A Short View on the Relationship of Mathematics and Game from Literature Context and Concept of the (Educational) Mathematics Game

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Abstract: In this study, the concept of game and its relation to mathematics are focused in the context of mathematics education. First of all, the concept of game is discussed and then possible relationships between mathematics and game from the viewpoints of the authors are put forward for discussion under some certain titles. The study presents the fields in which mathematics and game are related in two dimensions. The first dimension is about the studies in literature which examine mathematics and game under certain titles determined by the authors. The second one suggests a conceptual point of view of the interaction between mathematics and game by means of mathematicians' and mathematics educators' thoughts. Finally, this point of view is reduced to the question "what is mathematics game?"

Key words: Game · Mathematics · Mathematics Game · Educational Mathematics Game

INTRODUCTION

Mathematics is regarded as one of the most important lessons which is thought to be necessary to be learned by most parts of the society and which is encountered in getting a job. However, at the same time, it is thought to be a lesson that is boring, hard, causes anxiety and must be learnt as a result of obligation. For instance in Sam and Ernest's study results concerning public images of mathematics carried on 548 adults, two statements with the highest percentage are *mathematics is difficult* [frequency (f)=70] and *mathematics is boring* [f=58] [1, p.201]. Such kind of impressions, in case of being ignored and disregarded, cause students to worry, to experience stress and later experience psychological negativities such as anxiety and fear. Anxiety is at the top of the problems encountered in the field of mathematics [2]. In his [2] research in which he collected a wide literature, while he was listing some of the reasons for the mathematics anxiety as *the factors related to the structure of mathematics, educational factors, the factors regarding the attitudes of families,* The author emphasizes that one of the main reasons as well is *the educational methods used in teaching mathematics* [2]. The basic factors to be discussed at this moment are the methods, devices and their ways of use to be able to develop students,

- Who believe the necessity of learning mathematics as well as learn it with pleasure without anxiety,
- Who are aware of the fact that mathematics is not only an essential lesson for passing some exams but also a part of life every time and everywhere in which problem solving is necessary and there is reasoning?

One of the learning methods and devices under discussion is thought to be "game".

Game is a concept which does not have a general definition to be accepted by everybody as it is considered to be the common name of actions that have many types for the purpose of different goals. In addition to the existence of many kinds of games such as sports games, child games, theatre plays, strategic games, pc games, different focuses are encountered about the definitions and properties of games when handled in terms of philosophy, sociology, anthropology, psychology and educational sciences even in the event that only one kind of those games are dealt with.

While John Dewey describes game as unconscious behavior without an expected result, it is described as activities realized willingly with rules in a certain setting by Huizinga. To Spencer, game is getting rid of the unnecessary energies. To Eibesfeldt, it is an active form of apprenticeship. Gross thinks that game is a kind of preparation for the following phases of life. Mitchell and Mason state that it is expressing oneself. Finally, to Gulick, it is doing what is wanted [3].

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Another definition given by Dönmez (1992) is, Game is the most effective learning process for children whether with a certain purpose or not, with rules or without rules. It is a thing in which children participate willingly and with pleasure. It is the base for children's physical, cognitive, language, affective and social development as a part of real life [4].

If game is dealt with in terms of the importance it has in the mental and affective education of an individual and the reasons for playing games, it is possible to increase these definitions. (see; [3,5-8]). Because games have been studied in such a wide range, it is thought that trying to give a definition of the concept of game which this study has taken as a basis will be helpful from the point of view of the general features that a game has to possess. From this point of view; game can be defined as structures;

Making possible for the students to study individually or in groups, enabling them to learn while having fun, combining easily many methods and techniques, making it possible to establish a bridge between mathematical concepts and daily life, having strong visual side, providing to make use of teaching devices more usefully.

The main reason why games are dealt with in this explanatory frame is to draw attention to the thought that games are the bodies that can be applied for different purposes especially in mathematics education and that can increase the effectiveness of mathematics teaching.

Why Games in Mathematics Education? This question is perhaps one of the most basic and the most difficult questions to be answered in this study and studies with similar purposes. That's why our approach is to reach a consequence to contain two dimensions.

The first one is composed of the collection of studies in literature considering the concept of game in mathematics education from different viewpoints under some categories. It is aimed to form an opinion by shortly explaining the researches in different categories, that games can be used for different purposes and how wide games are spread in mathematics education. The second one aims to define some points to be focused on in the interaction of games and mathematics and so to discuss the concept of mathematics game.

The Categories Depending on the Researches in Literature Aiming at the Concept of Game in Mathematics Teaching: There are a large number of researches aiming at using games in mathematics teaching and at game–mathematics relation in literature. In developed countries the game–mathematics relation has been studied from many standpoints with the help of the

researches beginning from 1960s and in 1980s and after in gradually increasing numbers. Our approach here is to summarize the study subjects in literature under some different categories rather than to list many samples from these studies. Thus, a perspective regarding the effect areas and the contributions of games in teaching of mathematics will be tried to be formed. Of course it is possible to increase the categories below, or to relate them with each other. The categories may not be regarded as completely independent from one another. For example, the games affecting the success in mathematics can also be dealt with cultural or technologically supported games. However, our approach is to reach some topics concerning the research subjects and shortly detail those topics. Categories can be listed as follows;

Game and the Success of Mathematics: Randel and Morris, in their wide field scanning (mathematics, social sciences, logic, physics, biology) about the effectiveness of games for educational purposes, examined 67 researches [9]. In this comparative study, it is stated that mathematics is the most appropriate field to use games. The research data about the mathematical games included in the same study indicate that games increase *the success of mathematics* and the marks that express this success. Inamdar and Kulkarni state that the students in the sample group who have used the computer game "hole-in-the-wall" frequently have an important improvement in their test scores [10]. On the other hand, they show that there is not a considerable difference between experiment and control groups in the post-test given for Science and English.

The Popularization of Mathematics and Game: Guzman, trying to make a detailed analysis on the relations between mathematics and games by considering the real nature of mathematics and games, their situations of application and the interaction which they had with each other throughout history, in addition, describes games as an important tool in the popularization of mathematics [11].

Game, Culture and Mathematics: Realizing that games are in close touch with cultures has caused them to have the property of being a tool in anthropological studies and they have become a source of inspiration for researches to be made over the three play of *culture-mathematics-game*. According to Bishop, because games are thought to be one of the six universal mathematical activities of all cultures, they are largely related to mathematics [12]. Barta and Schaeling discussing mathematics as a culture,

have put forward the thought that when a connection is formed between mathematics and culture in classes, some information can be gained related to what kind of typical activities people did in the past in different cultures [12]. They came to the conclusion that combining mathematics and culture and helping students compose content as individuals forming their own learning result in a more effective learning. Garage highlighting that cultural games are of importance in teaching mathematics in terms of pedagogy states cultural games will be able to be of help to teachers in terms of the fact that their students comprehend the relationship between the teaching method in class and their specific learning ways and the cultural activities from the point of view of their being the source of educational knowledge [13]. Moreover, Morris listing cultural mathematical games, one of the important measurements of the relation of cultures with mathematics presents the explanations of 24 mathematical games in different cultures and the connections dealing with the changes between cultural perspectives and the structures of games [14].

Game-Computer-Mathematics: Games, as an important field of informatics technologies which have become a great sector, have a gradually increasing demand in education as well because of their audio-visual features. In the consequence of the relations between educational needs and the elements that games possess, (logic, memory, imagination, problem solving) the improvement of educational games have become possible [15]. The studies made as to the effects of computer and video games especially in mathematics lessons are gradually increasing and positive findings are being put forward. Some of the significant studies made on this field are [16-22]. In this field, some of the studies that can be given as examples for mathematics education are [23, 24] and [25]. In the literature collection made by TELMA European Research Team, presented in Kaleidoscope's study, a wide range of information is given in this field and 4 groups of researches made over the developed games are mentioned. The first game "*Aquamoose 3D*" is an on-table surrounding design with 3 dimensions created to help learning the information about the behavior of Parametric equations. Elliot and Bruckman, examining this game, expressed that students used mathematics to produce not only interesting graphical forms but also mathematical difficulties to share with others [26]. The second game "*Thinklets*" has been developed by Freudental Institution. These are devices similar to the game produced to start learning at home with the help of web, to decrease the gap between learning at home and in

school and to make mathematics rich. The third one is the games of "E-GEMS" (Electronic Games for Education in Math and Science). One of the important results that was reached by Klawe, studying on "*Phoenix Quest*" and "*Super Tangram*" developed by Kamran Sedighian, is that computer games have an evident effect in children's learning and enjoying mathematics [27]. Inkpen *et al.*, examining E-GEMS games in general, also state that to transfer the subjects of mathematics into a computer game atmosphere enables children to have connection with the subject and after the games children create some attitudes towards the necessity and meaningfulness of mathematics [28]. The fourth game included in the study of TELMA is "zoombinister" developed by TERC. This game is composed of 12 stages based on reasoning aiming the group ranging from 9 years old to adulthood. In order to progress in these stages, the logic of deduction, the ability to test hypothesis and to reason are required [25].

Game-Pedagogy-Mathematics: Another interesting and striking approach that can be related to the relationship of mathematics and games is the idea of taking advantage of pedagogy for applying games in classes [29]. This idea can be summarized as persuading teachers to try games in their classes with the help of connecting the elements in the game structures with the accepted teaching-learning theories. Becker, in his study, tried to define the relation of Gadge's (Conditions for Learning) and Gardner's (Theory of Multiple Intelligences) theories with the elements in games.

Game-Motivation-Mathematics: Dweck (1996) states that motivation has a central role in every kind of learning activity [24]. For that reason, motivation becomes important in games as well. Scanlon et. al. who relate the reason of the increasing academic interest in games to motivation, state: "the increase in the academic interest in mathematics begins with a simple idea, games motivate and their motivating strength can be benefited to add spice to the field of education" [30, p.127]. Motivation is believed to be a more necessary element in learning mathematics when compared to the other fields. Especially, it is one of the major things that students must be provided with to help them overcome the barriers caused by the negative viewpoints towards mathematics. Therefore, the motivational support of games can make important contributions to learning in mathematics education. Begg *et al.*, express that motivation according to the teachers is one of the most valuable factors to the educational experience by the use of games in education [23]. To Connelly, who studied the difference between

Table 1: Relationships Between Question Form and Mathematical Heading and Ideas

Form of Question	Mathematical Heading
How do I play this?	Interpretation
hat is the best way of playing?	Optimization
How can I make sure of winning?	Analysis
What happens if … ?	Variation
What are the chances of … ?	Probability
Form of Statement	*Mathematical Idea*
This game is the same as …	Isomorphism
You can win by …	A particular case
This works with all these games …	Generalization
Look, I can show you it does …	Proving
I record the game like this …	Symbolization and Notation

traditional approaches and cooperative games used to motivate students in classrooms, games have an important effect on students' motivation [31]. Klein and Frettag's study about the effects of using an educational game for motivation showed that educational games affect 4 motivational components: interest, coherence, confidence and satisfaction to a great extend [32].

The Interactions between Games and Mathematics: In most of the studies that aim to define the relationships of mathematics and games, it is emphasized that both two concepts have more similarities with one another than thought. Moreover, it is possible to encounter common definitions in which both concepts are included while stating the description and properties of mathematics and games. While Faulkner is defining the concept of game as "the [process] established on real life experiences in which the basis of mathematical thought is built" [33]. Umay puts forward "games are largely mathematics, mathematics is completely a game"[34]. Davis and Hersh in their writings named "The Philosophy of Formalist Mathematics" state that what mathematics expresses according to the formalist mathematician is just a logical deduction game beginning with arithmetic [35]. Leibniz wrote the following to De Mountmort in 1715;

Men are never more ingenious than in the invention of games; the spirit finds himself there at this leisure … it would be desirable to have a whole course about games mathematically treated [11, p.363].

Guzman's thought about the structure of games and mathematics is that their structures are visibly similar because of acting with continuous loyalty to the set of rules and with the acceptance of certain objects and the rules defining them [11]. When we analyze the games existing in our lives since our childhood, we can realize that we collect data relative to an event, a fact or a situation, classify and record data, form a model on a

piece of paper or on the board or mind to solve an encountered problem, make some counting on that model and display behavior such as trials and errors, planning and applications, arranging the life areas, the locations of objects and their positions to themselves and using of them according to time, place and people (listing, combination, matching). Aren't all of these things mathematics itself or dealing with mathematics actually? From this point of view, it is possible to put forward that some skills targeted with mathematics education have been actually gained with the help of games by the students before coming to mathematics classes in different periods of their lives. Games involve not only basic skills but also the structures of thought and behavior aiming at some topics in mathematics. It can be observed that when focused on apparent situations included in games, forming a match between the resulting main questions and mathematical headings and ideas are possible. One of these matches is illustrated in Table 1 from [36]. It may be possible to increase this and similar matches. But, what must be focused on is not to increase the number of these matches in the process of producing a persuasion on the relation of games with mathematics but to discuss how they can be acquired by students in mathematics lessons through medium of games. This subject to be studied won't be handled here because it is the theme of other investigations in which deep analyses are made especially about the structures of educational games.

After all, it is thought that a certain limitation can be made possible by dealing with the concept of "*mathematics game*" for at least further surveys to be made.

What is Mathematics Game? In the consequence of the abundance and rapid growth of information sources nowadays, numerous mathematics games in books and periodicals and on internet are encountered. The wide range of these games makes it hard for them to be defined

and for their properties to be comprehended. For this reason, it is expected that the first comprehensions of teachers and students, when mathematics game is mentioned, should generally be in the forms which the games they have seen or known left in their minds. Although there are a large number of mathematics games in literature, it can be said that the studies aiming at what is mathematics game or what kind of features it must have are not sufficient enough. Then, how can a teacher or trainer decide on what kind of a route to follow when he wants to benefit from mathematics games? This question makes the classification of games and the necessity of the examination of their effects in mathematics education according to their types a current issue. All these reasons have led us to describe what mathematics game is and what kind of features it must have. This investigation will approach this subject mainly with two perspectives. The first one is dependent on (a) the interest of professional mathematicians in games and the second one is (b) dependent on the approaches of mathematics educators about game.

- Mathematicians have been interested in games throughout history. What can be the reason directing them to be interested in games? Is it the curiosity to the unknown or the similarities they find in the nature of game and mathematics? Although it is hard to know the answer exactly, a partly understanding can be enabled to be formed by dealing with some ideas. Guzman, states that it is a common situation in mathematics history that the presentation of an interesting question (like The Seven Bridges of Königsberg, Four Color Problem) in a game-like atmosphere or the genius observation of a situation seeming to be innocent causes new thinking models [11]. While undertaking the function of drawing the attention of those except the ones interested in mathematics professionally by relating mathematics and life, such kind of games have given the possibility to serious advanced mathematical studies and even the appearance of new study fields. Some of the problems of this type;

Cattle Problem of Archimedes, Fibonacci's Rabbit Problem, Cardan's Ring Puzzle, Tylor's Knight's Tour Problem, Euler's Thirty Six Officers Problem and Seven Bridges of Königsberg Problem, Hamilton's Icosian Game, Kirkman's School Girl Problem, 15 Puzzles of Sam Loyd, Lucas's Towers of Hanoi and Ernö Rubik's Rubik Cube [37].

When looked at the games listed above it can be thought that they are different from mathematics game generally comprehended at the first glance. In understanding the game aspects of these forms which can be regarded as problems depending on observation and logical deductions on the objects or events existing in daily life, to examine the concept of mathematics game which Holton, et. al. defined will be useful. To them, "mathematics game" (MG);

By mathematical [game] we mean that part of the process used to solve mathematical problems, which involves both experimentation and creativity to generate ideas and using the formal rules of mathematics to follow any ideas to some sort of a conclusion [7, p. 403].

A MG has six features.

- it is a solver-centered activity with the solver in charge of the process;
- it uses the solver's current knowledge;
- it develops links between the solver's current schemata while the play is occurring;
- it will, via 3, reinforce current knowledge;
- it will, via 3, assist future problem solving/mathematical activity as it enhances future access to knowledge;
- it is irrespective of age (p. 404).

When approached with this aspect, game can be understood as an individually problem solving process that has curiosity and investigation instinct in it. From the viewpoint of mathematicians, the thought that game is discussed as a logical relaxation which is not necessary to be directly relevant to their study fields, problem setting and solving and the action of producing rivalry and interest can be put forward. We take the definition of [7] as a basis for the first group from which in mathematics lessons they can be benefited as "mathematics game".

- Another approach to the concept of "mathematics game" includes a viewpoint shaped on the educational game concept to enable more usefulness to game educationally. In order to differentiate this kind of games from the other group, we will use the term *"Educational Mathematics Games"* (EMG). The basic features of an EMG are;
- having only 2 players
- involving only thinking skills (no physical activities other than moving on a counter, making a mark etc. is required)

- offering full information at all times (the state of play is clearly visible to both players and there are no hidden elements as in playing cards)
- not generally involving luck (exceptions to this will be made)
- people might well play for pleasure (this excludes "educational games")
- being usually finished within a reasonable span of time (this is merely to exclude such games as chess, draughts, etc. which, though acceptable in other respects, are impractical for our purposes)
- requiring a minimum of special equipment (this allow multiple copies of a single game to be made or reproduced as cheaply as possible and rules out proprietary games needing special boards, pieces etc. as well as (usually) having an extensive set of rules). It is listed in [36].

Two similar definitions for EMG are given under the title *Instructional Game* in the monograph called *Learning and Mathematical Games* by [38]. In the first definition, the first five criteria are based upon Inbar and Stoll's study and the left two features are put forward by Bright and Harvey (p. 5);

- A game is freely engaged in,
- A game is a challenge against a task or an opponent,
- A game is governed by a definite set or rules. The rules describe all of the procedures for playing the game, including goals sought; in particular, the rules are structured so that once a player's turn comes to an end, that player is not permitted to retract or to exchange for another move the move made during that turn.
- Psychologically, a game is an arbitrary situation clearly delimited in time and space from real-life activity.
- Socially, the events or the game situation are considered in and of themselves to be of minimal importance.
- A game has a finite state-space (Nilsson, 1971). The exact states reached during play of the game are not known prior to beginning of play.
- A game ends after a finite number of moves within the state-space.

Second, the features included in the game definition of Fletcher who excluded games of one player are as follows [38, p.6];

- There is a set of players (two or more).
- There is a set of rules which provide choices of behavior for the player.
- A set of possible outcomes (payoffs, goals) is specified or determinable.
- There is a conflict or interest among the players.
- Each player has a certain capacity to act (a set of resources) and a pattern of preferences among the goals.
- There is an information system.

Through the use of these three approaches we felt it necessary to give a final definition of an EMG in order to increase the effectiveness and usability of EMGs in mathematics education. To do this we manipulated the previous definitions and made some additions. So finally, an EMG is a form which has 8 criteria;

- having one or more players
- having some defined rules
- ending in a certain period of time
- requiring strongly the skill of thinking
- paving the way for the actualization of some learning objectives in the involved subject
- making it possible for the mathematical thinking to improve by the way of questioning the state-space in the game
- aiming the learning and reinforcing of a certain mathematical concept or subject (or a group of them)
- enabling to a formal assessing-evaluating with its interacting structure about the mathematical subject or concept, the educational objectives and state-space.

CONCLUSION

Blanchard and Cheska (1995) point out that game is not something different from the work done in leisure and it is one of the types of learning with its universally accepted form [15]. The information given above is in the effort of proving that this thought is also valid in terms of mathematics learning. All the information dealt with shows that making use of games in mathematics education not only increases the success in mathematics, but also the concepts of mathematics and game have lots of interactions directly or indirectly.

Such a multi dimensional approach leads to kind of awareness about the fact that game, obviously has effects and roles in mathematics education beyond only having fun. This awareness emphasizes the importance of

the subject in terms of its being a research field. Furthermore, it is seen that the concept of mathematics game, educational mathematics game and their characteristics can be discussed from several different perspectives. They should be considered to be learning tools that can be benefited in mathematics teaching. Furthermore, each of them should be taken into consideration as a necessary form to become a research field.

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