidance, more than half of the students reported that they had that feeling and, thirdly by sociability reporting that they had felt connected to other students and recognized for their achievements. These results are in line with state-of-the-art publications using the Gamefulquest questionnaire such as [47]. As a practical implication, it is important to keep the playfulness feeling of the SG supported by guidance and sociability as they seem to be key gameful dimensions to provide a positive gameful experience for High Schools learning programming. A certain level of challenge could also be seen as enjoyable, as it provides feelings of accomplishment and success and they are socially recognized [48], [49].

Regarding RQ4 about the differences in the perception of the experience between male and female students as reported by them to the Gamefulquest questionnaire [39], it has been found that female students rated slightly higher the gamefulquest dimensions than male students. This result corroborates the ones found in RQ2 against any social stereotype of women playing less, or with less interest or ability using SGs for education too. As a practical implication it should be noted that, if needed, more motivation should be provided to male students than female students; teachers should provide the same resources to both, as women are even going to perceive the SG for learning programming better than men.

B. LIMITATIONS

As in all experimental research, this study also presents some limitations that should be taken into account. Firstly, the number of participants is not as high as would be desired as it was not possible to gather more students. However, it is a typical sample size for most papers in this field and, given the normality of the data, the statistical results are robust, although the number of cases is low, because the necessary conditions to carry out this statistical inference with all the necessary guarantees are fulfilled.

To perform the hypothesis tests presented, the necessary conditions for each one of them had been previously tested (normality and homocedasticity in the samples to carry out the t-test). A larger cohort would reinforce the arguments about the game's efficiency. It is our intention to repeat the study with more students as future work. A second limitation is that all the participants belonged to the same school and country. The study should be repeated not only with more students, but with students from other schools and countries to remove any cultural impact, and to explore more diverse international factors.

VII. CONCLUSION

Using Serious Games (SGs) to teach programming to High School students significantly increases their learning scores. This improvement is similar for male and female students as gender does not appear to be a discriminating factor. The DFD-C serious game was created using the LG-MG model taking into account the three kernels to design effective SGs for education: theory, contents and game design.

An experiment in which 38 K-10 students were split into control group (no use of DFD-C) and test group (use of DFD-C) was carried out during the 2019-2020 academic year. Students in the test group significantly improved their scores in a knowledge pre-post test, both for men and women.

It can also be concluded that High School women and men students perceive the gameful experience as positive, with slightly higher positive perception by women. Students in the test group (use of DFD-C) were asked to complete the validated Gamefulquest questionnaire to explore their gameful experiences regarding accomplishment, challenge, competition, guidance (guided dimension), immersion, playfulness, and social experience. Playfulness was the dimension rated higher followed by guidance and sociability. Female students rated the gameful experience slightly higher than male students. It seems that women not only performed as well as men in the tests, but also perceived a little better the gameful experience.

A future version of DFD-C will include topics such as repetitive cycles and functions, it will improve the immersion on the game, and it will also improve of the contest part, for instance, challenging the player to work harder and get rewards. A new experiment with a larger number of students from different countries (i.e. Spain and Ecuador) to also test social and individual differences in the learning of programming fundamentals and their perception of the gameful

experience using the new version of DFD-C is intended to be conducted at a future date.

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