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Aplicações de Gamificação na Educação em Matemática: Um Mapeamento Sistemático

Gamification Applications in Mathematic Education: A Systematic Mapping

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RESUMO
O ensino de matemática apresenta uma série de grandes desafios, que são de grande número e variedade. Esses desafios seguem os alunos desde a infância. Existem autores que argumentam que os conceitos matemáticos aprendidos no ensino médio têm uma natureza mais operacional ou prática e podem interferir na capacidade de aprender conceitos matemáticos mais abstratos, ensinados no ensino superior. A educação tradicional e tecnicista, baseada apenas na visão do professor em que ele age da maneira que aprendeu que lhe foi passada ao longo do tempo, agora é coisa do passado. Com o amplo uso da Internet, computadores e tecnologias da informação, vivemos em um mundo globalizado, onde novas tecnologias são apresentadas a nós todos os dias. Os alunos nesse contexto, onde as aulas são totalmente tradicionais, se sentem desencorajados e buscam outras atividades para desenvolver e passar o tempo. A gamificação pode ser definida como uma metodologia que está sendo usada como mecanismo de jogos, estética e pensamento do jogo para envolver as pessoas, motivar a ação, promover o aprendizado e a solução de problemas. Esse mapeamento sistemático selecionou 45 artigos recentes relacionados ao uso da gamificação no aprendizado de matemática e apresenta orientações futuras nessa área de pesquisa.
Palavras-chave: Gamificação; Educação; Matemática

ABSTRACT
The teaching of mathematics presents a series of great challenges, which are in a great number and variety. These challenges follow students since childhood. There are authors who argue that the mathematical concepts learned in secondary education have a more operational or practical nature, and it can interfere in the ability to learn more abstract mathematical concepts, taught in higher education. Traditional and technicist education based only on the teacher's view where he acts in the way he learned that was passed on to him over time is now a thing of the past. With the widespread use of the internet, computers and information technologies we live in a globalized world where new technologies are presented to us every day. Students in this context, where classes are totally traditional, feel discouraged and seek other activities to develop and spend time. Gamification can be defined as a methodology that is being used as the mechanisms of games, aesthetics and thinking of the game to involve people, motivate action, promote learning and problem solving. This systematic

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mapping selected 45 recent papers related to the use of gamification in mathematical learning and presents future directions in this research area.
Keywords: Gamification; Education; Mathematic

1. INTRODUCTION

The teaching of subjects related to mathematics in undergraduate courses presents a series of proven challenges for work in the area (RAFAEL; ESCHER, 2015), mainly regarding the students' difficulty in associating logic concepts taught in these disciplines, as well as difficulty in applying concepts related to problems in other areas of knowledge.

These challenges are intrinsic to the area of mathematics, and are applied in solving problems in other disciplines (RAFAEL; ESCHER, 2015) (MADEIRA et al., 2019). The difficulty in associating concepts and consequently in applying problem solving techniques is common, and even more evident in engineering courses, as the curriculum has mathematical-based disciplines applied to the application and application of techniques in other disciplines, more specific.

Such difficulties are pointed out as one of the causes of the high levels of failure in these disciplines and the students' lack of interest in mathematics, be it pure or applied (ALVES et al., 2016). An area of research that has been applied in the teaching-learning process to increase student interest is called gamification, defined by KAPP (2012) as a methodology that is being used as a game mechanism, aesthetics and game thinking to involve people, motivate action, promote learning and problem solving. Gamification has been applied in several areas and educational domains, showing improvement in several aspects in the teaching-learning process, including in the teaching of mathematics.

To investigate the main focus of the recent research in this area and how the gamification elements have been applied in these works, a mapping of the recent literature has been conducted and is presented in this work.

The paper is structured as follows: In Section 2 we present the research dimensions of the systematic mapping. These research dimensions are directly

related to the mathematical education in graduation courses and the use of gamification techniques in education. In Section 3 we present the process of the systematic mapping related to the research in the application of gamification techniques in mathematical education. In Section 4 we present the analysis of the results and the discussion related to these analysis. Finally, in Section 5 we present the conclusions of this research.

2. RESEARCH DIMENSIONS

In this Section we present the main concepts related to the proposed systematic mapping. First, we present the actual context of mathematic education considering Brazilian reality in graduation courses and the main challenges related to it. After, we present the main concepts related to the application of gamification in education.

2.1 Mathematics in Graduation Courses

The teaching of mathematics presents a series of great challenges, which are in a great number and variety. These challenges follows students since childhood. In gratuation courses, specially in engineering, it is also difficult for students to fix concepts in the learning of differentials and integrals, related to the disciplines related to mathematics in these courses of graduation (CURY, 2000).

Considering the Brazilian engineering graduation courses, in the first four semesters, the basic cycle takes place, with subjects such as mathematics, physics, chemistry and computing content. The disciplines related with calculus (frequently called as Calculus A (or Calculus 1) and Calculus B (or Calculus 2)) are mandatory disciplines in engineering and STEM courses. The difficulties that students have in these disciplines can have a profound impact on the development of the course, and may lead students to postpone the completion of the course (MADEIRA et al. 2019).

The Brazilian National Curriculum Guidelines for the Undergraduate Engineering Courses provides in its article 9 that in the pedagogical projects of graduation courses must attend the basic content (BRAZIL, 2015), such as:

Administration and Economics; Algorithms and Programming; Materials science; Environmental Sciences; Electricity; Statistic. Graphic expression; Transport Phenomena; Physics; Computing; Mathematics; Mechanics of Solids; Scientific and Technological Methodology; and Chemistry. The importance of mathematics in engineering is largely due to the formulation of problems, choice of methods and mathematical concepts are essential in the training of engineers (ALVES, et al, 2016). Mathematics seeks a very wide range of attributes, such as increased logical reasoning, such as understanding problems and abstraction (ALVES, et al, 2016).

In related research there are reports of difficulties by the students to resolve relatively simple questions, such as performing the calculation of the value of a function at a given point, drawing simple graphs or completing the square of an expression (NASSER; TORRACA, 2012). One of the main problems identified is that the content of the mathematic disciplines, which usually starts with the functions content and ends with the presentation of the concept of integral, is fundamental to understand other mathematical issues, disciplines of physics and chemistry (MADEIRA et al. 2019). Part of the researchers in the field associates this difficulty with the gap resulting from the lack of necessary content in elementary and high school and the student disinterest about this area (RAFAEL; ESCHER, 2015). There are authors who argue that the mathematical concepts learned in secondary education have a more operational or practical nature, and it can interfere in the ability to learn more abstract mathematical concepts, taught in higher education (ALVES et al, 2016).

The problems of evasion and retention of students lead to other problems, which are factors perceived by society and which leave the domains of universities (SILVA FILHO, 2007). Generally, universities do not have structured programs to combat dropout and tend to be more concerned with attracting new students than with retaining existing ones. Engineering courses in Brazil have a high dropout rate, which directly interferes with the number of engineers trained per year (REIS et al. 2012).

According to the census presented by INEP (2018), Brazil has a total of 299 public university campuses, of which 107 are universities, 13 university centers, 139

colleges, 40 Federal Institutes and Cefets. In this context, Brazil has a total of 37.962 university courses distributed in bachelor's, undergraduate and technological courses. In these courses, there are 8.450.755 students enrolled in the most diverse areas of knowledge. In 2018, in the engineering area, there were a total of 1.170.660 students enrolled and only 155.494 graduates (13.29% of the enrolled students).

Nasser & Torraca 2012 indicate two alternatives to reduce dropout: (i) develop an alternative proposal for high school mathematics classes, which anticipates situations and problems in Calculus, generating what we call readiness for the study of Calculus, and (ii) encourage basic mathematics activities with freshmen from universities, aiming to fill learning gaps and assisting in the abstraction necessary for mastering advanced mathematical thinking. Another proposed solution is to use computational resource methods to try to help students understand the main concepts presented in Mathematics (MADEIRA et al. 2019).

In the educational environment, innovations happen, whether in teaching methodologies, in the performance of teachers or in the tools used, not needing to be something totally new, but something that promotes improvements and acts as a facilitator of the teaching-learning process (REIS et al., 2012). One of the most recent innovations in education is the application of gamification techniques in the learning process.

2.2 Gamification Applied in Education

Traditional and technicist education based only on the teacher's view where he acts in the way he learned that was passed on to him over time is now a thing of the past. With the widespread use of the internet, computers and information technologies we live in a globalized world where new technologies are presented to us every day. Students in this context, where classes are totally traditional, feel discouraged and seek other activities to develop and spend time.

Society also needs professionals trained with this profile in the organizations. In the view of the globalized world and the constant technological developments, society in general needs critical, proactive students capable of managing their own learning.

In this way, the teacher starts to work more as a learning advisor directing the focus of the process and leading the student to build together with the school and their colleagues a new professional profile, valuing teamwork and the role of each individual seeking more pleasurable experiences that lead to constant learning. Thus, enabling the introduction of tools capable of better this and bringing one into the school a more pleasurable, pleasant environment and capable of leading the student to seek protagonism in his own learning is a great challenge for all the actors who think about education.

For that, it takes into account all the technological changes that brought us innovations in the way of creating, sharing, building knowledge and information (FARDO, 2013) making an incorporation of digital culture within the school more and more strong. A very interesting option due to the great popularity among young people are the use of games. According to (HUIZINGA 1980), “the game is a function of life, but it cannot be precisely defined in logical, biological or aesthetic terms. The concept of play must remain distinct from all other forms of thinking through which we express the structure of spiritual and social life”.

2.2.1 Gamification Definition

Given this context, Gamification can be defined as a methodology that "is being used as the mechanisms of games, aesthetics and thinking of the game to involve people, motivate action, promote learning and problem solving" (KAPP, 2012).

Based on the information on gamification, the authors demonstrate a wide range of techniques that are used to make a gamified process feasible. Understand why some games have a greater number of fans or are more engaging and able to achieve their goals is possible, in part, by analysis of the mechanics of the game and the techniques used by it.

2.2.2 Gamification Elements

This section presents the elements that can be used for the gamification process. These elements are intended to engage, motivate, train and encourage

positive behavior (LOPES, 2015). We will adopt the definition of Game made by Karl Kapp (2012), where game is defined *"a system in which players engage in an abstract challenge, defined by rules, interactivity and feedback, which results in a quantifiable and often causes a reaction"*. The main gamification elements are: (i) Goals, (ii) Rules, (iii) Conflict, Competition or Cooperation, (iv) Time, (v) Rewards, (vi) Feedback, (vii) Levels, (vii) Narrative, (ix) Esthetics, (x) Fun. These elements are presented in the sections below.

2.2.2.1 Goals

Goals are a very important part of games. The simple introduction of a goal adds objective, focus and measurable results (KAPP, 2012). So in many games the objectives are clear and straightforward as you play you see the progress in this way at all points of the game you see it like this.

Thus through visual understanding of the game the player can define how far he is from one goal or another by providing feedback with his indication of progress. The objective is the main device to determine the level of effort at a given point in the game, strategies, movements and, ultimately, who wins (KAPP, 2012).

Goals must be well structured and sequenced to have sustained meaning to motivate players to achieve those goals (KAPP, 2012). In instructional terms, you must create a terminal goal and support it with a number of goals. Because when a player reaches an objective the game ends then stipulating several minor objectives leading to a major objective is important to provide a sustained game.

Playing an objective-oriented game thus involves when the game determines the pattern and the ultimate goal, players try to find the ideal path by getting there (KOSTER, 2013). Even if the objectives are well planned, the rules can spontaneously arise, things that the designer did not foresee.

2.2.2.2 Rules

For assays involving biofilm formation, a 0.78% EO solution was prepared following the procedure adapted from Oliveira et al. (2010). First, the oil sample was

dissolved in DMSO (2%) followed by dilution with saline solution (0.85%, m/v) containing Tween 80 at 0.5% (v/v).

Biofilm formation was assessed by microtiter-plate test according to (STEPANOVIĆ et al., 2000, MILLEZI et al., 2016). In 96-well polypropylene microplates, bacterial inoculum and EO solution were mixed into the wells at a ratio of 1: 1 (v/v). In the simplest form, a game is a set of defined rules. Rules to indicate the number of players, rules that define how to score points, or rules indicating what is allowed in the game (KAPP, 2012). Rules are one of the essential qualities of games: every game has a set of rules. On the other hand, every set of rules defines a game. Rules are the formal structure of a game, the fixed set of abstract guidelines that describe as a function of the game system (SALEN, TEKINBAŞ, ZIMMERMAN, 2004). In this way, SALEN, TEKINBAŞ & ZIMMERMAN (2004) proposed a system of rules with three parts, named:

- Operational Rules or Game rules: They are the rules used for players to be able to play the games, they are the guidelines and how the user will use the game, be it board or digital.

- Constitutualtive Rules: Constitutive rules are the mathematical logic behind the games.

- Implicit Rules: These are the unwritten rules of a game. These rules concern etiquette, good sportsmanship and other implicit behavior of the game.

A note of clarification about the difference between the rules of a game and the rules of strategy: rules like we understand them here as the formal structure of a game is not the same as strategies for playing, even though the two may seem similar.The plates were incubated aerobically at 37 °C for 18 h under orbital shaking (80 rpm) (Tecnal, Brazil). For the positive control, wells were filled with the bacterial inoculum and the TSB broth in the ratio of 1: 1 (v/v). In the negative controls, wells were filled with the solution of OE and TSB broth in the ratio of 1:1 (v/v) or only with the TSB broth.

2.2.2.3 Conflict, Competition or Cooperation

Kapp (2012) defined that games involve conflict, competition and cooperation. Conflict is a challenge offered by a significant opponent, but this conflict can also be the system of the game, as the elements of the game try to prevent the characters from progressing and achieving their goals.

Competition, on the other hand, is where opponents are prevented from impeding themselves, instead devoting their full attention to improving their own performance. In this case, the meaning of the play is to achieve the best possible achievement against your opponent.

Cooperation is the act of working with others to achieve a common result. This is the social figure of the games that many players like. An important point is that good games are able to use a little of the three definitions to try to involve and promote the gamer a greater immersion in the context of the game.

2.2.2.4 Time

Time is an element that has many functions within the design of the game. The most obvious is to use time to motivate the activity and action of the game. Time can also be a resource that needs to be allocated during the game to perform a certain task or to achieve an objective (KAPP, 2012). Time is also importante if used with other gamification elements, like rewards. For example, a game can show the rewards of a player in realtime, and not only in the end of a phase, stage or in the end of the game.

2.2.2.5 Rewards

Games are systems of meaning. It is within its artificial limits that rewards and punishments are interpreted as positive or negative and gain strength to shape the player's behavior (SALEN, TEKINBAŞ, ZIMMERMAN, 2004). In the process of creating rewards and punishments, game designers shape the actions that players must take in the future. There are two views on rewards and badges: one is to make them as easy as possible to obtain at the beginning of the game, so that players are addicted and want to continue playing. The other school of thought is to avoid easy badges that are not related to activities that are rewarding in themselves (KAPP, 2012).

Reward structures have a role to play as an integral part of games and not the focus of a gamification effort. While it is fun to get a high score on a video game, it is just as fun to inform others that you are the one who received the highest score and the image is at the top of the leaderboard. In gamification, there must be a greater deepening of these reward systems and they will work with them because basically rewards serve to stimulate intrinsic and extrinsic motivation (FARDO, 2013).

Intrinsic motivation describes activities performed by themselves that satisfy the basic psychological needs for autonomy, competence and relationship, giving rise to the experience of will, will and pleasure.

The extrinsic motivated activity is performed for a result separable from the activity itself, such as rewards or punishments, which prevent the autonomy to satisfy and give rise to experiences of unwillingness, tension and cohesion explains (JOHNSON et al, 2016). Badges, points and rewards are not all bad is that they are not the only element of gamification. Reward structures have a role to play as an integral part of games and not the focus of gamification. The leaderboard is a list of the best scores in the game, for those who play the game can see all the names or initials and scores of the players. It was a simple invention, but it created a powerful motivator to play the game repeatedly and gave players the chance to interact socially in discussions around the game and higher scores (KAPP, 2012).

Example of intrinsic reward: Knowing how to play a certain song masterfully, how to lose weight (weight loss program), or be able to decipher a certain puzzle (BRAZIL; BARUQUE, 2015). An example of extrinsic motivation: Recognition badges, points, cash bonuses, discount coupons, merchandise, equipment or virtual or even real items (BRAZIL; BARUQUE, 2015).

2.2.2.6 Feedback

Feedback in learning or playing is designed to evoke a correct message about behavior, thoughts or actions. The feedback bulletin is designed to indicate the degree of *"right*" or "*wrong*" of an answer, action or activity. Feedback immediately informs

the student whether he did the right thing, wrong or somewhere in the game, but does not tell the student how to correct the action. Through this element, the player can instantly see the result of his actions, which makes it a powerful way to keep the player focused, adapt his strategies in order to overcome his mistakes and keep the direction towards the goals (FARDO, 2013).

Learning presumably inherently unpleasant makes it palatable by adding presumably gradable gameplay, inserting learning tasks into an entertainment game or spicing up "learning tasks with game feedback (DETERDING, 2015).

1.2.1.1 Levels

The games have different types of levels. One is the level or mission structure, by which players progress from one level to the next as they progress towards the end of the game. The other level concept is the degree of difficulty the player chooses when he or she enters the game for the first time. The third level is the level of experience and skills that the player receives while playing the game (KAPP, 2012). In most games the levels indicate progress, but it is clear that gamified experience designers will not use traditional levels with those found in video games, the levels serve as markers for players to know where they are in the game (ZICHERMANN; CUNNINGHAM, 2011). So within these different types of levels we have.

- **Player levels**: As the player progresses through the game, he or she gains more and more experience so that players who stay true to the games reach higher levels in the games (KAPP, 2012);

- **Difficulty levels**: Games are generally designed to offer options regarding the level of difficulty of the challenges proposed to their players, starting at an easier level and as the game progresses, the level of difficulty will increase (FARDO, 2013);

- **Game Levels**: The game levels are the subdivisions in chapter, stages, phases where it is understood that the player has overcome a series of minor challenges and that he has fulfilled a path (FARDO, 2013);

- Character levels**:** In some types of games, the avatar does not remain unchanged from start to finish as the player progresses, your character also acquires experience. This mechanism allows the character to become stronger, acquire new skills and powers, earn more resistance (FARDO, 2013).

2.2.2.8 Narrative

The combination of a good story with the media resources of games influences the player's involvement through the interactivity they provide. Not all games are based on a narrative plot, but in gamification this element can be quite useful. The "story" element provides relevance and meaning to the experience. It provides context for the application of tasks (KAPP, 2012). The narrative has three important aspects: the narrative itself (the story being told), the interface (how the aspects inherent to the game are articulated, that is, how the game works as a game) and the technological dimension (which concerns the technical execution of the game, of what is possible to do with the technology available to it) (BRANCO; PINHEIRO, 2006).

2.2.2.9 Esthetics

Esthetics refers to the player's experience in the game (FABITO; CABREDO, 2019). The esthetics related to game design, is directly linked to its interface, games that can be considered highly beautiful on the one hand can prove to be quite complicated and difficult to understand by the user.

The space in which the game is played becomes boring without esthetics. Appropriate aligned visuals, attention to detail, simple contrasts or colorful backgrounds create an immersive environment that contributes to the overall game experience. Esthetics help players to get involved in the game experience. Art, a careful mix of descriptions and attention to design elements become attractive (KAPP, 2012).

Esthetics appears in games as an element of paramount importance, as fundamental as its own design and development. It will be aesthetics to adapt the

properties of the game's context so that the visual and conceptual expressions of the game are congruent (ROCHA *et al*, 2006).

2.2.2.10 Fun

Fun is a daily linguistic label for the experience of having fun mainly due to the need for satisfaction (DETERDING, 2015). Games are directly related to fun, and if it weren't, they might not be as popular (FARDO, 2013). Thus, the fun that games provide comes from learning to overcome a challenge, mastering a new task, understanding a new puzzle.

In education we have many examples of the use of gamification. Game technologies are a component of pedagogy. The question of using gamification in the learning process is not new in theory and pedagogical practice. the role of game technologies in the learning process and the combination of the elements of the game and the educational process depends a lot on the teacher understanding the functions of educational games (ZAMYATINA *et al*., 2015).

Zamyatina *et al*., (2015) developed a game within the framework of the "Mathematics Modeling Discipline" for students of National Research Polytechnic University of Tomsk (TPU), with a specialization in "Applied Computer Science", "Corporate Information Systems". The main objective of teaching "Mathematics The discipline Modeling" is developing the ability of students to process analytical data with greater possibility of systematization in the form of mathematical models. The skills acquired by students when studying this subject can be used to perform a number of professional tasks. Classes with the use of game technologies reached the following results:

- Facilitates the emotional perception experienced;
- Develops creativity;
- Promotes students' confidence in their own skills;
- I teach students to work in teams;
- It shapes the motivation for independent work;
- It forces improvisation and creativity;

- Promotes students' independent activity;

- Teaches students to develop their point of view;

- Promotes psychological comfort in the classroom.

Current trends in online education to engage students using gamification strategies to reduce school dropout and increase student motivation in a playful way can be one way to engage. However, learning and understanding STEM concepts (science, technology, engineering and mathematics) is a challenging task and requires that educators not only teach solutions to problems (PIRKER *et al*., 2015). By pairing instructional content with a game cycle, user judgments, behavior and feedback can be used to engage users and achieve instructional goals (PIRKER *et al*., 2015).

Working with online and mobile labs facilitates a wide range of different interactions with learning concepts, which is a perfect starting point for integrating gamification strategies and models. Gamification strategies can be integrated directly into online or mobile experiments, which require user input integrations and feedback possibilities, or built as structures around the experiment (PIRKER *et al*., 2015).

3. SYSTEMATIC MAPPING RESEARCH

In this systematic review we seek to investigate the use of gamification as a learning tool through scientific articles that work with gamification. Another point that the work intends to identify are models and works already carried out by other researchers in the area to serve as a basis for the studied product, as well as to identify which techniques are most used for this.

Systematic review is an important resource in evidence-based practice, which consists of a form of synthesis of research results related to a specific problem (GALVÃO *et al*., 2004). It is a method used to answer a specific question about a specific problem. In other words, a rigorous synthesis of all research related to a specific question / question about the cause, diagnosis and prognosis of a problem in

a certain area of knowledge, but it often involves the effectiveness of an intervention to solve this problem (ERCOLE *et al*., 2014).

To carry out this work, the methodology developed by (PETERSEN *et al*., 2008) was chosen. The essential steps of the systematic mapping study process are the definition of a research question, conducting the search for relevant articles, article screening, abstract keywords and extraction and mapping data. Our methodology is divided into a set of steps defined as (PETERSEN *et al*., 2008):

- **Research Question Definition**: The main objective of a systematic mapping study is to provide an overview of a research area and to identify the quantity and type of research and the results available;

- **Conduct research for primary studies**: Primary studies are identified using research strings in scientific databases or manually browsing through conference proceedings or publications of relevant journals;

- **Filtering of Papers using Inclusion and Exclusion Criteria**: The inclusion and exclusion criteria are used to exclude studies that are not relevant to answer the research question;

- **Keyword Summary**: Keyword is a way to reduce the time needed to develop the classification scheme to ensure that the scheme takes into account existing studies;

- **Data Extraction and Study Mapping**: When the classification scheme is in effect, the relevant articles are classified in the scheme, that is, the actual data extraction occurs.

It was defined as the main research question of this work: *"How to use a game in the mathematics teaching process?"* And as a secondary question, we tried to identify if *"Is there a guide for the application of the game in the teaching of mathematics?"*. From the research questions, a research argument was defined. This argument as the main words related to the research question. The search argument used (1) for the search on several search engines was:

gamification AND (learning OR education) AND (math*) (1)

Using the search argument, a search was performed on four search engines: Springer Link[1], ACM Digital Library[2], Science Direct[3] and IEEE Xplore[4]. Only works directly related to the research question were considered for the recovery process. In addition, the following inclusion and exclusion criteria were defined:

- Complete articles with four or more pages;
- Papers written in English or Portuguese;
- Articles published in the last five years;
- Scientific articles published in events or journals related to education, mathematics or information technology;
- Verification of the title and abstract.

This search has the objective of verifying a consistent amount of data that lead to trace parameters and techniques capable of answering the research question, verifying the theories used and how gamification is being implemented in the learning process in mathematics. In the first data search using only the search string without applying the inclusion and exclusion criteria, we had a total of 231 articles selected, as shown in Table 1.

Table 1 – Selected articles in the first search

Search String / Search Engine	**IEEE Xplore**	**Science Direct**	**Springer Link**	**ACM Digital Library**
gamification AND (learning ou education) and (math*)	46	90	71	24

[1] Springer Link: https://link.springer.com

[2] ACM DL: https://dl.acm.org

[3] Science Direct: https://www.sciencedirect.com

[4] IEEE Xplore: https://ieeexplore.ieee.org/Xplore/home.jsp

After, we made the second search, using all exclusion criteria and an analysis of the title and the abstract, seeking to verify the direct relationship between the research question and the articles included, presented in Table 2. After the application of all exclusion and inclusion criteria, 45 articles were selected with relevance for research.

Table 2 – Selected articles after analyzing the title and summary

Search String / Search Engine	**IEEE Xplore**	**Science Direct**	**Springer Link**	**ACM Digital Library**	**Search String / Search Engine**
gamification AND (learning ou education) and (math*)	25	11	1	8	gamification AND (learning ou education) and (math*)

In this paper, we sought to highlight the possibility of gamification in providing mathematics students a better learning performance. In this way, to present a broad view of studies on gamification in the area of education in the discipline of mathematics, evaluating which are the main elements of games used, which studies already exist and the existence of instructional objects capable of easily developing the application of these elements. The analysis of the selected works is presented in the next Section.

4. ANALYSIS

An analysis was done to identify studies already existing in the area of gamification in mathematics education, which elements of games are most used to gamify in these areas and if there is any instructional object for this teaching of mathematics in the subject of Calculus. Thus, this study was divided into two stages, named: (i) Main characteristics of the analysed works and (ii) Analysis on gamification techniques.

4.1 Main characteristics of the analysed works

The first analysis was made in relation to the main characteristis of the works. The analysed criteria are: (i) year of publication, (ii) country of the authors, (iii) audience that made the evaluation of the proposal and (iv) educational contexto where the evaluation was made. The results of this analysis is presented in Table 3.

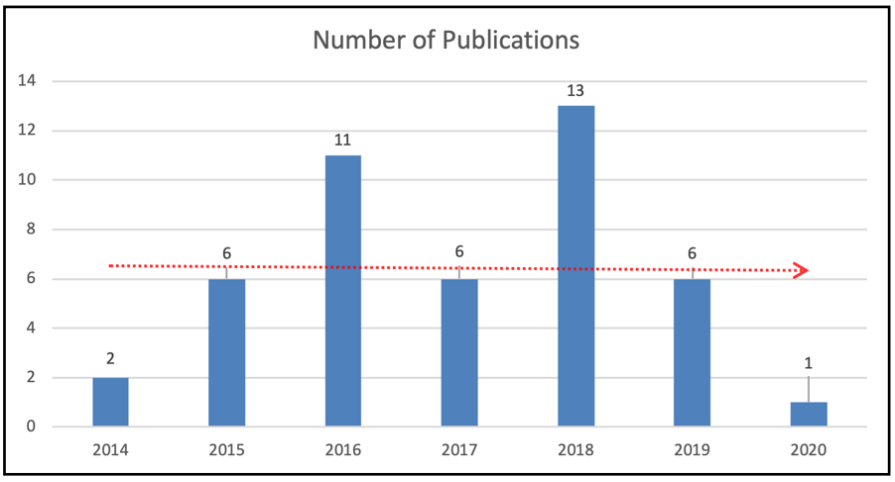
Table 3 – Analysis of main characteristics of related work

Work	Year of Publication	Country	Audience that made the Evaluation	Education Levei
(ALBERTAZZI *et al*., 2019)	2019	Brazil	-	-
(KUSUMA *et al*., 2018)	2018	lndonesia	-	-
(TODA *et al*., 2019)	2019	Brazil	Teachers	Higher Education
(HAKAK *et al*., 2019)	2019	Malasya	--	
(ALBUQUERQUE *et al*., 2017)	2017	Brazil	Students	Higher Education
(JAGUŠT *et al*., 2018)	2018	South Korea	Students	Middle School
(QIAN; CLARK, 2016)	2016	USA	Students	Middle School/ Higher Education
(TOPTRCEANU, 2017)	2017	Romanian	Students	Higher Education
(ÇAKIROGLU *et al*., 2017)	2017	Turkey	Students	Higher Education
(HÔLLIG *et al*., 2020)	2020	Germany	Students	Higher Education
(ZAINUDDIN *et al*., 2018)	2018	Hong Kong	Students	Middle School
(FEATHERSTONE *et al*., 2019)	2019	UK	Students	Higher Education
(WONG *et al*., 2016)	2016	Malasya	Students	Higher Education
(HAMMERSCHALL *et al*., 2019)	2019	Germany	Students	Higher Education
(SU *et al*., 2016)	2016	Taiwan	Students	Middle School
(MOZGALEVA *et al*., 2018)	2018	Spain	Students	Higher Education
(BULLÓN *et al*., 2018)	2018	Spain	Students	Higher Education

(BROWN *et al*., 2016)	2016	USA	Students	Middle School
(ROBLEDO-RELLA *et al*., 2017)	2017	Mexico	Students	Higher Education
(KAMIMURA *et al*., 2018)	2018	Japan	Teachers	Middle School
(PIRKER *et al*., 2015)	2015	Austria	Students	Higher Education
(CUNHA *et al*., 2018)	2018	Brazil	Students	Middle School
(TODA et lal., 2015)	2015	Brazil	Teachers/ Students	Middle School
(ZAMYATINA *et al*., 2015)	2015	Russia	Students	Higher Education
(CLERKIN *et al*.,2016)	2016	USA	Students	Higher Education
(JAGUŠT *et al*., 2017)	2017	Croatia	Students	Middle School
(IFIGENIA *et al*., 2018)	2018	France	Students	Middle School
(PRIMO *et al*., 2016)	2016	Brazil	Students	Middle School
(TODA *et al*., 2014)	2014	Brazil	Students	Middle School
(MAKRIS *et al*., 2018)	2018	Germany	-	-
(SANMUGAM *et al*., 2016)	2016	Malasya	Students	Middle School
(SUH *et al*., 2015)	2015	Hong Kong	--	
(SANMUGAM *et al*., 2016a)	2016	Malasya	Students	Middle School
(DE SOUZA SOMBRIO *et al*.;2016)	2016	Brazil	Students	Middle School
(LAMERAS *et al*., 2015)	2015	Greek	Students	Higher Education
(BROWN *et al*., 2018)	2018	USA	Students	Higher Education
(ORWIN *et al*., 2015)	2015	Australia	Students	Higher Education
(FLORES *et al*., 2016)	2016	Spain	Students	Higher Education
(XIAO *et al*., 2018)	2018	Japan	Students	Higher Education
(KORN *et al*., 2017)	2017	Cyprus		Students
(HALLOLUWA *et al*., 2018)	2018	Sri Lanka	Students	Middle School
(GONZALEZ; *et al*, 2014)	2014	Spain	-	-
(BALDEÓN *et al*., 2016)	2016	Spain	-	-
(BARRIOS *et al*., 2018)	2018	Japan	Students	Middle School
(ANPARASANESAN *et al*., 2019)	2019	England	--	

It can be oberved in Table 1 that a great majority of the analyzed works were applied by students, both in basic education and in higher education. This fact demonstrates that few studies in this area have proposed solutions directly aimed at teachers (and a technical application of gamification by them).

Figure 1 – Number of publications by year



As exceptions were the works developed by (TODA *et al*., 2015), (TODA *et al*., 2019) and (BALDEÓN *et al*., 2016), which focused in methods to apply gamification techniques. Figure 1 presents the number of publications by year (the Tendency line is marked in red). The analysis of the papers was made in December of 2019. The paper marked as published in 2020 is a preprint to be published in a edition in 2020.

4.2 Analysis on gamification techniques

In this stage of the research, we verified which the main gamification elements were used in the researched works. The game elements are responsible for developing a more pleasant experience for their participants and are of fundamental importance in the gamification process. For LOPES *et al*., (2015), they have important functions, such as increasing engagement, motivation in various areas of knowledge, having intrinsic and extrinsic motivators, making users have fun while learning.

We verified the following gamification elements that were present in each work: Narrative (Section 2.2.2.8), Pontuation (Section 2.2.2.5), Feedback (Section 2.2.2.6), Levels (Section 2.2.2.7), Cooperation (Section 2.2.2.3), Rewards (Section 2.2.2.5), Goals (Section 2.2.2.1), Realtime (Section 2.2.2.4) and Objective History (Section 2.2.2.6). In Table 4 we present the relation of related works and the gamification techniques, used in each work.

To clarify the infomation regarding to the use of gamification elements in the analysed works, we present in Figure 2 the frequency of the gamification elements in analysed works.

It can be observed that the Feedback and Pontuation are the most common used elements in the selected works. The application of pontuation in these works were made in many forms, the most common were the simple presentation of the points in a private mode to the users or the presentation of points to all users throught the use of a pontuation board. It can be observed that Goals and Rewards (which are commonly used in games) are adopted in a great number of works.

Cooperation and Narrative are less used in the selected works, we observed that they are common in the approaches that present long games or solutions that envolves social networks.

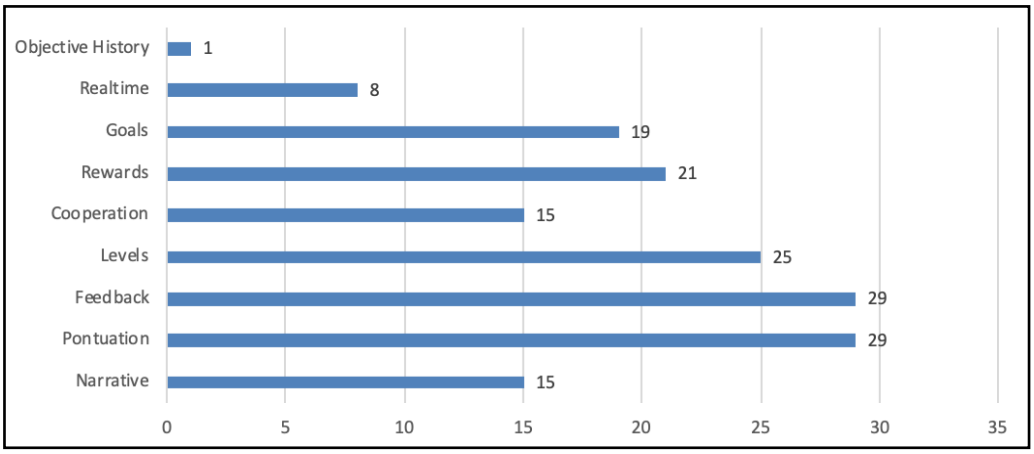
Table 4 – Analysis of gamification elements used in each related work

Work/Gamification Element	**Narrative**	**Pontuation**	**Fedeeback**	**Levels**	**Cooperation**	**Rewards**	**Goals**	**Realtime**	**Objective History**
(ALBERTAZZI *et al*., 2019)	–	✓	✓	–	–	–	–	–	–
(KUSUMA *et al*., 2018)	✓	✓	✓	✓	✓	–	✓	–	–
(TODA *et al*., 2019)	–	✓	✓	✓	–	✓	✓	–	–
(HAKAK *et al*., 2019)	–	✓	✓	✓	✓	✓	✓	✓	–
(ALBUQUERQUE *et al*., 2017)	–	✓	–	✓	–	–	–	–	–
(JAGUŠT *et al*., 2018)	✓	✓	✓	–	✓	✓	✓	✓	–
(QIAN; CLARK, 2016)	✓	–	✓	–	✓	–	✓	–	–

(TOPTRCEANU, 2017)	✓	✓	✓	✓	✓	✓	✓	✓	–
(ÇAKIROGLU *et al.*, 2017)	–	✓	–	–	–	✓	✓	–	–
(HÔLLIG *et al.*, 2020)	–	–	–	–	✓	–	✓	–	–
(ZAINUDDIN *et al.*, 2018)	–	✓	–	–	–	–	✓	–	–
(FEATHERSTONE *et al.*, 2019)	✓	✓	–	–	–	✓	✓	–	–
(WONG *et al.*, 2016)	–	✓	–	–	–	–	–	–	–
(HAMMERSCHALL *et al.*, 2019)	✓	–	✓	–	–	✓	–	–	–
(SU *et al.*, 2016)	–	–	–	–	–	–	–	–	–
(MOZGALEVA *et al.*, 2018)	✓	–	✓	✓	✓	✓	✓	–	–
(BULLÓN *et al.*, 2018)	–	✓	✓	–	–	–	✓	–	–
(BROWN *et al.*, 2016)	–	–	✓	✓	✓	✓	–	✓	–
(ROBLEDO-RELLA *et al.*, 2017)	–	–	–	–	–	–	–	–	–
(KAMIMURA *et al.*, 2018)	–	–	–	–	–	–	✓	–	–
(PIRKER *et al.*, 2015)	✓	✓	✓	✓	✓	✓	✓	–	–
(CUNHA *et al.*, 2018)	✓	–	✓	✓	✓	✓	✓	–	–
(TODA *et al.*, 2015)	–	✓	–	✓	–	–	✓	–	–
(ZAMYATINA *et al.*, 2015)	–	–	–	✓	–	–	–	–	–
(CLERKIN *et al.*,2016)	–	✓	✓	✓	–	–	–	✓	–
(JAGUŠT *et al.*, 2017)	–	✓	✓	✓	–	–	–	✓	–
(IFIGENIA *et al.*, 2018)	–	✓	✓	✓	–	–	–	–	–
(PRIMO *et al.*, 2016)	–	–	✓	✓	✓	✓	–	✓	–
(TODA *et al.*, 2014)	–	✓	–	✓	✓	X	–	–	–
(MAKRIS *et al.*, 2018)	–	✓	✓	–	–	✓	✓	–	–
(SANMUGAM *et al.*, 2016)	–	✓	–	–	–	–	✓	–	–
(SUH *et al.*, 2015)	✓	✓	✓	–	–	✓	✓	–	–
(SANMUGAM *et al.*, 2016a)	–	✓	–	–	–	✓	–	✓	–
(DE SOUZA SOMBRIO	✓	✓	✓	–	–	✓	–	–	–

et al.;2016)									
(LAMERAS *et al.*, 2015)	✓	✓	✓	✓	–	–	–	–	–
(BROWN *et al.*, 2018)	–	✓	✓	✓	–	–	–	–	–
(ORWIN *et al.*, 2015)	✓	✓	✓	–	✓	✓	–	–	–
(FLORES *et al.*, 2016)	–	–	–	–	–	–	–	–	–
(XIAO *et al.*, 2018)	–	–	✓	✓	–	–	–	–	–
(KORN *et al.*, 2017)	–	✓	✓	✓	–	✓	–	–	–
(HALLOLUWA *et al.*, 2018)	✓	✓	✓	✓	–	✓	–	–	–
(GONZALEZ; *et al*, 2014)	–	✓	✓	✓	✓	✓	–	–	✓
(BALDEÓN *et al.*, 2016)	✓	–	✓	✓	✓	✓	–	–	–
(BARRIOS *et al.*, 2018)	–	–	✓	✓	–	–	–	–	–
(ANPARASANESAN *et al.*, 2019)	–	–	–	✓	–	–	–	–	–

Figura 2 – Frequency of gamification elements in analysed works



The least used elements in the researched works were related in a certain way to time: Objective History, which describes the possibility of the player to follow the history of objectives already achieved in the game in detail and thus have a more complete notion of the path taken in the game , and Realtime, that is, the presentation of the scoring information in real time to the player, without the need to

make the player need to complete a specific objective, only then to know how many points he has achieved.

5. CONCLUSIONS

In this article, we sought to highlight the possibility of gamification to provide mathematics students with better performance in learning, and thus present a broad view of studies on gamification in the area of education in the discipline of mathematics, evaluating which are the main elements of games used, which studies already exist and the existence of instructional objects capable of easily developing the application of these elements. Gamification has gained a great deal of space due to its great capacity to improve the teaching-learning process among most students. But for that we must know the main points and the right elements to gamify in education.

For this purpose, a mapping research was carried out, which allows researchers to enter the field of study, seeking to capture the phenomenon from the perspectives contained in the most recent works in the area, contributing to the area in which it is inserted in the field of study, seeking to capture the phenomenon. from the perspectives contained in the documents. This research presents a quantitative approach - when well executed - to allow an understanding of what an area or activity or segment actually manifests and thus allow decision making on a matter of managerial relevance (DE SOUZA *et al*., 2016).

It was observed in the mapping process that the vast majority of the work developed was focused on students, with games proposals and gamification techniques applied. The exceptions were the works of (TODA *et al*., 2015), (TODA *et al*., 2019) and (BALDEÓN *et al*., 2016), which focused in methods to apply gamification with other techniques in learning process. Thus, the development of methodologies, guides and techniques with a focus on how to apply gamification in this area can be considered an open research question.

Other important observation was related to the application of gamification elements in the proposals. It was observed that the Cooperation is used in a minor amount of the selected works but is a current trend topic (it was found mainly in the most recente works), we observed that Cooperation and Narrative are common in the approaches that present long games or solutions that envolves social networks. Objective History and Realtime was the least used elements and still need to be better evaluated in the works related to this area.

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