

# CENGO: A Web-Based Serious Game to Increase the Programming Knowledge Levels of Computer Engineering Students

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**Abstract.** In recent years, games are used to increase the level of knowledge and experience of individuals working in different domains. Especially in the education field, there are several different serious games to teach the subjects of the lectures or other educational materials to students in an enjoyable way. Hence, this study proposes a quantitative research approach to increase the programming knowledge levels of the first-year undergraduate students at computer engineering departments. For this aim, a responsive web platform was developed to teach the syntax and logic of C programming language by using some game elements. Therefore, the students have a chance to repeat the topics related to C programming language continuously since the platform is always accessible. To figure out the efficiency of the designed environment, 10 first-year computer engineering students were selected. According to the results obtained from the user tests, this game can be used as an educational tool, which supports the traditional training methods, to increase the knowledge levels of students about the syntax and logic of C programming language.

**Keywords:** Serious games, continuous education, personal improvement.

## 1 Introduction

University life is one of the most important factors affecting the success of individuals in business life [1]. Although it is a critical time-period for individuals, most of the students do not realize the importance of the education given in the university [2]. When the reasons why the students do not give enough importance to university life at the expected level are analyzed, it is observed that most of the students have adaptation problems in the first year of their university lives [3]. Unfortunately, many students with adaptation problems cannot succeed in exams and get low grades [4]. When the students start to get low grades from the exams in their first year at university, their stress level increases so that their motivation decreases [5]. And, this situation becomes an infinite loop that pulls the student into the unsuccessfulness spiral. As a result of this situation, students start not to interest with the lectures [6]. In order to prevent such undesirable situations, teaching techniques and strategies play an essential role to gain students' interest in class [7].

According to the studies in the literature [8–10], traditional teaching strategies cannot motivate the students sufficiently. In support, Limon [11] points out that students request alternative teaching techniques instead of traditional educational system. To provide this alternative teaching technique, computers and other technological tools can be used in education domain since they become more interesting for the students [12]. At this point, educational games propose more attractive and interesting learning environment for students by increasing their sense of competition [13]. For this reason, this study proposes a serious game to help students to gain familiarity about the syntax of C programming language and experience about the logic of computer programming. In this way, it is aimed to teach the concepts and logic of the programming in an enjoyable manner.

The overall structure of the study is formed as follows: Section 2 begins with the literature review of the study. Then, Section 3 illustrates the methodology of the research and the system description. The next section presents the findings of the study. Finally, the last section explains the conclusion of the study by discussing the results.

## 2 Background and Related Works

Games are generally used to entertain individuals [14], however, they are also widely used in education domain in recent years since they improve the strategic thinking skills of individuals [15]. In addition, they also increase the motivation of the participants so that the learning process of the individuals on a new topic accelerates [16]. Digital game-based learning concept provides several different useful digital games for the individuals because of the widespread use of computers, mobile phones and tablets [17]. These games are preferred by people of all ages and as a result of this situation, their personnel development can be affected in a positive manner due to properties of these games [18].

There are many studies in the literature that use the features of the games to teach the subjects of different courses to the students at different levels since games are engaging for every age group [19]. In the first study, Liu and Chu [20] designed a game to increase the success and motivation of the students for learning English. This game was tested with a group of students in order to understand its efficiency. According to the results obtained from this study, it has been observed that games provide better learning outcomes compared to other techniques and increase the motivation of the participants. In this scope, the other study was completed by Van Eck and Dempsey [21]. This study contains a computer-based simulation game to increase the mathematical abilities of the students. This game was tested with the participation of 123 second grade students. During the testing phase of the study, the students were divided into 5 groups with different training techniques. The results indicate that the improvement of the students working with the game was more than the improvement of the students in the other groups. Another study developed by Tuzun et al. [22] contains a three-dimensional game for students studying in elementary school. This game was tested with the participation of 24 students and it was emphasized that the games motivated the students to work more. Anderson and Barnett [23] also created a video game to teach the basis of the electromagnetism to middle school students. To understand the impact of the game on the learning progress of the students, the game was tested with the students. As a result of this study, it was concluded that games can be efficiently used in the education domain. In the other study, Homer et al. [24] produced a digital game by aiming to increase the cognitive skills of high school students. 82 students played this game for 6 consecutive weeks. The results illustrate that video games are beneficial tools to increase the cognitive skills of the students.

The above studies show that educational games are effectively used in all levels of education. In the literature, there are also some similar studies that contain different types of games in order to increase the programming skills of the individuals. In the first study, Kazimoglu et al. [25] designed an innovative serious game to enhance students' analytical thinking skills. Due to the properties of this game, the students have the opportunity to apply the basic concepts of programming such as condition structures, loops and etc. in a fun way. In addition to the fun elements, the game also consists of different levels of difficulty. The students have to pass these levels in order to progress in the game. There is also a robot in the game that helps students when they have some troubles in solving the problems. Thanks to this robot, students can see their mistakes more quickly and have the chance to repeat the important points about the programming. In order to understand whether the game provides the indicated features or not, 25 students participated to the study in order to test the game. According to the findings of this study, the game enhances students' algorithm development skills. Another study completed by Shabalina et al. [26] contains a serious game to improve the programming skills of students about C# programming language by increasing their motivation and willingness to study. In this game, each player has their own characters with some properties. A player's

character has limited properties at the beginning of the game. When the player participates more game sessions and wins the games, the properties of his/her character are increased. Therefore, this situation motivates the players to increase the features of their characters. According to the findings obtained from this study, games improve the knowledge and skills of individuals by having fun. In another study, Adamo-Villani [27] developed a serious game which focuses on teaching the operator precedence concept in the introductory level of programming. In this game, the participants try to exit from a maze which contains different mathematical operations. If a participant correctly solves the question by using the mathematical operations in a proper way, s/he becomes more closer to the exit of the maze. Otherwise, the wrong answers throw the participants away from the exit. This game was tested with 14 undergraduate students to understand the efficiency of the game. According to the results obtained from the tests, the game is useful to teach the operator precedence to the students. Another game-based learning environment was developed in the other study by Li and Watson [28]. The aim of this study is to explain the concepts of simple programming such as constructing loops or using functions to novice computing students by developing a game. For the assessment of this game, 6 experts were selected and an interview lasted 30 minutes was administered with them. The findings of this study suggest that this game can be used as an effective learning environment for teaching the basic concepts of programming to novice students. Jordine et al. [29] also conducted a study which contains a serious game to teach the basics of Java programming in mobile devices. This game includes the game elements of the classical tower-defence game. The students have to develop some code blocks in order to pass levels by creating the towers in the game. According to the point of views of the authors, this game can be widely used in the universities as a learning tool which supports the classical teaching methods.

### 3 Methodology

As shown in Figure 1, this study has 2 different phases. After reviewing the literature and proposing the serious game for teaching the basic concepts of C programming language to the first-year undergraduate students at computer engineering departments, a paper-based version of the game was developed as a board game in the first phase of the study [30]. The board game version of CENGO can be played by multi-players (minimum 4 and at most 6) in a sequential manner. The aim is to reach to the end of the race-course which contains 21 steps by answering the questions at the different difficulty levels. There are 5 different types of the questions in this game. These are:

1. Easy Questions
2. Medium Questions
3. Hard Questions
4. Random Questions
5. Bonus Questions

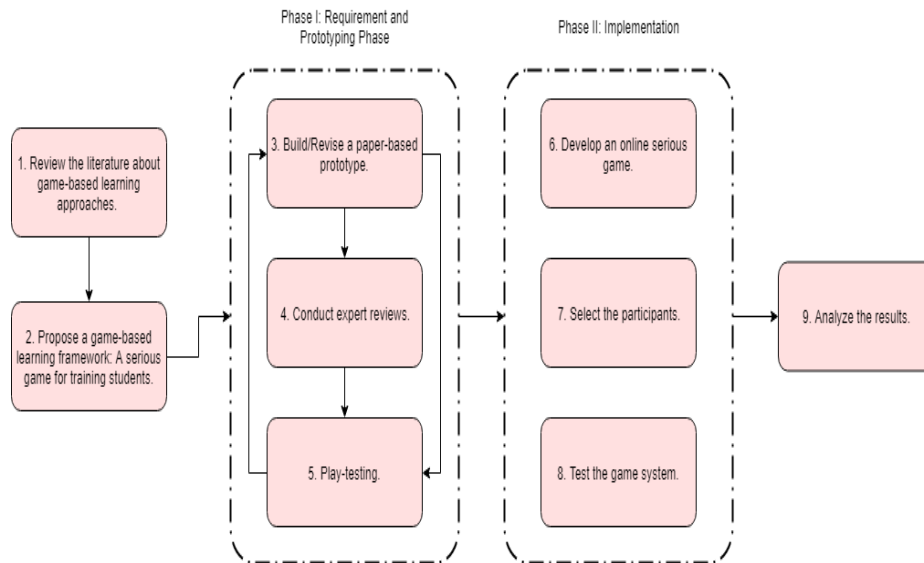


Fig. 1: Development Phases of CENGO

The difficulty levels of the questions are understood from the colors on the race-course. Each type of question has a certain time for getting answer from the players. The players have to give answers to the questions within this time limit. If a player gives a correct answer, s/he moves one step forward on the race-course and additional time is given to the player in order to answer the question on the new step. Otherwise, the turn is changed to other player. There are different bonus cards in the game such as *half time*, *return*, *play hard*, *go to and break*. If a player gives correct answer to the bonus questions, s/he randomly selects one of these bonus cards. When a player gets bonus cards, s/he can use these cards at any time of the game in order to take advantages by preventing the progress of the other players or moving forward on the race-course. In order to understand the efficiency of the paper-based version of the game, a quantitative research approach supported by validation interviews was applied as a research methodology. Firstly, the game was analyzed by 3 experts who were the lecturers at a computer engineering department. During this analysis phase, a set of semi-structural interviews was administered with the experts to get their opinions about the game. According to results obtained from these interviews, the game can be used as a training tool to teach the basic concepts of C programming language. To support this claim, 10 students were selected to test the game. During this testing phase, the students have participated both a pre-test and a post-test in order to figure out the efficiency of the game. The numerical results obtained from these tests illustrate that the game motivates the students to play so that their knowledge levels about C programming languages are increased.

In the second phase of the study, an on-line version of the game was developed in order to create more efficient training environment for the students by eliminating some disadvantages of the board game version. The first disadvantage of the board game is that although this game aims to increase the repetition of the subjects of the C programming language course by motivating the students, the students cannot play this game by yourself since the game requires multi-players. If a player does not find any other players to play the game, s/he cannot play the game so that s/he does not have a chance to study the indicated topics. This situation directly affects the learning progress of the individuals in a negative way. The other disadvantage can be considered as physical conditions. The board game cannot be available for every hour due to its properties. Hence, this situation also limits the usage of the game.

The factors mentioned above suggest that the effect of the board games can be increased by developing a system which provides a continuous teaching process for the students. For this reason, this study proposes a web-based serious game to increase the programming knowledge levels of computer engineering students. Although the on-line version of the game contains some properties of the paper-based version, it has some differences. First of all, this study introduces not only a game, but also a system that can be used by the users from 3 different user types. These user types are *Administrator, Lecturer and Student*.

The administrators are responsible for managerial operations of the system such as adding new courses and new lecturers into the system, assigning the existing courses to the lecturers, accepting students' registration requests and etc. Lecturers are responsible for adding new questions into the system for the courses assigned to them. In addition, lecturers can follow the status, scores and missing points of the students enrolled in their courses. Finally, students can select and register to the existing courses, join and play the game, observe their missing points and the scores of the played game sessions, and get feedback for the wrong answers given during the game sessions.

The on-line version of CENGO is a single player game so that the students do not need to find any other players to play the game. Hence, the first disadvantage of the initial version of CENGO is eliminated. The students can play the game whenever they want to increase their knowledge levels about the basic concepts of C programming language. The on-line version has also a race-course which contains 21 steps as shown in Figure 2. The game contains 3 types of questions as follows:

1. Easy Questions
2. Normal Questions
3. Hard Questions

As shown in the race-course of CENGO, the easy questions are represented by green color, the normal questions are represented by yellow color and the hard questions are represented by red color. When a student starts to play the game, s/he is on the first step. Hence, an easy question comes to screen. At the same time, a timer at the right corner of the screen starts to count the time in order to measure how much time the student spends to finish the race-course.



Fig. 2: Race-Course of On-line Version of CENGO

The content of the question is displayed in the “*Question*” text-box. After observing the question, the student has to write C code into a text-box centred on the screen in order to solve the listed question. When the student completes the code block, s/he should click “*Compile*” button which stands at the bottom of the screen. This button helps to understand whether the code block developed by the student is correct or not. For this operation, this platform has ability to dynamically run and compile the C code written in the text-box by using “*code on the fly*” logic. In addition, it is also necessary to figure out whether the code block produces the correct outputs or not. For this operation, the system provides that the lecturers in the system can enter both the inputs and the outputs of the questions while they are recording them into the system. Therefore, the platform can place the inputs entered by the lecturers into the necessary input fields and execute the code. After that, it compares the produced output and the recorded output. If they are matched, the student gives a correct answer and moves one step forward on the race-course. When a student gives a correct answer to the question, s/he earns scores, however, the score earned depends on the difficulty level of the questions. The value of the giving correct answers to easy questions is 50 points, 75 points for normal questions and 100 points for hard questions. If a student gives a wrong answer to the question, s/he cannot gain any points and moves to another question. In addition, students have a chance to skip the questions in order not to lose time if they consider that they cannot solve the question. This option was added into the system, because, the winner of the game sessions is determined in every 3 days by taking into consideration of both points earned and time spent during the game sessions. If two players have the same score, but one of them has lower time, then, the player who has lower time will be a winner for the related time period. Hence, developing a right strategy

by clicking skip button to decrease the total time in a game session plays a critical role to be a winner.

When the student finishes the game session, s/he is listed on the leadership board with respect to his/her score earned and time spent. If the student can stay at the top of the list for 3 days, s/he will be a winner of the related time period. For the winner students, the game presents some badges which provide some special powers to the students. In every 3 days, a badge is randomly produced and the winner student takes this produced badge as a reward. The badges in the game are listed as follows:

- **Double Timer:** If a player has this type of badge, s/he can use this badge against any player at any time. When the player who is punished from another player by using this badge plays a game, the total amount of time spent in the game doubled because of the property of this badge. However, if the player who get the penalty answers all questions correctly in the game, s/he will be free of the influence of this badge. The player with the badge does not have a right to show the badge again.
- **Returner:** If a player has this type of badge, s/he can use this badge against any player at any time. When the player who is punished from another player by using this badge plays a game, s/he goes one step back in every three steps in the race-course and the points s/he wins are deleted if s/he has. However, the player who get the penalty has the chance to get rid of the impact of this penalty if s/he can give 4 correct answers to the questions in each difficulty level. The player with the badge does not have a right to show the badge again.
- **Compeller:** If a player has this type of badge, s/he can use this badge against any player at any time. When the player who is punished from another player by using this badge plays a game, all questions will become hard questions. This means that easy and normal questions will not be asked to the player in this game session. However, the player who get the penalty has the chance to get higher score if s/he can give correct answers to hard questions since the value of hard questions is higher than the values of the other type of questions. The player with the badge does not have a right to show the badge again.

As it can be understood from the definitions of the badges, they provide some advantages to the students who have them. However, they also provide some advantages to the students who get the penalty if they can complete the necessary operations in order to overcome the effects of the badges. When a student gets a penalty from a badge, s/he must enter a game session immediately. Otherwise, s/he will not be listed in the leadership board prepared in every 3 days since s/he did not face the problems occurred from the badges. Therefore, the badges force the students to play the game so that they have a chance to increase their knowledge levels about C programming language in an enjoyable way by solving more questions during the game sessions. In addition, the game provide a competitive environment between the students in order to get higher



ranks in the list. For this reason, the students are tend to join game sessions more. In this way, they continuously study the concepts of C programming language.

## 4 Results

The research methodology of this study was selected as a quantitative research approach. In order to understand the effect of this study on students, the designed game was tested with a group of 10 computing students. These students were randomly divided into two groups: one for the control group and the other for the experimental group. At the beginning of the study, a pre-test which contains 20 multiple choice questions was conducted in order to figure out the knowledge levels of the students about C programming language. Students were given 40 minutes to complete the pre-test. At the end of this period, each question asked in the test was evaluated over 5 points and the test was evaluated over 100 points in total. The results obtained after the pre-test are shown in Table 1.

Table 1: Pre-Test Results of Control and Experimental Group

	Control Group	Experimental Group
Student 1	20	15
Student 2	25	20
Student 3	15	25
Student 4	40	20
Student 5	35	45

After the pre-test, participants attended a 4-week training program. During the training period, the students in the control group did not play the game for the topics of C programming language. They have studied these concepts from traditional resources.

Table 2: Post-Test Results of Control and Experimental Group

	Control Group	Experimental Group
Student 1	35	45
Student 2	30	55
Student 3	20	45
Student 4	35	60
Student 5	50	75

The students in the other group have just played the game to increase their knowledge levels about C programming language. They were not allowed to use any other resources related to the C programming language concepts. After the training period, a post test which is the same test with the pre-test was administered to the students in order to observe the difference between the knowledge levels of them. The results obtained after the post-test are shown in Table 2.

In addition to the above numerical values, it was followed how many game sessions that students in the experimental group have participated and the percentage of the correct answers that students in the experimental group have chosen in both the first and the last game sessions in order to understand the effectiveness of the system. The results obtained from this analysis are shown in Table 3.

Table 3: Data Obtained from CENGO for Students in the Experimental Group

	The First Game Session	The Last Game Session	Total Number of Entered Game Sessions
Student 1	23.8	57.1	10
Student 2	19.0	38.1	13
Student 3	33.3	47.6	12
Student 4	19.0	66.7	22
Student 5	52.4	85.7	15

## 5 Discussion and Conclusion

The main objective of this study is to design a web-based serious game which aims to teach the basics of the C programming language to the first-year undergraduate students at computer engineering departments. Within the scope of this aim, an on-line platform where the students can continuously play the game with the other students in a competitive and enjoyable environment has been developed. 10 students were selected and randomly divided into 2 groups which are control and experimental groups in order to test the system. At the beginning of the study, a pre-test was administered with the students in both groups to understand their knowledge levels about C programming language. According to the results obtained from the pre-test, the knowledge levels of the students in both groups were almost the same to each other since the average score of the control group was calculated as 27 and the average score of the experimental group was calculated as 25. After the pre-test, a training period has started and lasted 4 weeks. During the training period, while the students in the control group has studied the topics of C programming language by using traditional

methods, the students in the experimental group has played the game for that subjects. At the end of the training period, a post-test was administered with the students in both groups to figure out the efficiency of the game platform by analyzing the difference between the pre and post test scores of the students. The results of the post-test indicate that the students in the control group could not significantly increase their knowledge levels while the knowledge levels of the students in the experimental group increased significantly. In addition to this numerical analysis, how often the players in the experimental group used the game platform and the impact of the usage of the game platform on the success of the students was measured during the 4-week training period. According to these measurements, it was revealed that the students who often used the game platform gives more correct answers to the questions in the game sessions at the end of the training period. As a conclusion, the findings of the current study suggest that this game platform can be used as an educational tool to support the traditional methods to teach the basic concepts of C programming language.

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