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Brazilian and Spanish Mathematics Teachers' Predispositions towards Gamification in STEAM Education

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Abstract: This article reports a multiple case study in which we analyse Brazilian and Spanish mathematics teachers' opinions about and predispositions toward gamified activities in STEAM education. To obtain data, we administered a survey to 56 in-service mathematics teachers in primary and secondary education from these countries. The survey had been previously validated throughout an expert judgement process. Our results show a high percentage of teachers who think this kind of activity has positive effects on students' development, improving their affective domain toward mathematics and required skills for mathematical competency. Notwithstanding, many teachers report insecurity and lack of training for employing such educational methodologies.

Keywords: teacher predispositions; gamification in education; gamifying learning; STEAM education; mathematics; Brazil; Spain

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1. Introduction

Fostering students' motivation, engagement, and behavioural changes is an appealing objective that researchers argue the gamification of education could achieve [1–4]. Additionally, it seems desirable to educate people with interdisciplinary knowledge and develop skills and abilities for autonomously and critically acting, living, and working in a complex and ever-changing twenty-first-century world, which is promised by STEAM Education—an interdisciplinary approach among the areas of Science, Technology, Engineering, Arts and Humanities, and Mathematics [5]. Therefore, we could conjoin these goals by thinking of gamification as an educational strategy for pursuing and promoting STEAM Education [6], for example, in mathematics [7].

STEAM Education has recently become a trend in educational development [8] that promotes learning throughout and for the interdisciplinary enterprise [5]. We find it across all educational stages: from early childhood education until higher education [4,9]. Originally, the term STEAM derived from the acronym STEM [10]. The National Science Foundation (NSF) in the 1990s formalised the acronym STEM concerning the four areas of Science, Technology, Engineering, and Mathematics [11]. Afterward, STEAM Education emerged as a new pedagogy during the Americans for the Arts-National Policy Roundtable discussion in 2007 "to help counterbalance the increased focus on STEM subjects and the decline in arts education in the U.S." [10] (p. 32).

STEAM has cognitive and affective objectives, namely STEAM Literacy [12], and also democratic and utilitarian goals (skill development) [13]. STEAM is based on educational philosophies such as Deweyan pragmatism and the premise that learning should be constructed through (reflection about) experience [14]. The term STEAM aligns well with many methods [5] especially active and collaborative ones, e.g., the maker movement, Project Based Learning (PjBL), Problem Based Learning (PBL) [8], augmented reality [15], and gamification [6].

Gamification is a neologism derived from the digital media field [16]. The first use of this concept, in 2003, is attributed to Nick Pelling, a British game developer. [1]. Although gamification is a relatively young topic, it is an increasing research interest topic [2,3]. A bibliometric survey showed the geographic distribution of research in the gamification of education: from 100 countries, the United States of America has the largest share of publications on the subject (almost 13%), while Spain comes closely behind with almost 9%; the results placed Brazil in the fifth position in the list (4.2%) [4].

Deterding et al. [17] (p. 02) define gamification as "the use of game design elements in a non-game environment". Although there is no consensus of a specific definition and scope for gamification, according to the literature review, the definition from Deterding et al. [17] is the most widespread and accepted [1,18]. Among these game elements, we encounter reward-action contingency (RACs): leader boards, scoring, and badges [19]. Additionally, mission, narrative, character, level, aim, resources and items, and collaboration are game elements applied in learning gamification [18]. However, if we have applied game elements, how does gamification work in a non-game environment? One major difference between gamification and designing conventional games remains because we apply gamification regarding some desired outcomes from a particular context, while also providing some enjoyment. The latter has internal objectives concerning pure entertainment [18].

Mora et al. [18] found in a literature review of 40 publications generic framework designs for gamification (35%) and frameworks for specific contexts, which they categorised as business (45%), learning (15%), and health (5%). Hamari et al. [2] found empirical studies of gamification in various contexts. In this paper, we address studies of gamification in the educational context.

In education, gamification is reported as a powerful tool for teachers at all levels in the educational system [1]. Hamari et al. [2] reviewed the literature in empirical studies of gamification and observed that educational context was the most reported. All articles reviewed reported learning outcomes as mostly positive: increasing motivation, engagement, and enjoyment. Additionally, gamification encourages extracurricular and interdisciplinary learning [1]. Mora et al. [18] acknowledged a consensus that design frameworks in education explicitly reveal the importance of defining clear objectives. Gamification differs conceptually from serious games in this aspect. Serious games immerse learners into the gameplay and attempt to hide educational objectives. In gamification, educational objectives are visible [1]. According to the literature, researchers commonly report unclear objectives as the main reason for failure in gamification designs [18].

The literature suggests gamification as an active method for STEAM education. Cleophas [6], for example, reported a case study of STEAM-gamified activity employed in Brazil. She designed and applied it using many game elements, such as score, a classification table, and progress feedback. She included content knowledge of the history and fundamentals of chemistry: chemical bonds, formulas, stoichiometric balance, reactions, and ammonia synthesis. She pointed to interdisciplinarity within STEAM areas: including poetry and caricature (Arts) and chemical calculations and logic association (Mathematics). The author considered that the activity also involved technology and engineering, although she treated them as resources and not proper knowledge areas. Technology was referred to as the use of technological tools, mobile applications and social media, and engineering simply as applying manipulative material for constructing molecules. Cleophas [6] argued that the STEAM gamified approach permitted graduating challenges, promoting spaces for feedback, motivating and engaging students, and fostering collaboration among them.

Mendes et al. [20] reviewed gamification applied to teaching deaf students and related to learning sign language. They note that this usage was reported in few countries, e.g., Brazil, Egypt, and Romania. According to them, gamification is in its commencement as an inclusive strategy, but it has already been shown as an avenue for creating communication systems between deaf people and deaf people and listeners through sign language.

In mathematics education, as an area that is part of STEAM education, gamification is present from the first educational levels [21,22] and throughout all the stages, especially in secondary education [23]. Computer science, social sciences, engineering, and mathematics are, in this order, the most reported areas in the gamification of education [4]. However, gamification in mathematics is sometimes misconceived, and the term gamification is improperly used in the description's framework and/or the analysis of games. Muñoz et al. [24] points to four key characteristics that should be met in a gamified activity in mathematics: (1) it proposes a problem to be individually or collaboratively solved to achieve rewarded objectives; (2) it creates challenges between users; (3) it accounts for scores, so that students receive gifts or prizes; and (4) it creates levels and rankings so that students can receive feedback, compete, and compare their results. These indicators maintain strong links with an approach to teaching mathematics through mathematical processes of problem-solving, reasoning and proof, communication, connections, and representation, more linked to thinking and doing than to memorising concepts and reproducing procedures [25].

Based on a review of gamified activities in mathematics, we find several digital games where students have to perform tests to achieve a goal using technological devices, e.g., mobile phones [26–28]. Jagušt et al. [1] (p. 451), for example, reported an empirical study about a gamified lesson using tablets in lower primary mathematics classes in competitive, adaptive, and collaborative conditions. Compared to the control group, non-gamified activity, "three other gamified conditions showed positive trends in terms of several solved tasks as time passed, with the adaptive condition being the most prominent, followed by competitive and collaborative conditions". Notwithstanding, the adaptive condition was statistically significant as causing the greatest amount of stress among students and led to the greatest number of incorrect task competition attempts. The authors also re-examined error role in education, arguing that gamification may provide a welcoming ambience for incorrect answers in the initial phases, and this strategy can be effective for learning.

Despite the excitement around gamification, there is some controversy. Mora et al. [18] observed that some frameworks consider using technology as a prerequisite for gamification, while some researchers support that "[g]amification can also be done completely offline by adding motivational narratives as a prequel to an activity or by awarding paper badges or medals for certain educational achievements" [1] (p. 456). In this sense, gamification could be associated with object-based learning (OBL) [29], wherein manipulative materials play a pedagogical role. Most frameworks of gamification address fun as a relevant aspect to be considered during the design process of gamification. Issues such as risk, feasibility, and investment are often disregarded [18]. It is worth remarking that Dubbels [19] argues that gamification is reported as easy or expensive to construct, compared to game design.

Hamari et al. [2] pointed out that some studies showed that the results of gamification may not be long term, but caused by a novelty effect. A decrease in students' motivation and satisfaction over time has been reported, comparing gamified with non-gamified courses [1]. Muñoz et al. [24] warned that repetition of this type of activity ends up causing boredom in students, whom we intend to motivate a priori. Disengaged students are powerfully motivated when facing something new, but as soon as they have to apply the knowledge they still do not have, and if they do not promptly learn with these activities, these students end up disconnecting quickly. Others reported possible negative outcomes that need to be paid attention to, such as increasing competition, task evaluation difficulties, and design features. It seems that gamification alone may not sustain the effects on students' interest, motivation, and satisfaction levels [1].

Studies and experiences with escape rooms have also proliferated [30–32], which again present the same problem: it creates great expectations when used for the first time, but since we cannot repeat it, once its features become known, it loses the initial potential for motivation. This type of activity also has the disadvantage of requiring much work to be prepared, and then it is hard to be adapted to other students or other contents. This does not happen when using games in mathematics class, as it has been implemented for decades.

The existing literature addresses true gamification in learning mathematics, while some experiences misconceive gamification in mathematics by referring to it when concerning game usage in education. Additionally, the previously commented upon inconsistencies and controversies found around the subject should be considered. Altogether, this also leads to a requirement for investigation into teachers' opinions, since they are indeed agents with a relevant role in teaching. Studies have analysed teachers' beliefs about gamification, and they have found that teachers have positive opinions about it [33–35]. For example, students develop learning, skills, and the affective domain [33,34] in a gamified teacher training course [35]. Notwithstanding, there are practically no studies in Spain and Brazil that have analysed the effect of implementing gamification as a tool to promote mathematics learning and instruction. Concerning gamification, Alabbasi [34] concluded that teachers have a positive perception of incorporating it into online learning. They consider, for example, that gamification improves students' motivation towards course goals, elevates students' satisfaction, and promotes the urge to go beyond the requirements of the course. It increases attention and the curiosity to navigate multiple elements in the learning management system [34].

STEAM Education research also lacks an understanding of teachers' beliefs [36–38]. Kim and Bolger [36] remark that despite Korean teachers considering that STEAM educational programs can have a positive impact on elementary education, many are reluctant to take part in STEAM education. Teachers' negative perception of STEAM education is mainly justified by their belief in insufficient training and experience [36]. Teachers may have different perceptions of interdisciplinary approaches, e.g., secondary teachers who exhibit a more negative view of the potential impact of STEM education on student achievement when compared to primary teachers [38]. Among the concerns, teachers report an increase in their workload, difficulty in coordinating with teachers from other knowledge areas [38], and a lack of support from peers and school administration [37].

Considering the background described and these gaps in the literature, this study aims to analyse the predisposition of mathematics teachers in primary and secondary education to carry out gamification activities in STEAM education.

2. Materials and Methods

This is a multiple case study [39], employed as descriptive research with a mixed design: a quantitative and a qualitative part, which are interrelated in the way that one complements the other.

2.1. Participants

Participants of the study are 56 mathematics teachers, 24 being in-service in Brazil and 32 in Spain. They work with students whose average age ranges from 10 to 16 years old. Table 1 summarises sample distribution by gender and education level for both countries.

Table 1. Research sample of Spanish and Brazilian teachers was distributed per gender and education level.

Gender/Education Level [1]	Spain		Brazil	
	Primary School (10–12 Years)	Secondary School (12–16 Years)	Primary School (10–14 Years)	Secondary School (14–16 Years)
Woman	8	13	7	8
Man	4	7	2	7
Total	12	20	9	15

[1] Original education level names of primary school and secondary school in Spain, Educación Primaria and Educación Secundaria, and in Brazil, Ensino Fundamental and Ensino Médio, respectively.

Teachers working in primary school and secondary school have an average age around 50 years old and 40 years old, respectively, for both countries, Brazil and Spain. Concerning their degrees, in Spain, the primary school teachers had graduated with the specific formation of Primary Educator Teacher, except for one female teacher who had graduated in Pedagogy. Spanish Secondary School teachers' titles vary more: Mathematics (6), Engineering (5), Economics or Business Management (4), Architecture (3), Pedagogy (1), and Chemistry (1). In Brazil, Primary School teachers had graduated in Mathematics (4), Pedagogy (3), History (1), and Geography (1), and the teachers' trainings in Secondary School were in Mathematics (11), Chemistry (1), Law (1), Biology (1), and Engineering (1).

2.2. Data Collection

To collect data, we used a survey named "Gamification and Learning" (original name in Spanish "Gamificación y Aprendizaje"), proposed and validated by Cornellà [40]. According to Cornellà [40], the survey was validated though an expert judgment process, which included 17 experts. These people were distributed as experts in games and gamification (3), teachers with experience in applying gamification (7), experts in virtual learning environments (4), and experts in technology (3). The experts evaluated the adequacy between each block title and its questions, questions' relevance, and Likert scale adequacy. Cornellà [40] did corrections until the experts finally approved the survey.

We used Cornellà's [40] survey with few adaptations regarding our research objectives. For instance, we addressed gamification in mathematics in a general scope rather than focusing on virtual learning environments, as was originally the case. In addition, we included some questions related to STEAM Education.

It is noteworthy to say that the whole survey and its attachments were available in the language for each population sample: Catalan language for Spain (Catalonia Autonomy Community) and Portuguese language for Brazil. We divided the survey into three blocks.

Block A) These questions were designed to gather information about sample characteristics—age, courses, education level in which they work, and degree. Open-ended questions about prior experiences with gamification and STEAM Education were also included, so we could explore it qualitatively [41].

Block B) Two questions were included: the first is a Likert-type question scaled from 1 (not important) to 5 (very important), with a list of 18 general aspects regarding teaching the discipline of mathematics (e.g., content knowledge, ability to connect with students, method used in class, and others). In the second Likert question, teachers answered their (dis)agreement, ranging from 1 (strongly disagree) to 5 (strongly agree), to 21 statements about gamification in mathematics and interdisciplinary STEAM environment. Additionally, they evaluated a gamified activity framed in STEAM Education based on the activity Snap Hotels of Nguyen [42].

Block C) Four open-ended questions were included that were intended to explore other aspects that would permit identifying and evaluating teachers' predisposition and difficulties they consider they might encounter while employing activities in the interdisciplinary STEAM environment and/or gamified activities: (1) Teachers' beliefs about learning outcome differences between employing gamified and non-gamified activities. (2) Difficulties teachers believe they may encounter while engaging in a gamified activity. (3) Predisposition about using gamification in the next course. (4) How teachers envision the possibility of gamification in an interdisciplinary approach with STEAM areas.

2.3. Data Analysis

We analysed the Likert-type (close-ended) survey questions with descriptive statistics using frequency percentages for each item of scale. We used the R Studio Statistics program and its Likert library. This program exports data in the format of a horizontal bar graph, which permits observing respondents' positive and negative evaluation tendencies, but also neutral answer frequency, which makes it possible to perform group comparisons and address the occurrence of socially derisible responses (SDR) [43].

Analysis of the qualitative part of the study was based on constant comparisons according to grounded theory [41]. The following levels of analysis were considered. First, one author of this manuscript began by reading teachers' responses to become familiar with the content. Then, based on our research goal, we organised and structured information. At this first level, individual transcripts were arranged based on unit fragmentation or segmentation. While reading answers, teachers' dispositions to using gamification mathematics in education were noticed. For example: "*It motivates me a lot to think about implementing gamification in my class. I think it will arouse students' interest and passion*" (ProfEsp30). Raw data were transformed into useful data by first classifying and coding them.

Second, we established a group of categories. For example, in the first category, views of teachers were collected on how they use gamification in mathematics education. In this sense, the codification and categorisation of data were triangulated by comparing, ordering, and structuring to establish categories that allowed data to be compared.

Additionally, third, categories were renamed by the authors of the research, using the method of constant comparisons [41], which includes comparisons made between similarities, differences, and connections of the data. Units of information were scrutinised to see whether they clearly fell into a specific category. We further reflected on whether categories could be simplified and then grouped. We also considered the names and content of changed units, showing new relationships and possible new interpretations between categories. Thus, all aspects that prevented the definition of teachers' predispositions towards the use of gamification in mathematics education were renamed, eliminated, or simplified.

Again, it is worth noting that qualitative data were obtained in Catalan and Portuguese languages. Afterwards, these data were analysed by researchers who are native speakers of each one of these languages, so participants' original intentions could be better interpreted and captured in the analyses.

3. Results

The results follow the same order from the data collection instrument. According to the aim of our study, we analysed mathematics teachers' predispositions to carrying out gamification activities within STEAM education in primary and secondary school levels. First, we present results about the teachers' prior experiences in engaging in gamified activities and STEAM Education (Block A). Second, we present the results of closed-ended questions (Likert scale) in the form of two graphs: one about teachers' evaluations of the importance of general aspects related to classes of mathematics, and another graph about gamification in mathematics and an interdisciplinary STEAM environment. Additionally, they evaluated a gamified activity framed in STEAM Education based on the activity Snap Hotels of Nguyen [42] (Block B). Third and last, we wrote the results from analyses of four open-ended questions about gamification and STEAM Education (Block C). We present these results in the form of four tables (one referring to each question) structured with the names of corresponding categories in the first column; examples of teachers' response excerpts to qualify them in the second column; and columns with the quantification of the frequency that those categories appear in responses from Spain and Brazil.

3.1. Teachers' Prior Experiences with Gamified Activities and STEAM Education (Block A)

In this section, we present results about teachers' prior experiences with gamification in the current academic year. We present Table 2, which quantifies the proportion of teachers from Spain and Brazil who indicate having (or not having) conducted gamified activities in classes of mathematics in the current academic year (2020–2021 academic year or 2021 academic year in the Spanish or Brazilian calendar, respectively). In Spain, almost half of the total of teachers (46.9%) indicated they applied gamification in this academic year, with a higher frequency in the primary school (58.3%) compared to secondary school level (40%). In Brazil, on the other hand, the proportion of the country's total teachers who used gamification as a method in their classes in this academic year is a little more than a third (37.5%), with a much lower frequency in primary School (22.3%), which was less than half compared to the secondary school level (46.7%).

Table 2. Teachers who have previously carried out gamified activities in mathematics.

Have Carried out a Gamified Activity	Spain			Brazil		
	Primary School (10–12 Years)	Secondary School (12–16 Years)	Total	Primary School (10–14 Years)	Secondary School (14–16 Years)	Total
Yes	58.3% (7)	40% (8)	46.9% (15)	22.3% (2)	46.7% (7)	62.5% (15)
No	41.7% (5)	60% (12)	53.1% (17)	77.8% (7)	53.3% (8)	37.5% (9)
Total	12	20	32	9	15	24

A subsequent open-ended question asked for further explanation about the nature of the gamified activity from those teachers who positively answered to having applied one. In Spain, teachers reported that they applied gamification activities related to different resources and contexts: for example, a games table (2), online games (3), contests (2), and escape rooms (3). In Brazil, teachers mainly show that they employed table games (2) or online games (2). It should also be noted that around 16% of Spanish (5) and Brazilian (4) teachers considered gamification as manipulated didactic material, e.g. tangrams or multilink.

The proportion of teachers who indicated that they have worked with gamified activities in an interdisciplinary STEAM Education is much lower, as shown in Table 3: only 10 Spanish (31.2%) and 3 Brazilian (12.5%) teachers. Again, a subsequent open-ended question asked teachers to explain the nature of the gamified activities they applied within STEAM Education. In Spain, five teachers pointed to the STEAM areas they combined, while the other half did not specify. In Brazil, one teacher showed integrating mathematics and chemistry, while the others did not give more information. In addition, many have described STEAM without characteristics of gamification: for example, in the statement "*we photographed different objects in the school, then we analysed them and define each format and volume encountered*" (ProfSpain28).

Table 3. Teachers who have previously carried out gamified activities in mathematics framed in STEAM Education.

Have Carried out a Gamified Activity in STEAM Education	Spain			Brazil		
	Primary School (10–12 Years)	Secondary School (12–16 Years)	Total	Primary School (10–14 Years)	Secondary School (14–16 Years)	Total
Yes	33.3% (4)	30% (6)	31.3% (10)	11.1% (1)	13.3% (2)	12.5% (3)
No	66.7% (8)	70% (14)	68.8% (22)	88.9% (8)	86.7% (13)	87.5% (21)
Total	12	20	32	9	15	24

3.2. Teachers' Opinions about General Aspects of Math Class regarding Gamification and STEAM Education and Evaluating an Example of a STEAM Gamified Activity (Block B)

We present results from this subtopic in the form of graphs plotted in the R Studio Statistics program for Brazil and Spain combined. Following this, we address additional considerations about differences between the countries.

Figure 1 refers to a graph with Brazilian and Spanish teachers' evaluations of the importance of general aspects related to classes of mathematics. Before observing the graph content, it is worth explaining that each line in the graph is vertically organised. Additionally, each line contains a bar which may be dislocated from the central position according to how participants evaluated that corresponding element (Likert Scale 1 to 5): a high frequency of "Slightly important" and "Not Important" (1 and 2) make this line appear on the bottom of the graph, dislocating its bar to the left, and a high frequency of positive answers "Important" and "Very important" (4 and 5) makes this line appear on top of the graph and tends to dislocate its bar to the right, and this frequency percentage is shown on this side. The percentages of positive (4 and 5), neutral (3), and negative (1 and 2) answers are shown on the vertical axes in the left, middle, and right positions of the graph.

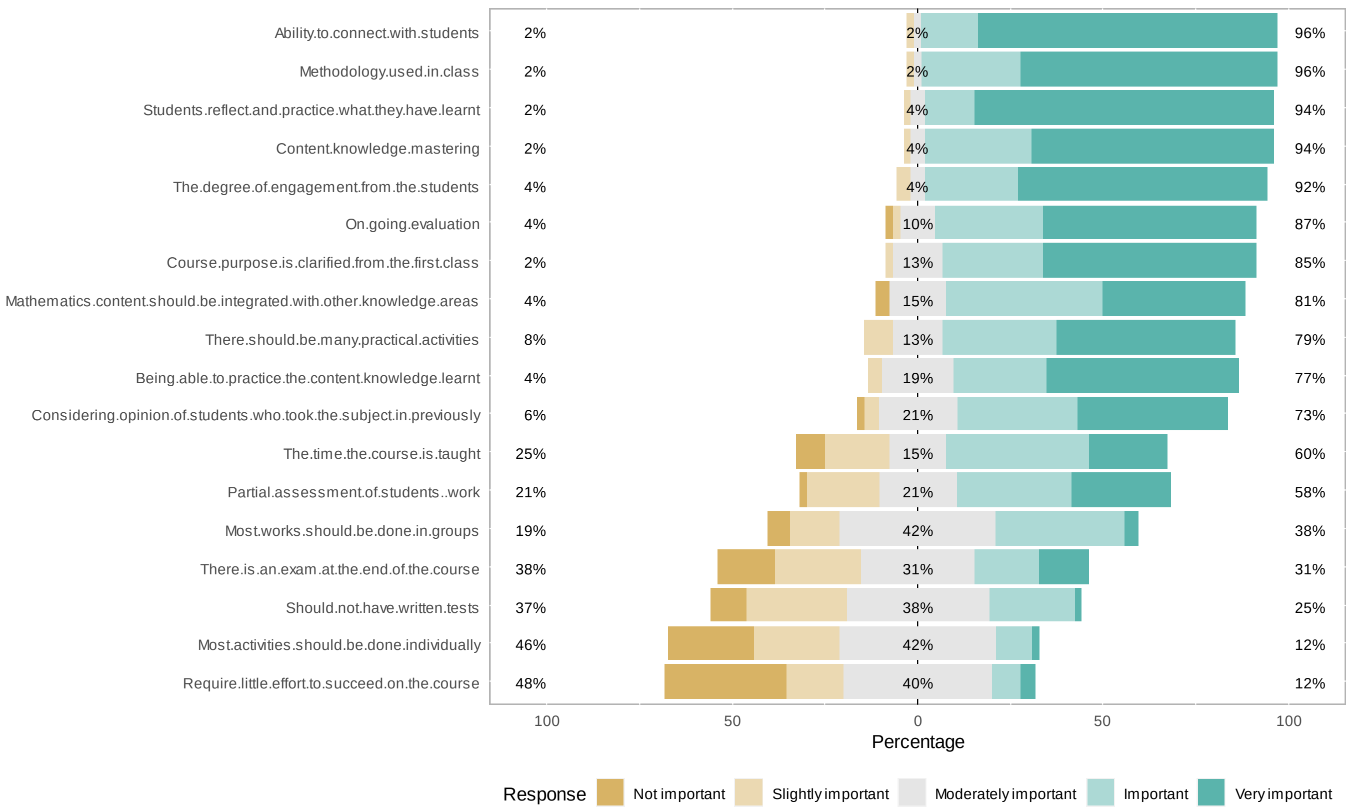

Figure 1. Brazilian and Spanish teachers' evaluation in the importance of general aspects related to classes of mathematics.

Finally, we address the content of the graph from Figure 1. First, we highlight aspects that teachers predominantly considered "Important" or "Very important": Ability to connect with students (96%), Methodology used in class (96%), Students reflect and practice what they have learnt (94%), Content knowledge mastering (94%), Students' engagement (92%), On-going evaluation (87%), Course purpose is clarified from the first class (85%), Mathematics content should be integrated with other knowledge areas (81%), There should be many practical activities (79%), Being able to practice the content knowledge learnt (77%), Considering the opinion of students who took the subject previously (73%), The time the course is taught (60%), and Partial assessment of students' work (58%).

The neutral answer "Moderately important" had a higher frequency percentage in the aspect Most works should be done in groups (42%), while it still presented a tendency towards a positive evaluation of importance (48%) compared to the negative pole (19%). In addition, the neutral answer had a slightly superior frequency in the aspect "Should not have written tests" (38%), but with a tendency towards a negative evaluation of importance (37%).

Teachers predominantly considered the following aspects "Not important" to "Slightly important": Requires little effort to succeed on the course (48%), Most activities should be done individually (46%), and There is an exam at the end of the course (38%).

Now, we draw attention to all items with a high frequency of the neutral answer "Moderately important". It had a frequency higher than 30% in the aspects Most works should be done in groups (42%), Most activities should be done individually (42%), Require little effort to succeed on the course (40%), Should not have written tests (38%), and There is an exam at the end of the course (31%).

In Figure 2, we present a graph with 21 statements about gamification in mathematics and the interdisciplinary STEAM environment. Additionally, a gamified activity framed in STEAM Education based on the activity Snap Hotels of [42] is evaluated. The graph construction and its structure are similar to Figure 1, with the difference that Likert scale refers to (dis)agreement to statements from each line, ranging from "Strongly disagree" (1) to "Strongly agree" (5).

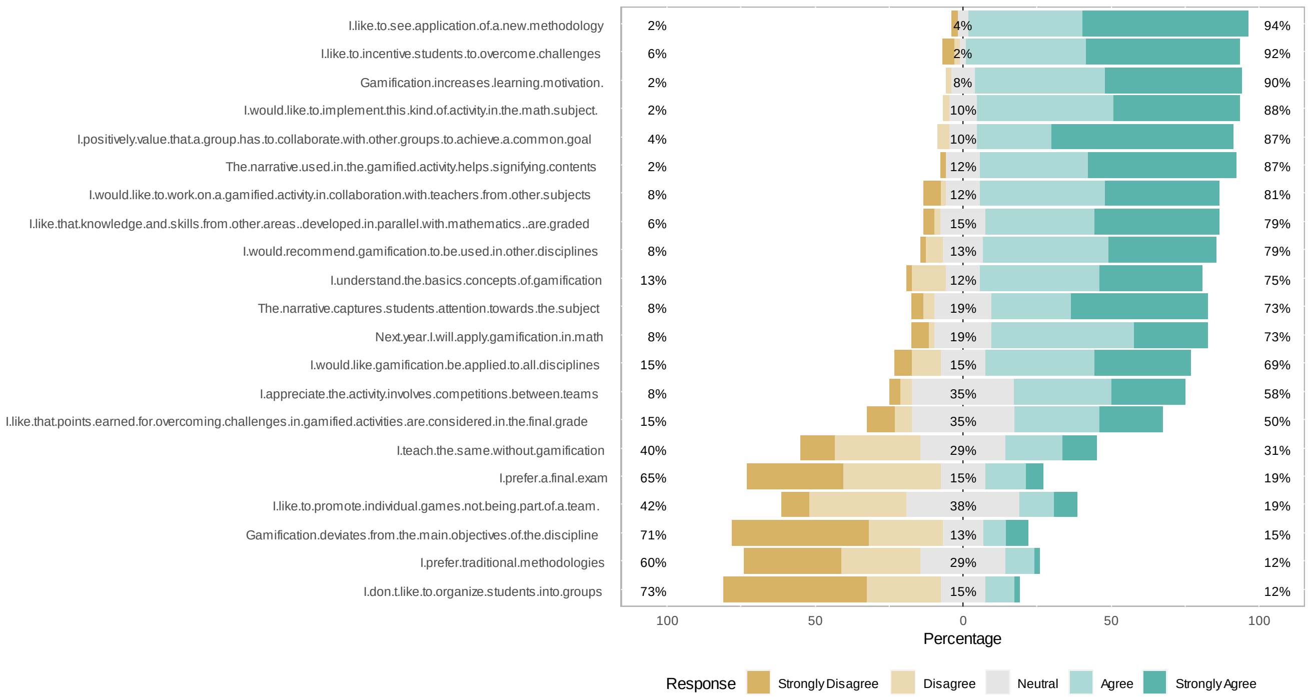

Figure 2. Teachers' opinions about gamification in mathematics and STEAM Education. Additionally, evaluation of a gamified activity framed in STEAM Education based on the activity Snap Hotels of Nguyen [42].

Teachers predominantly answered "Agree" or "Strongly agree" (4 and 5) to the statements: I like to see application of a new methodology (94%), I like to incentivize students to overcome challenges (92%); Gamification increases learning motivation (90%); I would like to implement this kind of activity in math subjects (88%); I positively value that a group has to collaborate with other groups to achieve a common goal (87%); The narrative used in the gamified activity helps signifying contents (87%); I would like to work on a gamified activity in collaboration with teachers from other subjects (81%); I like that knowledge and skills from other areas, developed in parallel with mathematics, are graded (79%); I would recommend gamification to be used in other disciplines (79%); I understand the basic concepts of gamification (75%); The narrative captures students' attention towards the subject (73%); Next year I will apply gamification in math (73%); and I would like gamification to be applied to all disciplines (69%). However, the following two statements still conserve a frequency tendency on the agreement pole: I appreciate the activity involves competitions between teams (58%) and I like that points earned for overcoming challenges in gamified activities are considered in the final grade (50%); it is worth noting the high frequency of the neutral answers, both of which were 35%.

From the bottom of the graph, we observe the statements to which teachers more frequently answered "Disagree" and "Strongly Disagree" (1 and 2). These statements include I do not like to organise students into groups (75%); Gamification deviates from the major objectives of the discipline (71%); I prefer a final exam (65%); I prefer traditional methodologies (60%); I like to promote individual games (not being part of a team) (42%); and I teach the same without gamification (40%).

Highlighting a high frequency of neutral answers, as reported above, the statements from the agreement pole I appreciate the activity involves competitions between teams and I like that points earned for overcoming challenges in gamified activities are considered in the final grade both had a 35% frequency of neutral answers. Some statements from the disagreement pole also had a high frequency of neutral answers: I like to promote individual games (not being part of a team) (38%); I prefer traditional methodologies (29%); and I teach the same without gamification (29%). No statement presented a frequency of neutral answers higher than the options of agreement or disagreement.

3.3. Teachers' Opinions about the Contrast between Gamified and Non-Gamified Activities, Issues in Gamification, and Gamification in STEAM Education (Block C)

Finally, yet importantly, we describe the results of the analyses of answers of four open-ended questions from Block C. We present these results in the form of four tables (one per question): the first column includes categories; the second column examples of teachers' response excerpts; and finally, columns with the frequency of responses from Spain and Brazil. These questions, presented below, intended to explore and identify what mathematics teachers' think about the differences between gamified and non-gamified activities, the difficulties of gamification in mathematics, their predisposition toward employing gamification, and how they envision the possibility of gamification in an interdisciplinary approach with STEAM areas.

1. Which differences do you think may exist between learning outcomes and learning processes when we compare a gamified and a non-gamified activity?

The analysis of answers to this question resulted in three principal categories of teachers' beliefs about the differences between gamified and non-gamified activities, as seen in Table 4. In the category Positive difference, around 81.1% of Spanish and 76.9% of Brazilian teachers considered differences by pointing to the advantages of gamification. On the other hand, and with a much lower frequency, in the category Negative difference, around 8.11% of Spanish and 3.85% of Brazilian teachers also considered the existence of differences, but in this case, pointing to the disadvantages of gamification. Additionally, third, in the category Not different, a few teachers considered no differences between gamified and non-gamified activities, 2.7% in Spain and no teacher from Brazil. The percentage of non-respondents in Brazil is more than double that of Spain: 19.2% and 8.11%, respectively.

Table 4. Teachers' beliefs about learning outcome differences between employing gamified and non-gamified activities.

Gamified versus Non-Gamified Activity		Teachers' Answers Excerpts	Frequency per Country	
			Spain	Brazil
Positive view towards gamification	Affective domain	"I believe student's interest makes them more open to rules, content and listening to teacher and colleague" (ProfBra20).	32.4%	34.2%
	Cognitive domain	"The difference remains in a manner to approach to content: students who learn with gamification have better memorisation and good memories about how they have learnt" (ProfEsp05).	10.8%	11.4%
	Skills acquisition	"Gamified activity enables logical reasoning skills development, contextualisation and interdisciplinarity" (ProfBra19).	27%	26.2%
	Did not specify	-	10.8%	3.85%
No differences		"They [gamified and non-gamified activities] are just methodologies, which can address content (vehicle). I do not think using one would be better than the other" (ProfEsp07).	2.7%	-
Negative view towards gamification		"Gamifying means providing time to students to build knowledge autonomously, make questions, analyse alternatives. Theoretically that is great, but it creates difficulties" (ProfEsp16).	8.11%	3.85%
Did not answer		-	8.11%	19.2%

Within the category Positive differences, we could induce subcategories regarding differences related to Affective domain, Cognitive domain, Skills acquisition, and Not Specified. The frequencies of these subcategories are similar between Spain and Brazil, aspects of Affective domain and Skills acquisition being present in approximately 30% of responses, and around 10% from the subcategory Cognitive domain.

2. Which difficulties do you believe one may face while engaging in a gamified activity in mathematics?

The results of the analysis of responses to this question resulted in the creation of four categories of issues, as displayed in Table 5, that teachers indicate are related to employing gamified activities in mathematics: Planning difficulties, Class management difficulties, Deficient teacher training, and Educational community reticence.

Table 5. Difficulties teachers believe they may encounter while engaging in a gamified activity.

Beliefs about the Difficulty in Gamified Activity in Mathematics	Teachers' Answer Excerpts	Frequency per Country	
		Spain	Brazil
Planning difficulties	"The required time complete it in class. If the class duration is of one hour, often there is no time to finish the activity. Many centres have limited resources" (ProfEsp05).	34.3%	34.6%
Class management difficulties	"Some students may dislike it, or get too anxious/nervous; others might be so competitive that they have to be redirected" (ProfEsp06).	25.7%	11.5%
Deficient teacher training	"Little teachers' experience while designing gamified activities and managing tools that would facilitate this task" (ProfEsp11).	20%	19.2%
Educational community reticence	"Breaking with traditional approaches: the biggest difficulty is being open to novelty since it means a greater expenditure of energy, many teachers will think like that" (ProfBra11).	-	15.4%
Did not answer	-	20%	19.2%

As a result, we detected some discrepancies between Brazil and Spain. Although the similarity in the frequency of respondents who pointed to issues within planning difficulties was approximately 34%, when we scrutinise the responses, we noticed differences. With Brazil, half of these responses suggested a lack of resources/investment as an issue when employing gamification in mathematics, e.g., in the excerpt: "*Since I work in a public school, we deal with limited resources. Frequently I spend my money to apply games or other methodologies*" (ProfBra20). Spanish teachers centred their attention on difficulties with the design and evaluation of gamified activities.

In the second category, Class management difficulties, the content of answers is similar for the countries, but it is more prominent with Spain, where the frequency is more than double that of Brazil: 25.7% and 11.5%, respectively.

We highlight another difference between the studied countries in the category Educational community reticence. A significant proportion of Brazilian teachers, 15.4%, show they are likely to face some reticence among peers or the scholar board when employing non-traditional educational methodologies such as gamification. Meanwhile, no Spanish respondent demonstrated this kind of difficulty.

Similarly, with around 20% of response frequency, Brazilian and Spanish teachers show Deficient teacher training as a difficulty in pursuing gamification in their classes. Approximately 20% of Brazilian and Spanish teachers did not answer this question.

3. How do you evaluate the possibility of using gamification as a teaching method in classes of mathematics? What are your feelings about it?

We could classify the answers from these questions into the categories Favourable predisposition and Unfavourable predisposition regarding teachers' intentions to attain gamification in their disciplines. Inside the category Favourable predisposition, we could distinguish three subcategories, as shown in Table 6, that qualify this predisposition: without indicating reticence, with reticence about deficient teacher training, and with reticence about lack of resources.

Table 6. Teachers' predisposition about using gamification in the next course.

Predisposition		Teachers' Answer Excerpts	Frequency per Country Spain	Brazil
Favourable	Not indicating major concerns	"It motivates me a lot to think about implementing gamification in my class. I think it will arouse students' interest and passion" (ProfEsp30).	43.8%	54.2%
	but showing insecurity or concerns about lack of formation	"I want it, but it generates in me some sense of losing control. Perhaps, gradually, it can be achieved" (ProfEsp23). "I would love it, but I am conscious I should receive training previously" (ProfEsp19).	34.4%	8.33%
	but showing concerns about lack of resources	"Again we face the difficulty of time and investments" (ProfBra22).	-	4.17%
Unfavourable		Little possibility regarding the pandemic scenario (ProfBra03).	-	8.33%
Did not answer		-	21.9%	25%

Most teachers, approximately 70% for both countries, who replied to this question show a favourable predisposition to employing gamification in their classes. Some of them, on the other hand, question this predisposition. For instance, 34.4% of Spanish teachers suggest that teacher training would be necessary, while in Brazil, only 8.33% pointed in this direction. Again, lack of resources/investment appears to be an issue that differentiates the countries, since only Brazilian teachers, 4.17%, showed a favourable predisposition but reticence considering this reason. Only Brazilians answered with an unfavourable predisposition, with an 8.33% frequency of responses in this country, e.g., justified by the pandemic scenario of COVID-19: "*I see little possibility, given the current pandemic scenario*" (ProfBra03).

4. How do you evaluate, in a gamified activity, the possibility of providing an interdisciplinary environment with some (or all) STEAM areas?

We categorised the results of this question into Possible and Not possible, referring to providing STEAM interdisciplinary environments through gamification. Most teachers in Brazil, 81.8%, envision this possibility, while in Spain, the percentage is 50%, as shown in Table 7.

Table 7. Teachers' beliefs about providing STEAM interdisciplinary environments throughout gamification as a teaching method.

Gamification as a Method for STEAM Education	Teachers' Answers Excerpts	Frequency per Country Spain	Brazil
Possible	"It is a good idea to evaluate when next academic year begins" (ProfEsp32).	50.0%	81.8%
Not possible	"Little possibility, since there is a curriculum to be accomplished" (ProfBra03).	28.1%	9.09%
Did not answer	-	21.9%	9.09%

Those who replied no possibility presented justifications for being sceptical about this association of gamification and STEAM Education, such as deficient teacher training—"*Currently, I see it impossible. It would be necessary to train all teachers before working collaboratively and in a multidisciplinary approach*" (ProfEsp05) —being difficult to assess—"*It is complex to know what to be evaluated and where it focuses on each discipline*" (ProfEsp07) —

difficulty in coordinating different disciplines, especially in the secondary school level—"*It requires much coordination and sometimes it is hard to gather*" (ProfEsp22) —or lack of adequate time—"*Feasible, but I imagine that organising it requires time that we don't have*" (ProfEsp15). In Spain, we also observed teachers from primary school, who regularly already have the same professional teaching subjects from different knowledge areas, evaluate this possibility more positively. Half of the teachers from secondary school did not see it as possible because, among the difficulties mentioned before, they found it hard to coordinate along with teachers in other STEAM areas.

4. Discussion

In this article, we analysed teachers' opinions and predispositions about gamified activities and the STEAM education approach. According to the literature review, mathematics is one of the STEAM areas that has been least considered so far in gamification (4). Studies of gamification in mathematics have mainly focused on the effect of this method on students' learning outcomes [21–24,28], reporting data, to some extent divergent, related to students' engagement, motivation, or satisfaction [1,2,24].

However, what is the role of mathematics teachers' predispositions and opinions towards gamification? What effects can those teachers' predispositions and opinions have on students' levels of engagement, motivation, and satisfaction? As previously shown, few studies in the literature address teachers' opinions and predispositions about the use of gamification in mathematics classes [33–35], and even fewer in the Spanish and Brazilian panorama.

Data from our study help to fill this literature gap. The first revealing result is that only half of the Spanish teachers and two-thirds of the Brazilian teachers who took part in our study have used gamification in mathematics. Important differences between the two countries emerge when we observe gamification. With Spain, teachers employed a wider variety of resources; comparing students' ages, while in Spain, they apply gamification more in the primary school compared to secondary school level, in the Brazilian context, it happens the other way around.

The results confirm increasing academic attention towards both gamification and competency-based education [33]. Currently, it appears slightly more palpable in Spain than in Brazil. The number of Spanish and Brazilian teachers who have worked with gamification within the STEAM Education approach is much lower, also observing some confusion around the concepts of both gamification [24,25] and STEAM.

Regarding teachers' opinions about using gamification, mathematics teachers at primary and secondary schools in both countries have highlighted that they consider mastery of content as essential in gamified activities, as well as other elements such as reflective and critical thinking skills [33] or engagement [34]. One aspect mathematics teachers least valued was that activities should be done individually in gamification. These data reinforce the findings of Martí-Parreño et al. [33] and Allabasi [34], which suggest that teachers believe gamification encourages team working and oral communication skills, along with social interaction.

Our findings address how mathematics teachers perceive differences and difficulties while using gamified activities within the STEAM Education approach, compared to more traditional ones. The results show, at first sight, a high percentage of teachers (around 80%) who think this kind of activity has positive effects on students' development, improving their affective domain toward mathematics and required skills for mathematical competency. Based on teacher opinions, we can complement the results from previous studies about students' affective domain, which suggests gamification alone may not sustain students' interest and motivation in satisfaction levels [1]. In this sense, we can add that gamification could be carried out in STEAM Education. In order for those features of the affective domain to be more highly attained, this approach to gamified activities needs to be authentic to provide an interdisciplinary environment.

Since teachers believe gamification in a STEAM approach promotes skills development for mathematical competency, we found the congruency that both teachers and policy makers should be encouraged to increase the use of gamification-based programs to develop students' competencies [33]. Concerning the main difficulties, we observed similarities and differences between the two studied populations: teachers from both countries misunderstand the concepts of gamification and STEAM, and they indicate insecurity and a lack of training in planning gamified activities, which points to the necessity for specific teacher training programs [35,36].

In the Brazilian case, half of the teachers refer to the lack of resources as the reason for not carrying out gamification in their classes, but we recall from the literature that gamification can be done with low investment in resources [19]. Since these teachers reported almost no prior experiences with gamification, and those few who reported included examples of activities that are not considered gamification, such as the use of manipulative objects, this leads to the interpretation that this complaint about lack of resources might be a clue about a misunderstanding of the concept of gamification.

Still focusing on the Brazilian context, teachers showed concerns about reluctance/resistance from teaching staff or school management when they want to carry out activities with methodologies such as gamification. Therefore, this seems to show that experts should design teacher training within models that consider the transformation of teachers' beliefs, such as with the realistic-reflective training model [44], to address this resistance.

Finally, in our study, we have also investigated teachers' predispositions to carrying out gamification activities in interdisciplinary environments with STEAM disciplines. The results from a closed-ended question show that around 80% of Brazilian and Spanish teachers agreed with the statements "*I would like to work on a gamified activity in collaboration with teachers from other subjects*" and "*I like that knowledge and skills from other areas, developed in parallel with mathematics, are graded*". Notwithstanding, further exploration in an open-ended question showed that this same favourable disposition of 80% only remained for Brazil. In Spain, there are differences between primary teachers, who are generalists and teach all STEAM subjects, and secondary teachers, who are specialists and only teach mathematics. In primary school, teachers see it as possible, but in secondary, more than half of the teachers do not see it as possible because they find it difficult to coordinate with teachers from other STEAM areas. This result confirms the findings of Part et al. [38].

The literature about Likert scales warns that people are likely to choose neutral options for reasons other than being neutral about the topic—for example, when respondents have no interest, or when they want to provide a socially desirable response (SDR): to respond according to what they imagine others expect them to answer or to avoid options that they think peers or any reference group would frown upon [43]. Neutrality in the agreement was around 40% with questions that address students' distribution: "Most works should be done in groups" or "Most activities should be done individually". Neutrality was around one-third of the responses when we scrutinised the evaluation and the statements "Should not have written tests", "There is an exam at the end of the course", and "Points from the gamified activity to be considered in the final grade". All this points to the possibility that teachers may give an SDR of a favourable disposition towards new methodologies such as gamification when they are not sure if they agree with it. Another statement directs us to this conclusion: almost one-third of teachers responded neutrally to "I prefer traditional methodologies".

We highlight that in open-ended responses, only 43.8% of Spanish and 54.2% of Brazilian teachers stated a favourable predisposition towards gamification without reticence. Reticence, whatever its form, might underpin indisposition. Another consideration could be due to the fact that 21.9% of Spanish and 25% of Brazilian teachers did not answer, while the question straightforwardly asked them to evaluate the possibility of using gamification as a teaching method in classes of mathematics. Not answering it may also point to some indisposition.

Our results show that it seems necessary to add a fifth characteristic that should be fulfilled, so that mathematics education could be promoted through the gamification method, to those already indicated by Muñoz et al. [24]: interdisciplinarity. Since teachers present a conceptual misunderstanding of gamification and STEAM Education, they report insecurity and lack of training for engaging in such educational methodologies [33–37]. They also may have an underpinning reluctance to designing and carrying out gamified activities within interdisciplinary approaches [36]. Along with this observation of ambiguous speech in which they are theoretically favourably considering new methodologies, they also show traits of indisposition when they think about actually applying them. In conclusion, there is an urgency for designing teacher-training programs framed within models that intend to transform professional competency by reflecting on teachers' prior experiences and beliefs about gamification and STEAM Education. Therefore, we recommend researchers to explore teacher-training programs in gamification and STEAM Education within a realistic-reflective framework, considering the possibility of distance learning modalities, especially for big countries such as Brazil [45]. The results qualitatively show interesting insights into teacher perceptions on gamification and STEAM Education in the countries of Brazil and Spain. Notwithstanding, the research has a limitation: the sample is small, and therefore the comparative results between the two populations cannot be generalised. Further studies with larger samples are necessary.

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