Developing a Framework for Designing Educational Aids through Games Method in Order to Facilitate Teaching Mathematics for Elementary Students

Rozita FARZAM¹, Marzieh ALLAHDADI²

¹Faculty member of Industrial Design, University of Tehran, College of Fine Art, Tehran, Iran, farzam.r@ut.ac.ir
²Faculty member of Industrial Design, college of Arts, Alzahra University, Tehran, Iran, m.allahdadi@alzahra.ac.ir

Abstract: The increasing technological advances in the present age reveal the need and necessity of primary teaching of mathematics more than before. Teaching mathematics should be done in order to increase the ability to gain scientific and technological literacy in students that this process begins from basic concepts such as the four main actions in mathematics. Therefore, several educational methods have been presented in this area in order to facilitate learning, which have been introduced and provided as educational aids and methods. Accordingly, this study, considering the age group of 7 to 9 years, as the most elementary age group in the country’s formal education to begin math learning, recommends designing of educational games in the form of a product as an effective way to improve quality of children’s education. Thus, this research used combined research method aiming at motivating and creating interest in students and also helping to the improvement of their learning level in math lesson. In the qualitative section, inductive analysis was used in order to obtain the framework, and in the quantitative section, library method was used in order for internal validation and the examination method of pre-test and post-test was used in order for external validation. Also, in order to obtain external validity of the recommended framework in learning the principles, it was implemented on 50 students in one of the schools in Tehran. Examining the effectiveness and external validation also showed that they can exercise math operations through a new method named game-teaching.

Keywords: educational aids; game; math operations; students.

Introduction

In the contemporary world, teaching and learning are among the complex issues that continuing them through traditional method will not be effective any more. Therefore, meaningful evolution in designing educational programs and materials, such as teaching and learning in order to amend and improve educational performance of learners has been assessed as a prerequisite for achieving sustainable development goals. Thus, in order to create the required reforms in educational system, this important point should be noted that teachers should use effective teaching methods while teaching, in order to increase educational performance and the amount of learning of learners (Slavin, 1996: 4). The results of reviewing international studies of mathematics and science reminds, more than ever, the necessity to change the content of textbooks in order to increase the functional aspects of math lesson, and to review the methods of teaching and learning and turning to active teaching methods (Haj Babayee, 1999: 10).

One of the teaching methods which is of interest to children and can be used in order to help children’s learning is playing games (Clark, 2006: 15). Playing games provides the basis for increasing the attention of children and their more involvement in educational homework (Qaraee and Fath Abadi, 2013: 34). Games are used in order for training and changing of attitudes (Joyce, Weil, Calhoun, 2004). Many studies have shown that playing games can be used in order to teach students’ conceptual understanding of theories such as the theory of natural selection (Herrero et al., 2014). Educational game is a planned, competitive, and purposeful activity which includes a set of roles and designs. Also, teaching which is accompanied with game provides a competitive environment for the child in order to achieve the goal and helps the students in the best way in order to solve educational problems (Shariatmadari et al., 2011: 88).

In a study entitled “The role of previous knowledge in learning new contents using math teaching games”, it has been pointed out that using educational aids can increase students’ interest and eagerness in learning. Accordingly, given the fundamental importance that math lesson has in a person’s academic progress, the experience and action approach can be utilized in which the student participates in learning through educational game (Rajabi Rad, 2014: 20). In order to extract the problems existing regarding teaching different lessons in elementary schools, after random selection of boys and girls schools in Tehran, using field research and interview methods, it was concluded that the most common problem of
teachers at elementary level is in relation to teaching math lesson. Since the foundation of this lesson is dependent on four main actions, many problems regarding teaching and learning of these issues were observed which maximizes the necessity for doing this study. Given the impact of using educational aids in stability and strength of learnt things, the purpose of writing this study was familiarizing with the benefits of game and teaching in order to understand the concept of numbers as much as possible, as using a marginal product has special importance in terms of synchronization and promotion of theoretical and practical teaching, that designing this device leads to easy recall of the issues of the four main mathematical operations (addition, subtraction, multiplication, and division).

Review of Literature

Prenski (2005) answering the question that what should we do so that our teaching will not be boring for our students states that our educational approach should be changed to learner-oriented approach, and emphasizes that “game-based learning” can be a good learner-oriented approach for today’s generation. Researches (Fullan, 2007) have also shown that games are more engaging, more enjoyable, and even more effective than traditional methods. However, in order to use this learner-oriented approach in learning and teaching, we are faced with lack of resources in the world. Even it seems that the resources that have been written in the field of teaching and learning have not paid much attention to playing games as a source, method, or tool for learning. Botturi and Loh (2008) state that, by reviewing several popular books in the field of educational technology, we have understood that few of them have considered game as a motivational activity for supporting and completing classroom lessons. Some teaching and learning specialists also consider playing games only as a competitive activity and exercise, that this viewpoint does not consider the real capabilities and potentials of playing games. By examining these books it seems that writers have eliminated game from the texts of educational technology and see it the opposite point of teaching and the readers of these books also oppose using games in teaching and learning. According to the above, the present research can add a resource to educational technology literature.

Also regarding doing research on matching the elements of games and the principles of teaching and learning, providing practical guidance on how, when, for whom, and in what conditions playing games and teaching and learning can be merged together in order to increase learning capacities
of game is required in today’s research in the field of game-based learning. In this regard, Chandler (2013) also argues that many researches have been done in the field of educational games. Most of these studies focus on what players learn from games, but we are facing a gap in researches regarding the issue that how teachers can combine the principles of learning and teaching with games, in order to improve learning.

One of the answers to the question that “How can we design suitable educational games?” is to use educational design patterns because these patterns show a structured method or map for designing and producing games (Kelle, et al., 2013). These patterns are not suitable for designing at micro level. The main issue of the present research is lack of a suitable pattern or framework in order to use games in educational design of cognitive area at micro level. The present research seeks to develop a framework for designing educational games in order for teaching different content types of cognitive area including facts, concepts, principles, and methods for teaching mathematics at elementary school at micro level. This framework introduces a method for integrating games in teaching and learning in cognitive area, for educational designers and game designers.

**Research method**

This research is quasi-experimental in terms of nature and objective, with pre-test and post-test design with a control group. Population, sample and sampling method: the statistical population of this research was all boy students of the first, second and third grades of elementary school of district 1 of Tehran and district 3 of Isfahan and their teachers at the academic year of 2914-2015. The statistical sample of the study is consisted of 50 students and teachers selected through simple random sampling method. For this purpose, among the elementary schools of district 1 of Tehran Educational Organization and district 3 of Isfahan, five schools were selected according to accessibility. Then all students and teachers were questioned. In this research, the following tools were used in order to collect data.

In this study, two methods of library and field study have been used. Library method has been used in this study in order to extract primary information from written research sources such as research articles and related books as well as Internet resources. These studies have focused on child psychology (age group 7-9 years), games related to the age group under this paper, and different methods of learning and teaching four main actions. In the field method, questioning, interview and observation methods have been used in order to record the results of holding workshop in the
elementary school of district 1 of Tehran. Then the educational aids available in Iran market and the products available in the world markets and also the existing software and applications were examined and the strengths and weaknesses of each of the educational aids and educational games were identified and according to the information obtained from each of the mentioned issues, the compilation criteria were determined based on the target group’s demands. Accordingly, products that were designed to help students learn mathematics better were collected.

Findings

Games’ mechanics

Games have various elements. Mechanics also have various types and roles, but in this research, the mechanics that are very important and outstanding in the types or styles of games have been proposed. In other words, the most important and the most used activities which players do in games have been presented in this study. The obtained mechanics are based on qualitative content analysis, including: problem solving, real practice and activity, designing, puzzle solving, story, decision making, classification, movement of parts, speed of action, collection, social interaction, implementation of activity and action, matching, movement, hierarchy, sorting items, acting with tools, role experience, fighting, construction, test and retest, resource management, elimination and destruction and repetition. With regard to teaching mathematics, each of these mechanics can be categorized, based on different cognitive types, as below:

A) Facts: puzzle, repetition, elimination and destruction, movements of parts


C) Method of work: problem solving, acting, implementation, decision making, puzzle solving.

D) Principles: problem solving, decision making, implementation, construction, management, designing, testing and recreation (Kapp, 2012).

Types of educational aids

In this section the educational aids available in Iranian market and the products available in world markets and also the existing software and applications have been examined. After analyzing the existing samples, the
educational aids were divided into two groups of educational and practice types.

**A) Educational aids _ educational**

These are the tools that have paid more attention to the educational aspect of teaching the four main actions, basically, and the student can use these tools for education from the beginning. Even if, after complete education, they can be used also as a tool for practice, still they are put in this group (figure 1).

![Figure 1: some examples of educational aids such as papilo, tally, stratum, and abacus (right to left); source: authors](image1)

**B) Educational aids _ practice**

In this group, educational aids operate based on previous knowledge, and the purpose for their creation is practice and repetition in order for fixing the knowledge. Students in relation to these tools only present answers based on their knowledge, and they have been thought the related method before using these tools (Figure 2).

![Figure 2: examples of educational aids, such as key game, Ta game, placing, Bingo (right to left); source: authors](image2)

**C) Software**

Software programs are provided to the market as mobile and tablet applications as well as computer software, that, due to the high speed of data processing in them, the automatic feedback can be observed in them at the
same moment and its being true or false can be understood. Also the ability to create attractive graphics attracts more attention in the audience of these types of products (Figure 3).

![Figure 3: examples of the existing software and applications](image)

**The relationship between playing games and learning**

Game is the experimental form of learning. Children learn through playing game; they discover new things; find out the properties of objects; imitate the adults’ behavior; recognize the world around them and adjust their thoughts. Playing game stimulates curiosity of the child and causes gaining new experiences. Children gain a lot of experiences during a game and realize many natural issues and phenomena. Vigotsky believed that playing game helps the child’s increasing growth and progress. Children enjoy playing, because in playing games they can do activities that are not possible for them in reality. If teaching is done through the game, students understand the subjects sooner and forget them lately. Using games in teaching math lesson, although makes teaching longer, but makes learning deeper, more enjoyable, and more practical (Broomes, et al., 2003: 154).

**Educational game design criteria**

The researchers’ studies on games and the method of children’s interaction with toys and stimulation of their growth by this method have shown that traditional toys are the most beneficial types of toy for stimulating the growing mind and body. On the other hand, electronic toys can prevent children’s creativity and reduce the time duration of attention. After analyzing the issues extracted from field studies and interviews, it was concluded that the teaching method in the new system of cognitive schools (which is based on incarnate and semi-incarnate teaching and the emphasis in teaching is on conceptual understanding through playing games) is a more effective teaching and has a higher efficiency compared to ordinary schools with traditional teaching method. And this shows that most teachers do not consider traditional method of teaching to be effective, and consider
teaching and practice through playing games with educational aids to be necessary for proper and deeper understanding.

Based on the researches it was determined that different senses do not have the same role in learning. These findings indicate that in a normal human about:

1. 75% of learning is done through using “sight” sense;
2. 13% of learning is done through using “hearing” sense;
3. 6% of learning is done through using “touch” sense;
4. 3% of learning is done through using “smell” sense;
5. 3% of learning is done through using “taste” sense.

Therefore, these should be considered when designing educational aids.

According to the obtained results, the criteria which should be considered in order to improve the performance of the final design have been summarized below:

- Existence of understandable visual symbols and signs related to the considered concepts for teaching and learning;
- Dimensions appropriate to the classroom teaching tool;
- Weight proportional to the operation method in order for ease of transport;
- Not being expensive compared to similar models available in the market;
- Observing safety appropriate to the user group (students aged 7 to 9 years);
- Focusing on senses;
- No need for muscle strength;
- Appearance and performance attractiveness in order to create motivation for interaction with the product;
- Creating motivation for practicing and learning concepts using games, excitement, competition and collaboration.

**Holding game workshop**

The main reason for holding game-teaching workshop is that students can practice the four main mathematical actions along with game and pleasure through the new method, so that through which they learn interaction with each other and transfer their learning and experiences to each other. Among the other goals that can be achieved by holding a scientific workshop are: trial and error, recognizing the problems existing in the game process and the appropriate time, examining the method of
communication, and the amount of students’ enjoyment from the game, as well as knowing the teachers’ opinion.

This workshop was held in May and June 2015 in the boys’ elementary school named “Badbadak” located in district 1 of Tehran (Figure 4). This scientific workshop was held for three groups in two different days. 12 students from the second grade in elementary school participated in this scientific workshop. It should be noted that all groups included four boy students that participated in the competition. The appropriate time for scientific workshop was considered as forty-five minutes.

![Badbadak pre-elementary and elementary school, District 1 of Tehran; source: authors](image)

**Figure 4:** Badbadak pre-elementary and elementary school, District 1 of Tehran; source: authors

One of the designed educational game devices named “Fourfold” with the following details which had the design criteria was used in the workshop:

1) Modular game board: 4 boards
2) Beads: four different colors for each person
3) Dice: four dices for each person
4) Question cards in four colors
5) Blue and orange score beads
6) Visual card: 16 ones
7) Beads related to visual cards: 16 ones
8) Score beads box: 4 ones for each person proportional to its bead color
9) The main box for cards and score beads

Generally, the workshop’s steps were planned as follows:
1) Four students were randomly selected from second grade students.
2) The final model of the game with all details and beads was presented to the students.
3) After the students sat, a brief explanation was given to them about the steps and process of the game.

4) The game began by throwing the dice and every person who gained the highest number could be the first one to enter the game board and move according to the dice number (The game’s rotation is clockwise in order to create equal opportunities for students).

5) The number of moves in the game cells is determined based on the dice number (number 6 has a prize).

6) After movement of the bead on each cell, the question card related to that color was given. In case of correct answer to the question, they took a blue score bead and put it in their score box and in case of wrong answer, they lose the score of that question.

7) In case of the bead being placed on signed cells, they could take a cream bead. The signed cell was only for creation of motivation and excitement for the game, but at the end of the game it was not considered as score.

8) If they got 3 points, they could see under the image cells and remember them.

9) After seeing the considered image, they should reach to the answering cell and show the bead to others so that they can take the card.

10) At the end, everyone who had more beads and scores was the winner.

11) The data resulted from the scientific workshop was collected through observation during the game.

12) The data were reviewed and the required changes were made both in the design and in the process of the game.

13) At this level, the game was completely edited and achieved the maximum desired efficiency.

Achievements and evaluation of game workshop results

During the workshop, all students in the determined groups were carefully observed and evaluated (Figure 5). The results obtained regarding the interaction of students with fourfold product are as below:

1. A number of students listened to the explanations with more concentration and became familiar with the game process, while some others paid more attention to the details and space of the game rather than the explanations. This dichotomy caused a difference in choosing right paths and knowing the game steps.
2. Students, who had tried various games before, dominated the game much faster and were more careful in mastery of the game; for this reason they acted more successfully in choosing the route and equally were more successful in answering their math questions. But with the passage of time and students’ awareness of the importance of concentration and being careful in choosing right paths and performing mathematical operations, other students also made their best efforts to gain more scores and this caused them to try more to have a performance similar to the successful persons.

3. Interaction was quite evident during the entire game time and this led to excitement and some kind of competition among the students. In some cases, in the case of a student’s delay in answering the operation, other students in the group tried to help him or even evaluate the answer that this work led to multi-dimensional concentration of the individuals, such that each person, in addition to his own questions, paid attention to the questions of others too. This caused them to carry out more operations and to be more careful in achieving the correct answer.

Figure 5: holding the workshop in Badbadak boys’ elementary school (right to left: the first, the second and the third workshops respectively); source: authors
Discussion and conclusion

Herrero et al. (2014) consider educational and learning activities for conceptual subjects in using the method of presentation of the important features of the concepts, examples and non-examples and using conceptual map in order to show the relationship between the concepts and the types and elements of the concept by using pictures in learning the concept.

Kapp (2012) states that learners, in order to learn concepts, must know the important features of concepts in order to be able to recognize and classify examples and non-examples of concepts; he suggests that in order to learn concepts in educational games, it is better to use the mechanics of matching, classifying, and experiencing the concept itself.

Work method is the series of steps that a learner performs in order to implement a work such as solving a math problem. In learning the subjects, the work method, the steps, and the method’s cycle are presented; the learners observe the steps of performing the work or the work method and then practice and perform it. In this regard, Prensky (2005) states that observing and imitating the steps of performing the method and practicing them is among the important activities of learning subjects through work method type. Also Van Eck (2010) states that the main feature of work method subjects is that several activities or works must be done in a specific sequence one after the other. In educational games, the steps of a work are done and a problem is solved step by step through mechanic or the element of time limitation, which means that the player must perform an activity within a specified time limit a. Then after the end of that time, the player must do the next step or activity within another specified time limit. In this way, the player will perform all necessary activities step by step in specified times. Therefore, learning is made faster through playing game, because a set of experiences is presented compactly and in a short time. Through interaction with each other, children learn and transfer their learning and experiences to one another. As was stated, using game is a kind of association or encoding in order for better learning of things that are learnt later or more difficult. And if game is accompanied by a lesson activity, the pleasure resulted from the game is linked to the lesson and the student will become interested in the lesson. During the game-teaching workshop, the students showed great interest in the game; and they practiced the four main math actions again and again without any force. Educational aids according to the recommended criteria cause that the student will like math throughout his life and use it in life. Initially, the game process and the appearance of the product were considered by both students and teachers, which showed
success of the project. Then, during holding of this scientific workshop, it was shown that students are more inclined to practicing and learning through game, instead of sitting in classroom and studying textbooks and listening to the teacher’s explanations. This interest was such that every student, in addition to answering his own questions, also tended to evaluate the answers of others, and this caused that the required conditions will be provided for them to understand the correct answer. Also, they could experience partnership and teamwork along with competition and cooperate with each other in choosing appropriate routes.

References


Chandler, C. (2013). The Use of Game Dynamics to Enhance Curriculum and Instruction: what Teachers can Learn from the Design of Video Games. Journal of Curriculum and Instruction (JoCI), 6(2).


Kapp, K.M. (2012). The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education. San Francisco: Pfeiffer.


