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Efficiency of game-based educational methods in mathematics based on emotional intelligence of students by using Data Envelopment Analysis (DEA)

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Abstract

Given the significance of mathematics and the challenges associated with its learning, using effective educational strategies can enhance comprehension and boost student motivation. Data envelopment analysis (DEA) is a mathematical programming model for evaluating the efficiency of decision-making units (DMUs) that have multiple inputs and multiple outputs. Efficiency measurement has always been the focus of researchers due to its importance in evaluating the performance of a company or organization. This study has aimed to investigate the effect of game-based educational methods on the emotional intelligence and academic performance of mathematics. In the practical part of this paper, 150 students who are here are placed in groups of 15 people. The relative efficiency values of these groups have been calculated by using the Games software in data envelopment analysis, and also the progress and regression of each group of students before and after the game have been obtained using the efficiency values. In general, it can be concluded that using game-based educational methods can help improve students' emotional intelligence and academic performance. However, some games require a review in terms of development, community selection, and implementation methods to achieve the best results.

Keywords: emotional intelligence, game-based education, math education, data envelopment analysis.

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1.Introduction

Despite mathematics' importance, learning it presents a number of difficulties for students. These challenges can be turned into opportunities for students to learn, understand and enjoy it by choosing appropriate educational methods. (Rees et al. translated by Norouzian, 2013). Mathematic is more challenging than theoretical and experimental studies. Mathematics requires more intelligence than other fields to understand different concepts. In several countries, mathematics is regarded as the most complex and challenging subject (Ghazala et al., 2017). Studies have indicated that student procrastination and poor performance in doing homework are caused by inadequate problem-solving skills (Agustin and Winarso , 2021). The literature has shown that educational techniques positively affect academic progress, motivation and welfare, as well as personal and creativity development. In educational process, the teachers' role is not only to convey scientific facts to students, but also to provide good conditions for learning and teach students how to think and to learn. Teachers and authorities are now paying attention to innovative and active approaches. These methods focus on the interests and skills of the students and teachers try to improve student's ability to listen, speak, read, write, infer, compare, contrast, analyze, construct and create. They provide the lesson material in accordance with this issue (Abadi, 2019).

Today, it is important to use the effective technologies to achieve learning goals in educational issues. Recently, it has been argued that the student-made knowledge is both valuable and sustainable in that the student are more involved in learning than the teacher and can generalize to other situations.(Khansari , 2021). The diversity of human learning time, which is as wide as life time, has caused some people to face problems in the normal process of teaching and learning despite the many differences they have in learning (Shivandi and Khalili, 2019). Due to the rapid changes in today's education sector, we have to adopt new methods, especially in the field of learning and teaching (Fathi Azar et al., 2013). Game-based learning is one of methods influencing student success and satisfaction. (Bulut et al., 2022; Sawatasky et al., 2017). The game improves students' motivational strategies to practice skills and provides a strong foundation for their learning (Blum and Yocom, 1996; cited by Khonsari, 2021). Many researchers believe that games as a teaching tool help students to solve problems. Playing the game also allows them to solve problems and develop strategies in a non-threatening environment. (Khanmohammadi,2023;

Khansari,2021; Sadeghche, 2021; Amrai, 2021; Moalemi, 2019; Sawatsky et al., 2017.) The findings of recent studies indicate that games can have a significant affect on learning for both children and adults. The advanced education systems of the world are always trying to increase the role of games and learning activities in education. Games have a positive effect on learning mathematics and can enhance decision-making, accuracy, focus, and attention span, while changing calculation performances from finger and paper counting to mental ones (Metikasari et al., 2019). Studies have demonstrated that environmental interaction and play can increase math skills and improve creativity and attitude (Bragg, 2007).

In recent years, the student performance has been one of the challenges in education and research. While a wide range of individual, social family and cultural characteristics are associated with student performance , some researchers emphasize the relevance of individual variables in this context (Kemmelmeier et al., 2005). It is essential to recognize and investigate individual differences to understand how individuals behave and teach. According to some researchers, although IQ plays an important role in academic performance and success, it may not accurately predict success, and other factors are effective (Ayesha & Khurshid, 2013). Recent studies have shown that in addition to intelligence, emotional factors such as emotional intelligence play an important role in organizing the learning process (Malik and Shahid, 2016; Nozari & Szmelter-Jarosz, 2022).

Emotional intelligence is a set of non-cognitive skills, talents and abilities affecting individual's ability to succeed and adapt to the demands and tension of surroundings (Bar-on, 2006) and is a set of abilities allowing you to accurately assess and express your emotion, and use it to arouse, plan, or achieve success(Mayer et al., 2004; Nozari et al., 2024). In addition, it is the ability to properly manage disturbed moods, control impulses, get excited, and be hopeful and optimistic despite disappointment and sadness. It generally is a social skill consisting of engaging in social interactions to control emotions in relationships (Efil et al., 2005). According to Mayer and others, the human cognitive system is affected and changed by emotions enabling individuals to understand the relation between performance and mood and act in an emotional manner. (Zenasni & Lubart, 2009; Nozari & Aliahmadi, 2023).

In addition, most studies have investigated the relationship between this construct and other psychological constructs including emotional intelligence (Hashmi, 2009), personality traits

(Avril, 1999), creative styles and interpersonal relationships, individual differences (Long et al. 2003), emotional diseases (Faz et al., 2007), creative behaviors (Avril, 2005) and self-efficiency (Kazemi & Shafaqi, 2011). In this regard, Fetorchi et al. (2023) investigated the students' emotional intelligence enhanced by game-based learning as an ICT tool and concluded that playing the emotional intelligence-based games and following the recommendations led to positive changes such as increasing emotional intelligence and reducing emotional energy and aggression. The results from the study include suggestions for teachers, trainers or organizations interested in implementing game-based learning programs. In recent years, more attention has been paid to new educational methods, including game-based education. Using game elements such as competition, challenge and entertainment, these methods teach mathematical concepts to students in an attractive and effective way.

While there are definite advantages to game-based education, it is not easy to rate and assess this form of education. The critical thinking, problem solving, and creativity skills developed in game-based education cannot be adequately assessed by traditional assessment methods like tests and quizzes.

Meanwhile, effective mathematics learning involves the use of emotional intelligence which is a set of skills and abilities enabling individuals to comprehend, control, and express their emotions as well as those of others. According to studies, students with high emotional intelligence better solve mathematical problems, work in groups, and complete challenges (Khadevi et al., 2021). This study can contribute to the wider field of emotional intelligence theory and learning by expanding the understanding of the effect of computer game-based learning as interactive ICT experiences on strengthening emotional intelligence and the quality of education.

2. The importance of assessing and rating game-based educational methods in mathematics

It is very important to pay attention to evaluating and rating the game-based educational methods in mathematics. By the indicators of emotional intelligence, it is possible to more comprehensively and accurately evaluate the efficiency of these teachings and identify their advantages and disadvantages.

2-1. the assessment of improvement

The assessment is not only about rating and classifying educational methods, but also is an opportunity to identify their advantages and disadvantages and improve the quality of education. The use of emotional intelligence indicators in assessment helps teachers and educational planners to optimize their teaching methods and provide students with more effective learning experiences. For example, suppose an educational game is used to teach the concept of fractions in math class. During the game, the teachers can observe the students' behavior as they are faced with challenges, interact with each other, and participate in the game. It presents valuable information about the effect of the game on students' emotional intelligence and provides the teachers with the knowledge to modify or change the game (if needed).

2-2. assessment of educational justice

Diversity in learning and students' needs require the use of different assessment methods. Focusing on measuring knowledge and mathematical skills, the use of traditional assessment methods can benefit students with higher intelligence in these areas and ignore students with higher emotional intelligence and social skills. For example, a student may have difficulty in solving traditional math problems but be very capable in working group and solving problems creatively. The student may not be able to demonstrate his/her abilities if his/her performance is determined by test results. However, the emotional intelligence indicators in assessment can be used to identify the student's strengths and weaknesses and help the student progress more effectively.

2-3. Assessment of transparency

By understanding the efficiency of game-based educational methods, parents, teachers, administrators, and policy makers can take informed decisions to adopt and implement these methods with greater clarity and assurance. Based on emotional intelligence indicators, accurate assessment provides the necessary transparency about the advantages and disadvantages of these methods. For example, parents who are doubtful about game-based educational methods can obtain detailed information of the effects of games by reviewing the assessment results based on emotional intelligence indicators.

3. Methodology

3-1. assessment based on emotional intelligence

It is an essential step to focus on assessing and rating game-based educational methods in mathematics based on the emotional intelligence indicators in order to improve the quality of math education and help students reach their potential in this field.

3-1-1. observation of behavior

Directly observing students who engaged in game-based learning activities provided information about their level of emotional intelligence, which has be seen through their interaction with each other, emotional management during challenges, participation in activities and motivation.

3-1-2. interview and Questionnaire

The students were interviewed and given emotional intelligence standard questionnaires that can provide deeper information about understanding, controlling and expressing their emotions.

3-1-3. data analysis

Data on game-related activities, such as time spent on problems, co-operation with others, and satisfaction levels, was gathered and analyzed to provide useful information about the effect of these methods on student emotional intelligence.

Carried out by the data envelopment analysis , this study has aimed to investigate the effectiveness of game-based educational methods in mathematics based on the emotional intelligence of students. Having the capacity to assess multi-index issues, data envelopment analysis is a suitable option for assessing game-based educational methods, because it evaluates games based on analyzing the results of the emotional intelligence questionnaire before and after playing the games. In addition, this study has aimed to answer the question of "which game has more effect on mathematics education" by using emotional intelligence as assessment measure.

3-2. data envelopment analysis

As mentioned earlier, the efficiency of game-based education in mathematics has been investigated. During this process, some designed teachings were used in the 7^{th} grade mathematics of secondary school, and their output were evaluated. Performance appraisal issues are among the management problems, which can be measured in various ways. There are two methods of

performance appraisal: parametric and non-parametric methods. In the parametric method, the functional form of the efficiency frontier is already known and some parameters of the production function have to be estimated. One of the main disadvantages of this method is that because the functional form of the efficiency frontier is known, the evaluated problems must follow a specific functional form, which is practically impossible in the real world (Bahari and Alirezaei, 2019). In contrast to parametric methods, there are non-parametric methods. Most researchers in this field have adopted and favored the widely used non-parametric method known as the DEA method. Because DEA constructs the efficiency frontier with as few assumptions as possible, it does not impose the special functional form on the efficiency frontier and allows the data itself to determine it (Bahari and Alirezaei, 2019). DEA is a powerful mathematical technique used to evaluate the relative efficiency and performance of multiple decision-making units in a set. DEA compares and consolidates the efficiency of decision-making units including companies, organizations, departments or any other entity consuming the same number of inputs to produce a certain number of outputs. The efficiency values performance scores show how well each unit performs in comparison to top performing units. This makes DEA particularly useful for performance evaluation, as it provides a relative measure of efficiency rather than an absolute value. Another distinctive advantage of DEA is to manage several inputs and outputs simultaneously, which makes it suitable for evaluating complex systems where different inputs lead to wide range of outputs. DEA provide decision makers with opportunity to consider interchanges between inputs and outputs and find the optimal balance that maximizes efficiency.

There are two main types of traditional DEA models: CCR and BCC, which serve as the foundation for the development of new models of this technique (Charles et al., 1978 and Banker et al., 1984). The difference between the two models lies in how they deal with problem-scale efficiency. In the CCR model, the units are assumed to operate under efficiency on constant scale that, increasing inputs leads to increased outputs, which is the foundation for efficiency on the standard scale.

While in the BCC model, the efficiency is considered to be a variable scale. On the other hand, variable returns to scale allow for scale inefficiency and account for situations where an increase in inputs does not lead to a proportional increase in outputs.

This study aimed to evaluate the effect of game-based educational methods on 7^{th} grade mathematics. For this purpose, several game-based educational methods were developed in the

first phase. In the next step, by selecting a number of groups equal in number to the educational methods, each of the games was assigned to one group in order to evaluate the level of efficiency. According to the aim of assessing the educational methods, the experimental conditions should be the same for all games as much as possible; therefore, it is necessary to pay attention to the points leading to fair assessment. In selecting educational groups, homogeneous groups should be used as much as possible, because heterogeneous groups may contain factors differing from other groups which affect the educational performance and lead to imbalances in the assessment conditions. Considering that these educations took place in the Qom city and according to the cultural diversity of the large-scale migrations to that city, the selected educational groups (schools) should not be far away. According to the special condition of this city, any change in the area will result in disruption of multiple cultural factors affecting educational activities; as a result, the output of the game cannot be attributed only to the game capacity.
In addition, in order to maintain the integrity of the educational conditions, one teacher is suggested to play the games so that the difference in the abilities of the teachers does not affect the test results, or an assessment committee should be established to harmonize the conditions of educations needed for uniformly played group games. All groups were selected from a specific grade (7^{th} grade) and all games were related to a specific topic. To evaluate the games, a questionnaire was designed to measure emotional intelligence indicators. Students can complete it before and after receiving intended education. After gathering the quantitative data from the questionnaire, the envelopment analysis method was used to assess students' ability based on emotional intelligence criteria. In this issue, each student was treated as a DMU and the emotional intelligence criteria were measured as the output of each student. Before and after playing the game, the DEA model was used for both data sets. The average efficiency of DMUs in each group (game) is considered as the efficiency for that game. Games were ranked based on the performance changes of each game.

The statistical population consisted of all high school students of Qom city (Iran) in 2024-2025. In this study, a multi-stage cluster sampling method was used, in such a way that the fourth educational district of Qom (Iran) was randomly selected from among the city’s educational districts after obtaining the necessary permits from central department of education. Then, two schools were selected in this district and participated in the study as a sample. Schering's Emotional Intelligence Questionnaire (1955; quoted by Bahmanzadeh, 2013) was used. Emotional

intelligence was measured by the questions of Schering's emotional intelligence questionnaire with 33 items.

Table 1: Questionnaire rating

Never	Rarely	sometimes	often	always
1	2	3	4	5

3-3. Analysis (interpretation) based on the rate of the questionnaire

Based on this analysis method, the obtained scores were added up and judged based on the following table. Note that the following points are for one questionnaire. For example, if you have 10 questionnaires, you must multiply the following points by 10:

- The lower limit of questionnaire scores is obtained in the following way:

The number of questions in the questionnaire * 1 = the lower limit of score

- Scores from the above 33 items are added up. The minimum possible score will be 33 and the maximum will be 165.
- A score between 33 and 55: the level of emotional intelligence is low.
- A score between 55 and 110: the level of emotional intelligence is average.
- A score higher than 110: the level of emotional intelligence is high

3-4. Validity and reliability of the questionnaire

3-4-1 Validity of the data collection tool

Validity refers to how accurately a method measures what it is intended to measure (Sarmed et al., 2011). In the study by Bahmanzadeh (2013), the initial draft of the questionnaire was prepared to determine its validity. After using the views of the supervisor and advisor, it was given to a number of experts in the study community; as a result, some corrections were suggested. Finally after correcting, the final questionnaire was made.

3-4-2. Reliability of data- gathering tools

The reliability of a tool is its degree of consistency in measuring whatever it measures; That is, to what extent research method produces stable and consistent results under the same conditions (Sarmed et al., 2013). In the study by Bahmanzadeh (2013), the reliability of the questionnaire components was obtained by Cronbach's alpha using SPSS software, as shown in the following table.

At last, the final questionnaire was designed with the necessary corrections and was performed on the main statistical sample group.

Table 2: Alpha coefficient

Row	questionnaire	Number of questions	Alpha coefficient
1	Emotional intelligence	33	0.89

The data envelopment analysis was used to investigate the efficiency of game-based educations. According to the fact that DEA is a linear programming model, GAMS software was used to solve the desired model.

4. Methodology

As mentioned above, the investigated data is related to the 7^{th} grade of the secondary schools located in the fourth district of Qom city (Iran). In the study, the indicators of emotional intelligence (self-awareness, self-motivation, self-control, social intelligence and social skills) are considered as the output of each DMU (student). To investigate the results of the designed games and provide a fair competitive environment for the designed games, it is necessary to consider some points in selecting test samples. According to Qom's immigrant-friendly environment which almost welcomes all ethnic groups, we tried to make the selected groups as homogeneous as possible so that the test results are not affected by some indicators such as education level, race native language, and bilingualism. To do this, all students were selected from the same region, school and grade level, and Qom -born students were participated in this test to avoid the effect of factors such as race and ethnicity on the results.

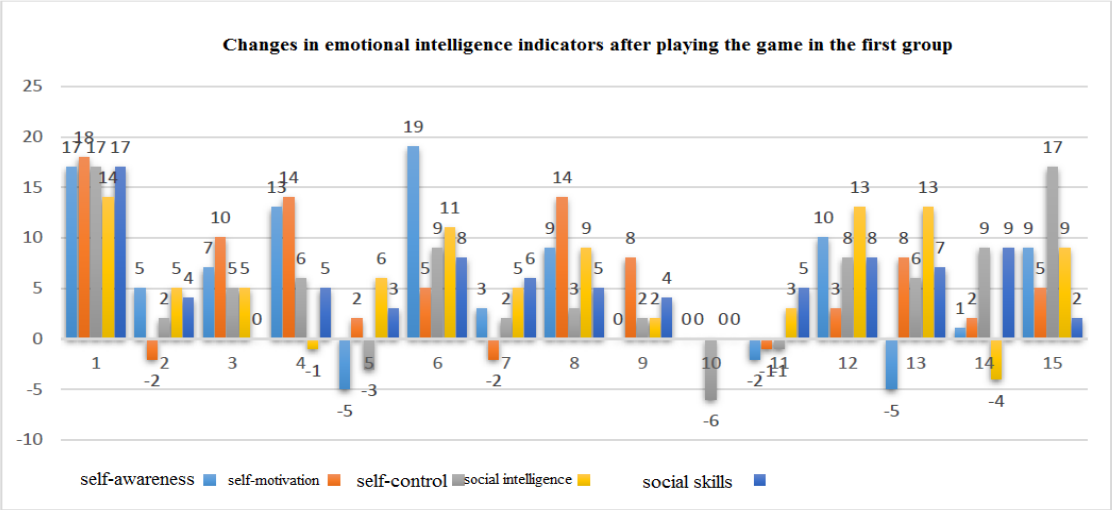

Figure 1: Changes in emotional intelligence indicators after playing the game in the first group

The designed questionnaire was given to the selected groups in an isolated environment (away from the effect of other students and parents) before playing the game to answer the designed questions.

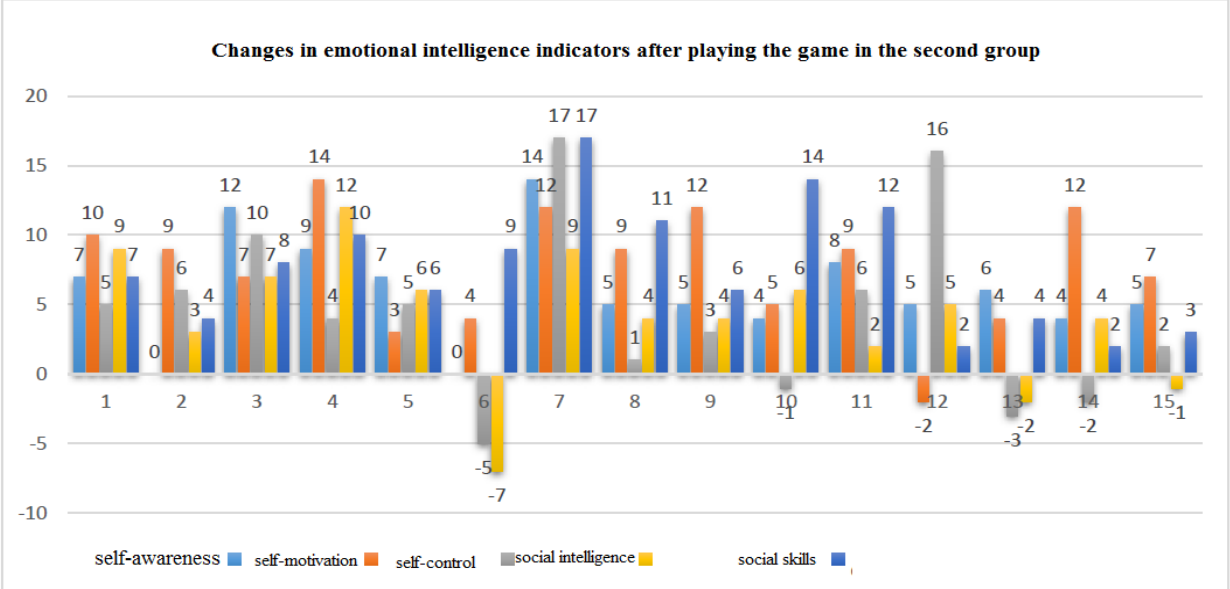

Figure 2: Changes in emotional intelligence indicators after playing the game in the second group

Because every student is required to answer the questions of the questionnaire again after completing the game-based education, they should not be aware of this issue because the students can remember the answers before the test and affect the results. Figures 1 and 2 respectively show

the changes in the emotional intelligence indicators for each student in the first and the second group. These changes were made due to the games played. In this figure, it can be seen to what degree the games have capacity to affect the indicators.

Considering that the used data is related to 10 groups (15 subjects per group), only the changes of the first two groups have been considered. To investigate other groups, refer to Appendix 1. Figure 3 shows the average changes in emotional intelligence indicators by educational games. The self-motivation and social skill had the highest average increase in this figure (7.67), indicating that according to these indicators (separately not as a whole), second game had the best performance. In addition, the lowest average increase is related to the self-control index in the sixth game (-0.13) which clearly shows the poor performance of this game in the specific index (not in general).

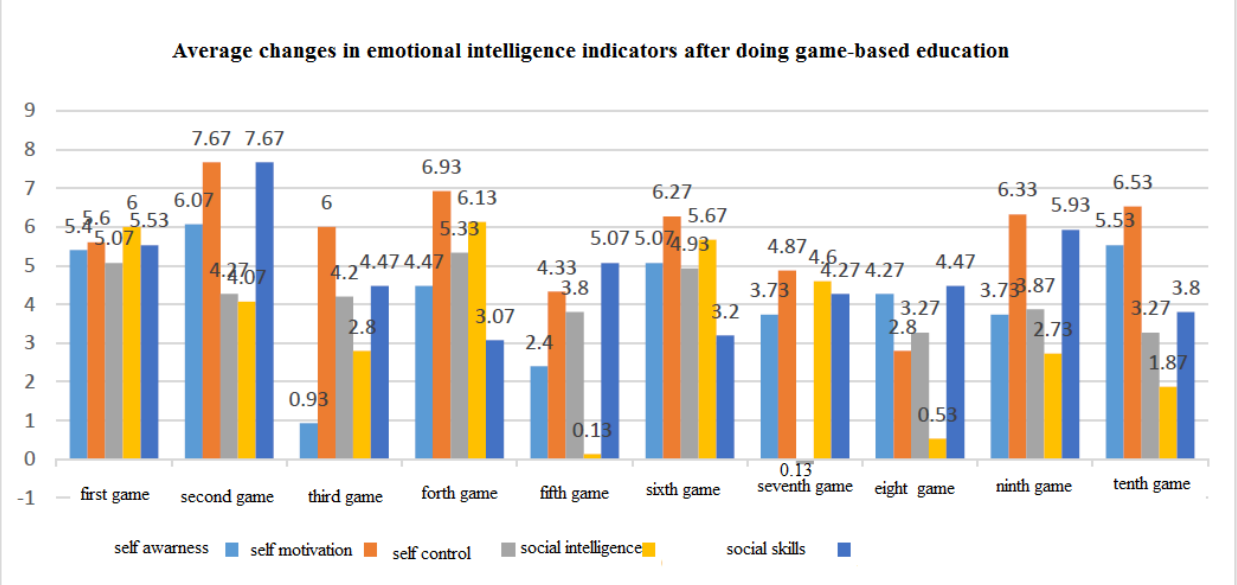

Figure 3. Average changes in emotional intelligence indicators after doing game-based education

After collecting and refining the data, the data envelopment analysis model is used to evaluate games, because their assessment is based on several indicators. But note that in this issue, the output of the education was evaluated by a specific education; therefore, the best model is one without input of data envelopment analysis, which is as follows (Liu et al., 2011):

According to Liu et al. (2011), in cases such as evaluating students' exam performance or the overall economic power of countries where no input is considered, such DEA models can be used to evaluate performance and efficiency.

The model 3 has been implemented for the data obtained from the questionnaire before the desired education and the results have been recorded. Considering that the model is implemented separately for each group (for which a special game is intended), one performance score is gotten for each student in each group. However, because the final aim of the study is to assess the games (groups), the average efficiency of each group is considered as the efficiency of that group. In addition, because a certain game has been played in each group, the changes in the efficiency score of each group after playing the game are considered as the performance of the game (table 1).

Table 3: Changes in efficiency after and before doing designed games

games	**Scores of efficiency from assessment of games based on emotional intelligence indicators**	
	After playing	**Before playing**
1	0.88	0.91
2	0.93	0.90
3	0.93	0.93
4	0.95	0.92
5	0.92	0.92
6	0.95	0.89
7	0.84	0.92
8	0.94	0.88
9	0.93	0.92
10	0.94	0.94

You can assess how each game performed by comparing the efficacies in table 1 and looking at figure 4.

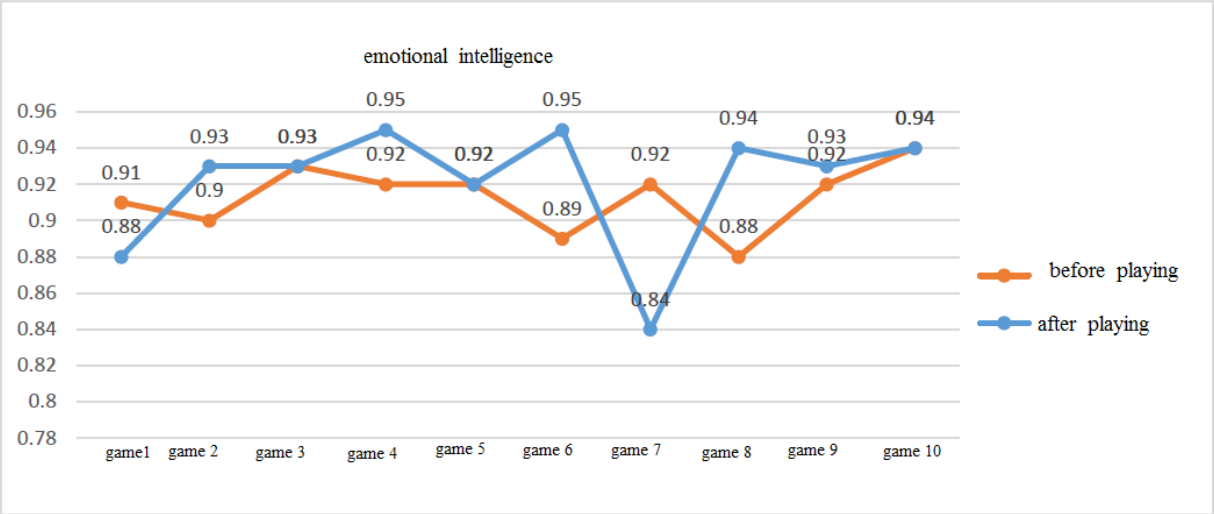

Figure 4. Changes in the efficiency before and after playing the designed games

As can be seen, the studied group's performance improved significantly in five of the designed games. In three cases, the games did not affect the students' emotional intelligence performance, and in two cases (the first and the seventh ones), the games adversely affect the students' emotional intelligence performance, which should be reviewed.

Table 4: Reasons for the need to re-evaluate the games that did not have good results

investigating the correctness of implementation	• Has the game been implemented completely and according to the instructions? • Are teachers and students thoroughly familiar with the game? • Was the learning environment suitable and free from disturbing factors? • Has there been enough time to play the game and observe its effects? • Lack of attention to these items can negatively affect the assessment results.
investigating the proportion of the game to the target group	• Was the game suitable for the age group and educational level of the students? • Has the game been designed according to the cultural and social background of the students? • Was the game challenging and engaging enough? • Incompatibility of the game with the target group can reduce the motivation and participation of students and affect the assessment results.

Investigating external factors	• Did any unexpected events or incidents happen during the game? • Were the students stressed or anxious during the playing the game? • Have other factors such as lack of resources or management problems affected the process of playing the game? • These factors can have a negative effect on the students' performance during the game and on the assessment results.
Diversity in assessment methods	• Have different assessment methods such as observation, interview, questionnaire and performance data review been used? • Have the assessment results been shared with teachers, students, and parents and asked for their opinion on the effectiveness of the game? • The game's effects may be underestimated by relying solely on one assessment technique.
Repetition and correction	• Is it possible to repeat the game by correcting the errors and necessary corrections? • Can the assessment results be used to improve the design and implementation of the game in the future?

The assessment has aimed to not only approve or deny a particular method, but also to identify its advantages and disadvantages and use this information to improve learning opportunities for all students. It is important to evaluate whether an educational method has negative performance. Many factors could have affected this result. These factors should be considered before deciding to eliminate a game. Here is a list of factors leading to poor performance of the game that assures a reader of the results obtained for these methods. It is mentionable that the study has aimed to investigate the effectiveness of game-based education in mathematics and does not intend to investigate the factors affecting the performance of games, but these factors are mentioned here to provide insight (Table 2).

5. Conclusion

In this study, a number of game-based educational methods were designed to investigate the effect of game on teaching mathematics based on emotional intelligence indicators. The study sample includes 10 groups (15 subjects per group) from one of the secondary schools in the city of Qom(Iran)and the selected groups were tried to be homogeneous as much as possible so that

external factors do not affect the results of education. The results from the study show that five of the designed games have a significant effect on the performance of students' emotional intelligence. In three games, there was no change in the emotional intelligence performance. In two cases, this performance was negative. Except for five games affecting the efficiency of students' emotional intelligence, the possible factors affecting these games such as ensuring the accuracy of the games, suitability of the game to the age of the audience, external factors, and changing or improving the evaluation method are suggested to be investigated. However, in the education, the meaning of assessment and rating is not to completely reject the nature of some games, and the designed game may be suitable for another subject.

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