Increasing problem-solving skill using electronic educational game

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Abstract— The use of educational games is one of the modern trends in teaching. Educational games are one of the most promising technologies for teaching practice in and out of formal educational environments. As a part of educational games technology, the electronic instructional game can be used to improve different skills of pupils in schools. Reviews of relevant researches show that there is a shortage in Arabic electronic instructional game. Through this paper, authors investigate the importance of using Arabic electronic instructional games. The current research focuses on the application of electronic instructional games in improving problem-solving skill. The game was designed and applied for a math curriculum of sixth-grade pupils in Egypt. The designed game is evaluated experimentally to investigate its impact on improving the problem-solving skill of the targeted pupils. The time of solving different problems was measured before and after using the game for many times. Analyzing the experimental results proves that the Arabic electronic instructional games can improve the Egyptian pupils' skill.

Index Terms— Electronic instructional game; Problem-solving skill; T-test; SPSS software program

1 Introduction

Qualitative development in the service of the educational process by using computers has become one of the most important challenges facing the educational systems all over the world. The spread of computer usage in education and the increase interest in educational computer games bring to the mind the importance of using the educational computer games in the learning environment [1]. There are five key claims about the use of electronic instructional games. The claims include building on sound learning philosophies, providing more engagement for the student, providing personalized learning opportunities, teaching 21st-century skills, and providing an environment for authentic and relevant assessment [2].

Nowadays a lot of games are found on the Internet, but a little of them can be considered as instructional games. Unfortunately, there is a shortage of Arabic instructional games for Arabic-speaking pupils. While there are a large number of researches on the perception of students and their reactions, the question of how to incorporate games into learning environments stays unresolved [3].

Computer games are considered as powerful tools for learning and they have great potential for improving students' skills. For instance, games that improve the capacity of the working memory can be considered as an important element in problem-solving [4]. Educational games pay learners to interact with educational materials and with other learners in educational positions dominated purposeful activity.

They also help to develop skills and interaction with the surrounding environment, which increase the ability of a learner to creative expression and creativity. They allow a space of freedom for the learner to express himself in the context of socially acceptable and enjoyable for him and around him.

Today's children are growing up with laptops, tablets, cell phones, and video calls in a rapidly changing digital age that is far different from that of their parents. A variety of technologies are all around us in our home waxes and schools [5]. They use this technology in their daily interactions. In 2005, the Federation of American Scientists found that many of the skills required for success in games such as thinking, planning, learning, and technical skills are also sought by employers [6]. Educational games could be used to engage and motivate learners while assessing complex skills [7].

Egenfeldt proved that skills such as problem-solving ability has increased within a game and may even transfer or increased across games [8]. Mete Akcaoglu presented the results of an experimental study applied to a number of middle-school students attended a summer program. The students were evaluated in problem-solving skills. The evaluation included the measurement of their skills in decision-making, system analysis and design, and troubleshooting domains, before and after attending the program. The results proved that there were considerable improvements in students' problem-solving skills after attending the program [9].

Meihua Qian and Karen Clark surveyed the most recent literature in regard to game-based learning which targeted 21st-century skills as outcomes. The paper discussed the game genres, game design elements, the learning theories used in these studies, in addition to the range of indicators, measures, and outcomes for impacts on 21st-century skills [10]. Gürbüz and others discussed the impact of a computer-based game developed as Weather Forecast Game. The game was designed to improve the problem-solving abilities of children. The children used simple visual and linguistic templates to develop algorithms and create criteria and to establish relationships between these criteria [11]. Games in education provide a vehicle by which students can explore and solve problems, make decisions, attempt challenges, and in general educational games contribute to learning broadly. The students who use

digital media, in the form of educational games, usually have a deeper content understanding and a longer retention rate of the course material than those who employ traditional methods of lesson delivery. Games foster collaboration, problem-solving, and procedural thinking [12] are considered as the most important 21st-century skills.

Nikolaos Chatziantoniou and others, have designed and developed a game capable of simulating realistic situations for the development of skills useful in the professional field and in particular leadership skills. The game was used to enhance and improve soft skills in leadership and to support or replacement traditional teaching methods [13].

This paper presents an application on the use of electronic instructional games in improving problem-solving skill. The game design is based on a proposed instructional design model framework. The game is designed based on the math curriculum for sixth-grade pupils in Egypt. The main objective of the designed game is to improve problem-solving skill for the targeted pupils. The designed game is evaluated experimentally to investigate its impact on improving the problem-solving skill. The result data are statistically analyzed and presented.

2. A Proposed Instructional Design Model

The authors have proposed a framework model in [14] that can guide instructional designers and/or game designers for the efficient use of games and simulations in educational environments. The proposed framework defined the essential and necessary components of a proper instructional design model for the creation of game-like learning environments. The framework consists of three consistent modules.

The first one "Learning module" is a tool to provide course materials in a logical, sequential, order, guiding students through the content and assessments in the order specified by the teacher. This module required Intended Learning Outcomes (ILOs). Learning module is divided into the main objective of the game learning content of the course, player goals and learning content.

The process of designing and developing the courses or materials brings greater efficiency and effectiveness in acquiring knowledge or skills for learners represents the second module which is called "Instructional Design module". The module is divided into four parts; Context, Learner Specifics, Representation, and Pedagogical. The module includes all the rules and steps required to make the game funny and achieving educational targets.

The last module is the "Evaluation module" which contains the reviewing and analyzing processes. This module is necessary for obtaining information about the effectiveness of student development. Evaluation module is divided into System feedback and Debriefing. The proposed system framework is shown in (Figure 1).

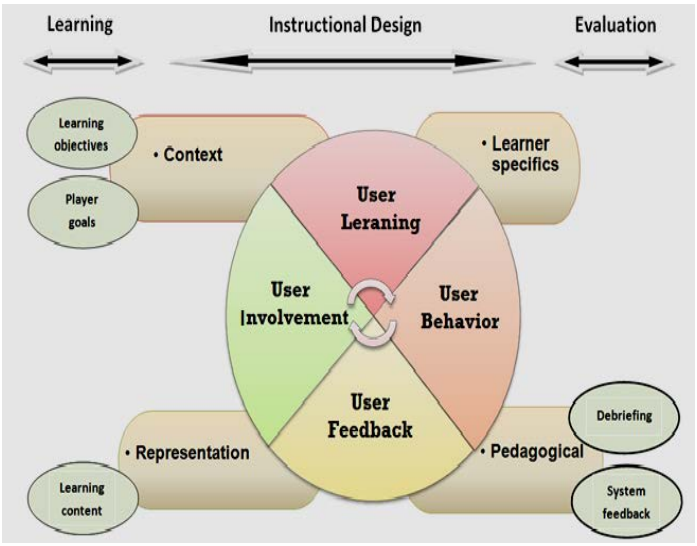

Figure 1. The Proposed Framework

2.1 "Coordinate it" Game

The proposed framework is applied to design an electronic instructional game used to improve problem-solving skill for the sixth primary pupils in Egypt. The game is based on the Egyptian Intended Learning Outcomes (ILOs) for primary schools. The objective of the game is to develop improving problem-solving skill and the time of solving the problem in Math curriculum for sixth-grade pupils.

In this game, the achievement of the ILOs for the sixth grade and is combined with the other objectives of the game. Four ILOs are targeted by the designed game. These ILOs include: (1) Being able to access the coordinates (x, y) that appear in front of him/her, (2) Exercise the right to access to coordinates shortest route possible, (3) Increase enthusiasm for proficiency determines the statistics in mathematics, and (4) Exercise accesses to the coordinates (x, y) the shortest path while avoiding obstacles.

In this study, Adobe Flash CS6 and its built-in programming language Action Script 3 (AS3) are used for programming the proposed game. The Action Script is a kind of language, similar to the English language, which humans can use to communicate with computers. There are many reasons which make the Flash as one of the most powerful tools for game development [15]. These reasons can be summarized as follow:

- **Web deployment:** For games designed to be available online, Flash is an appropriate program since Flash files are designed to be viewed in Web pages.
- **Small file size:** Flash is built on vector graphics and compressed sound files, which leads to a small size of the final game file compared to other programs
- **Plug-in penetration:** The plug-in that's required for viewing Flash files in Web pages is available with different browsers. In particular, more than 98 percent of the Internet users can view Flash content.
- **Server-side integration:** A dialog between Flash games and the server is seamless. Flash's built-in features, can communicate with server-side applications which in-

crease the possibility of chats, multiplayer games, and high score lists.

- **File sharing between the programmer and graphic artists/designers:** Programmers and graphic artists can work together using the same files, which is a rare feature in other game development languages.
- **Ease of use:** It is easy to learn the program and start creating games in a very short time compared to other programming languages.

2.2 Structure of the game

The general proposed Framework of instructional design is implemented to design this instructional game. The modules of the framework are applied to design the game as follows:

- **Learning module**

This module determines the game goals and (ILOs) of the game. Learning content is the Math course of the sixth grade. The player goal is to access the coordinates (x, y) that he/she reads it in the starting screen on time.

- **Instructional Design module**

In this module, the context is written in the Arabic language because it will be simpler for Arab (Egyptian) pupils to understand the game rule and objective in their mother tongue. The game rules allow one player only to play it.

Regarding learner specifics: the feature of the game depends on solvable problems in ascending levels. The measure of the player progresses in achieving the goals (win conditions) of each level is access to the point quickly while avoiding obstacles and through the shortest route and before the end of the timer. The levels of difficulty are increased gradually by increasing the number of obstacles.

Representation phase controls the player's possibilities for active and direct manipulation of specific aspects of the game by accessing to the coordinate (x, y) by click to the directions on the mouse.

Regarding pedagogical make the level of difficulty of the game gradually increases by increasing the difficulty of the places of coordinates (x, y) and increasing the number of obstacles. The player's achievement is recorded and the screen displays a message "you have successfully passed the level". The game gives the player feedback on the outcomes of his actions.

The player's score can be displayed either on the screen or in a printable report by clicking the "print report" button. An instructions button containing all the required information is provided. The lack of real-world consequences that actions within the game have; the only consequence is a possible loss of dignity when losing.

- **Evaluation module**

Concerning debriefing; the players can be evaluated as individual players or they can compete as a group under the supervision of a teacher. The teacher can print a report about every player. Concerning the system feedback; the achievement, progress, and score of each player are recorded and displayed within the game. Every player can obtain feedback on the outcomes of his actions.

2.3 Pseudocode of levels game description:

The following Pseudocode describes the game.

1. Start "coordinate it" game.
2. Select level option.
3. Initialize the number of levels n=0 and the Stage=1.
4. Add number 1 to the number of levels n=n+1.
5. Play level n (Stage)
6. If you succeed in avoiding obstacles
   Then goto step 7
   Else goto step 5
7. If you succeed in choosing the shortest route to determine coordinates
   Then goto step 8
   Else goto step 5
8. If Trial = 3
   Then goto step 9
   Else add number 1 to the Stage; Stage = Stage +1 and goto step 5
9. Check if n > 6
   Then goto step 10
   Else goto step 4
10. If you need a print report
    Then select report option and goto step 11
    Else goto step 12
11. Print report of student.
12. Select exit option.
13. End program.

2.4 Game playing description

The first screen of the game is a "welcome screen" which contains five buttons as depicted in (Figure 2). The first one is the **"Start game"** button; the second one is the **"Levels"** button where you can choose one of the eight ascending levels. The third button is the **"Print report"** button from which the teacher can know the progress of any player (pupil). The fourth button is the **"Instructions"** button from which the players can understand how to play the game. Finally, the fifth is button is the **"Exit"** button for ending the game. Figures 3 : 7 show screenshots of the resultant screens after clicking each button.

Figure 2. Welcome screen

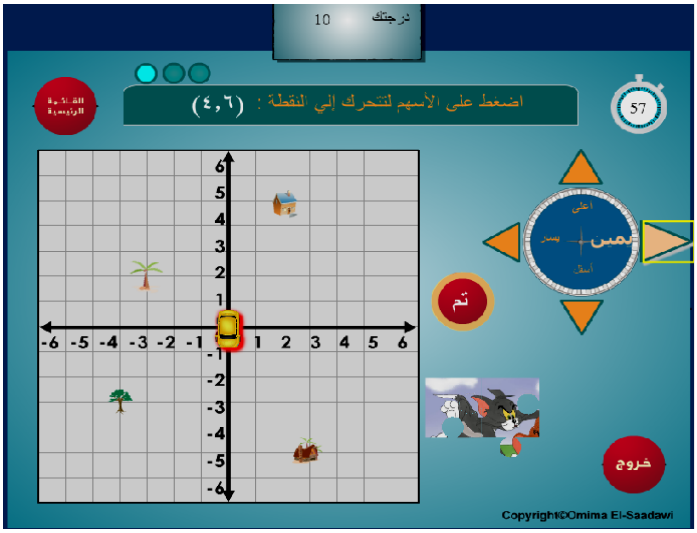

Figure 3. Start game button screenshot

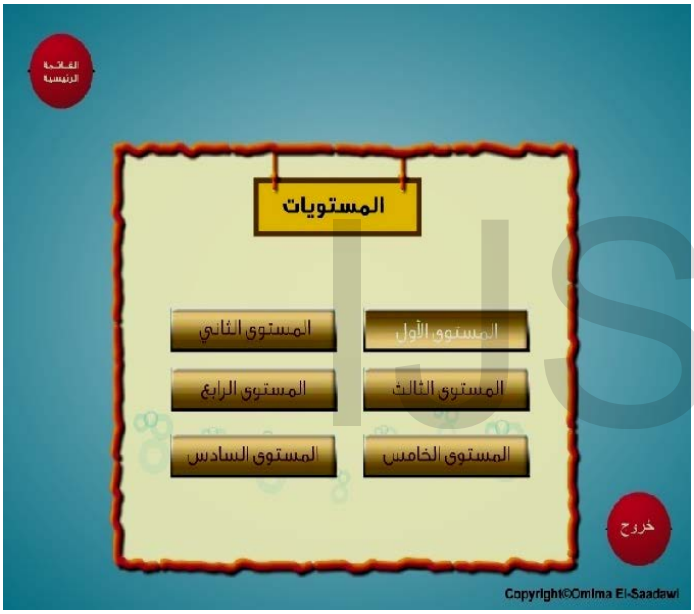

Figure 4. Levels button screenshot

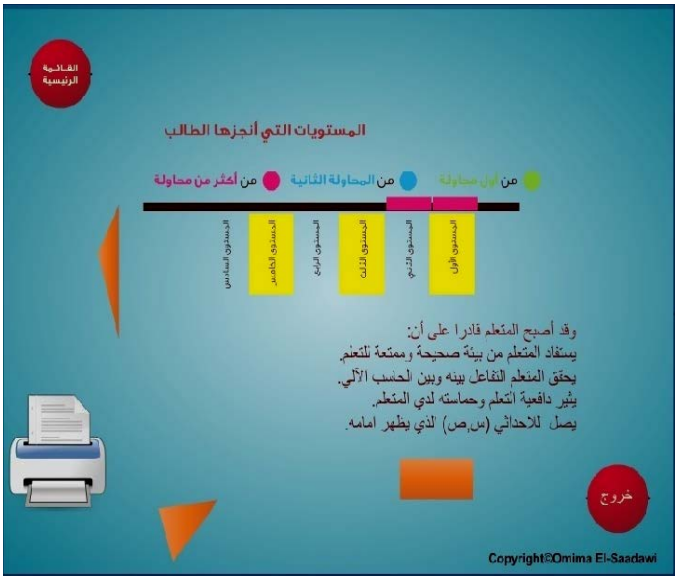

Figure 5. Print report button screenshot

Figure 6. Instructions button screenshot

Figure 7. Exit button screenshot

2.5 Assignment of the players

The aim of the player in this game is to access the coordinates (x, y) that he/she read it in the starting screen. The player wins the game (passes the level) by access to the point quickly while avoiding obstacles and through the shortest route and before the end of the timer. The game ends when the player passes all the prescribed levels (six levels for this game). In each level, the goal of the player is to access the correct point (x, y), but the difficulty of the level is increased gradually by increasing the number of obstacles.

3. EXPERIMENTAL RESULTS

The designed game is evaluated experimentally to investigate its impact on problem-solving skill. Firstly, the suitable assessment measure was chosen and modified so that it can be used to attain the goal of this study. The studied sample was divided into a control group and an experimental group. The measure was applied to both the control and experimental groups on the same day before the students try out the "Coordinate it" game. Then, the experimental group students try out the designed educational electronic game in multiple sessions. Then, the measure is applied to the two groups on the same day. Finally, the result data are analyzed using Statistical Package for the Social Sciences "SPSS" which is a well-known statistical software program [16].

3.1 Procedure of the experimental study

The following steps are followed to perform the experimental study:

(1) Chose a suitable problem-solving measure.
(2) Modify the chosen measure to achieve the prescribed goals.
(3) Prepare the study tools in their final form and detect their validity and reliability.
(4) Apply the problem-solving measure on the control and experimental groups on the same day.
(5) Let the experimental group play the "Coordinate it" game in multiple sessions.
(6) Apply the problem-solving measure after the students play the game on both the control and experimental groups on the same day.
(7) Analyze the results using the SPSS software program.
(8) Discuss the obtained data and present it in an acceptable form.

3.2 Problem-solving measure

In this study the authors choose the problem-solving measure approved by [17], it contains 32 paragraphs in its final form. This measure has many advantages such as: (1) It uses vocabulary that is clear and understandable for the young students in sample, (2) Its paragraphs cover nearly all problems solving issue, (3) It is suitable for research goals and (4) Its design is suitable for public so that it can be used for the studied sample. Since the measure is a general one the authors have modified it so that it can be used to assess the problem-solving skill. The modified measure consists of 32 sentences, with every sentence followed by four possible answers. The student has to choose one of the four answers, which gradually move on a scale from highly identical to nonidentical.

3.3 Evaluation procedure

The procedure of evaluation is summarized as:

- Positive statements are weighted as:
  Highly identical: 4 marks
  Somewhat identical: 3 marks
  Weakly identical: 2 marks
  Non-identical: 1 mark
- For negative statements (7,8,9,12,13,17,20,21,24,25,28,29,30,31), the marks sequence is inversed.
- Total marks of this measure are 128.

3.4 Statistical methods used in the study

In this paper, the semi-experimental designed is implemented for statistical analysis. It consists of control and experimental groups with prior and post measures. The T-test is used through the SPSS program to identify significant changes related to the application of educational electronic game.
The T-test is a statistical test that can detect the presence of a significant difference between two groups on a dependent variable. The test compares the average value of the dependent variable for one group to the average value of the dependent variable for the other group.

4. RESULTS ANALYSIS

The obtained data are statistically analyzed according to the statistical methods mentioned above and the results are then discussed. The study is applied according to two hypotheses as follows. The first hypothesis states that "There are no differences between the control group students in the pre and post measurement on the problems solving measure". The second hypothesis states that "There are differences between the scores of the experimental group students in pre and post in favor of the post-measurement on the problems solving measure". Table 1 illustrates the output of the SPSS program before and after applying the two hypotheses on both control and experimental groups; where N represents the number of the students' sample in each group.

Table 1. Paired samples statistics

		Mean	N	Std. Deviation	Std. Error Mean
Con G	Before	99.52	25	11.723	2.345
	After	99.44	25	11.737	2.347
Exp G	Before	98.60	25	11.180	2.236
	After	107.68	25	9.903	1.981

Table 2, illustrates the output of the SPSS program before and after applying the T-Test on both control and experimental groups. In this table; T is a measure of the size of the difference relative to the variation in samples data. Degrees of freedom (Df) is the number of values in the final calculation of a statistic that are free to vary. Statistically significant (sig.) is the level of statistical significance care confidence in the results. As long as the values of sig. are at the level of (0.00) to (0.05) it means that there is a real difference between the two groups and that the first group community different from the second group community, and we trust in this provision by 95% [18].

Table 2 Paired sample T-Test

	Paired Differences					T	Df	Sig.
	Mean	Std. Dev.	Std. Error Mean	95% Confidence Difference Lower	Upper			
Con.G	0.08	0.493	0.099	-0.124	0.248	0.811	24	0.425
Exp.G	-9.08	3.290	0.658	-10.438	-7.722	-13.798	24	0.000

It is can be observed from Table 2 that the values of (T) and sig. of the control group are 0.811 and 0.425 respectively. It means that there is no statistically significant value at a level of significance 0.05. This is an indication of the lack of statistically significant differences between the mean scores of the control group students to solve the problems in the two measurements pre and post measure.

On another hand, the values of (T) and sig. of experimental group are -13.798 and 0.000 respectively. This is an indication of the presence of statistically significant differences between the mean scores of the experimental group students to problem-solving skill in the two measurements pre and post measures. In this case, statistically significant value is equal (0.000) so that the variable proportion of the variation ($^2\eta$) must be calculated. The variable proportion of the variation is due to the independent variable [19].

$$\eta^2 = \frac{T^2}{(N-1) + T^2} = 0.5348477 \approx 0.53$$

From the above-mentioned results, the obtained value of $^2\eta$ is 0.53, so that there is a significant impact with a large difference in the degree of problem solving scale before applying the "coordinate it" game and after that. It means that 53% of the variance in the dependent variable (problems solving skill) incident necessarily due to the independent variable (educational electronic game), and can be interpreted in the light of the quality of the experimental treatment used.

4.1 Discussion of the results

Out of the previous experimental results the following conclusions can be deduced:

(1) There are statistically significant differences between the mean scores of the experimental group students in pre and post measurement scale to solve problems for the benefit of the post due to the application of electronic educational game.

(2) There are no statistically significant differences between the mean scores of the control group students in the two measurements pre and post measure to solve problems.

CONCLUSION:

This paper presented an application on the use of electronic instructional game in improving problem-solving skill. The game design is based on a proposed framework. The proposed framework is applied to design an electronic instructional game used to improve problem-solving skill for the sixth primary pupils in Egypt. The game is based on the Egyptian ILOs for primary schools. The objective of the game is to develop problem-solving skill and to improve the time of solving the problem in Math curriculum for sixth-grade pupils. The tested sample included 50 male/female students, they were selected randomly. It was grouped to control and experimental groups with prior and post measures.

The obtained value of $^2\eta$ is 0.53, which means that 53% of the variance in the dependent variable (problems solving skill) incident necessarily due to the independent variable (educational electronic game).

The results show that there are significant differences in the skill of problems solving between the experimental group students in the before and after the measurement because of using the designed game. The results prove also that the designed educational game can improve problems solving skill.

In a future work, the authors will increase the values of $^2\eta$ to increase variance in the dependent variable incident necessarily due to the independent variable.

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