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Research Article

Gamification in entrepreneurship education: A systematic literature review and future research agenda

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Abstract

Objective: This study aims to understand how researchers have approached gamification in entrepreneurship education and based on this analysis, propose directions for future research through the systematization of Theories, Contexts, Characteristics, and Methodologies (TCCM Framework). **Methodology:** The Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) protocol was used for the systematic review in eight research databases (Web of Science, Science Direct, Scopus, Springer, Emerald, Wiley, Sage, and Taylor & Francis). 33 empirical studies published between 2017 and 2022 were included. **Main results:** Most of the research did not explore a variety of existing theories, such as the Theory of Planned Behavior. Additionally, the works focus on higher education, with a gap in the context of primary and secondary education. It is suggested that samples be gender-balanced, mixed-method analyses, experimental and longitudinal studies. **Contributions:** The study contributes to literature by compiling the main approaches adopted in gamified entrepreneurship education. Additionally, it proposes a research agenda based on gaps in literature. **Relevance and originality:** This research adopts a joint approach of the PRISMA and TCCM protocols, advancing beyond the mere description of results, with the intent of grounding a proactive research agenda for the entrepreneurship academic community. **Managerial and social contributions:** The identification of best practices for the application of gamification in entrepreneurship education - game design and selection of learning objectives - provides insights for educators, policymakers, entrepreneurship support institutions, and corporate programs.

Keywords: Gamification. Entrepreneurship Education. Business Simulations. Systematic Literature Review. TCCM Framework.

Gamificação no ensino de empreendedorismo: Uma revisão sistemática da literatura e agenda de pesquisa futura

Resumo

Objetivo: Este estudo busca compreender como pesquisadores têm abordado a gamificação no ensino de empreendedorismo e, a partir dessa análise, propor direções para pesquisas futuras por meio da sistematização de Teorias, Contextos, Características e Metodologias (*Framework* TCCM). **Metodologia:** O protocolo *Preferred Reporting Items for Systematic Review and Meta-analyses* (PRISMA) foi utilizado para a revisão sistemática em oito bases de pesquisa (*Web of Science, Science Direct, Scopus, Springer, Emerald, Wiley, Sage e Taylor & Francis*). Foram incluídos 33 estudos empíricos, publicados entre 2017 e 2022. **Principais Resultados:** A maioria das pesquisas não explorou uma variedade de teorias existentes, como a Teoria do Comportamento Planejado. Ademais, os trabalhos se concentram no ensino superior, havendo uma lacuna no contexto do ensino fundamental e médio. Sugere-se que as amostras sejam balanceadas por gênero, análises com métodos mistos, estudos experimentais e longitudinais. **Contribuições:** O estudo contribui com a literatura ao compilar as principais abordagens adotadas na educação empreendedora gamificada. Ademais, propõe uma agenda de pesquisa a partir das lacunas na literatura. **Relevância e originalidade:** a pesquisa adota uma abordagem conjunta dos protocolos PRISMA e TCCM, avançando além da mera descrição de resultados, com o intento de fundamentar uma agenda de pesquisa propositiva para a comunidade acadêmica de empreendedorismo. **Contribuições gerenciais e sociais:** a identificação de melhores práticas para a aplicação da gamificação no ensino de empreendedorismo - o *design* de jogos e a seleção de objetivos de aprendizagem - fornece *insights* para os educadores, formuladores de políticas públicas, instituições de fomento ao empreendedorismo e programas corporativos.

Palavras-chave: Gamificação. Educação Empreendedora. Simulações de Negócios. Revisão Sistemática da Literatura. TCCM.

INTRODUCTION

An important premise in entrepreneurship literature is that although many skills are intrinsic to human beings, they can be awakened, trained and taught through Entrepreneurship Education (EE) (Grivokostopoulou et al., 2019; Hyams-Ssekasi & Taheri, 2022; Pérez-Macías et al., 2022). Thus, given the relevance of entrepreneurial activity for socio-economic development, the search for new pedagogical approaches to teaching entrepreneurship has sparked the interest of researchers, becoming an agenda in academic debates and on political and research agendas (Isabelle, 2020; Kauppinen & Choudhary, 2021; Memar et al., 2021; Zulfiqar et al., 2019, 2021).

From this perspective, the recent use of gamification in entrepreneurship education seems to be emerging as a potential tool for bringing theory and practice closer together (Aries et al., 2020; Grivokostopoulou et al., 2019; Pérez-Macías et al., 2022). In the educational field, the phenomenon of gamification consists of using the dynamics and mechanics of games in the teaching and learning process (Isabelle, 2020). The challenges involved direct students towards solving business problems and narratives that provide insights into business contexts. In addition, feedback, success and/or failure in the dynamics are essential parts of learning and encourage reflection (Fox et al., 2018; Hyams-Ssekasi & Taheri, 2022; Pérez-Macías et al., 2022).

Some recent studies have applied gamification to entrepreneurship education at primary (De Lourdes et al., 2017), secondary (Pratikto et al., 2021) and higher education levels (Aries et al., 2020; Isabelle, 2020; Catalán & Martínez, 2018; Pérez-Macías et al., 2022; Zulfiqar et al., 2019), demonstrating that this methodology has improved engagement, motivation (Fox et al., 2018; Takemoto & Oe, 2021) and performance, making students more confident to enter entrepreneurial activity (Zulfiqar et al., 2021). Furthermore, gamification in entrepreneurship education can increase Entrepreneurial Intention (EI) (Lara-Bocanegra et al., 2022; Ruiz-Alba et al., 2019; Zulfiqar et al., 2019), as well as entrepreneurial attitude and self-efficacy (Chen et al., 2022; Yen & Lin, 2022), since games help students to appropriate strategies to cope with the difficulties of entrepreneurship (Pérez-Pérez et al., 2021).

In summary, literature presents results that prove the importance of gamification in eentrepreneurship education and provides reasons for further study (Pérez-Macías et al., 2022; Pérez-Pérez et al., 2021). However, several questions about the state of the art need to be clarified. According to Pérez-Pérez et al. (2021), to broaden academic discussions about gamification in entrepreneurship education, it is necessary to know the main empirical approaches and how they can be adapted in different contexts. Moreover, Khodaei et al. (2022), Li et al. (2022), Pérez-Macías et al. (2022) and Thanasi-Boçe (2020) also highlight the need for structured information on this research topic. In this way, there is an urgent need to better understand where the studies were carried out; what types of gamification were used (digital or analog); the characteristics of the samples; the methods applied; the educational objectives of gamification, among other aspects.

Therefore, the problem raised by this systematic review article stems from the lack of systematized information on academic productions in this field. These arguments are supported by Khodaei et al. (2022) and Pérez-Macías et al. (2022), which strengthen the idea that this gap represents a barrier to the advancement of knowledge of the attributions of this theme. Therefore, given the need to analyze research related to gamification in entrepreneurship education, this study is based on the following research questions:

I. How has gamification in entrepreneurship education been approached and presented by researchers?
II. What are the future directions for research into gamification and entrepreneurship education?

Thus, the aim of this paper is to understand how current research has approached the topic of gamification in entrepreneurship education and to propose other directions for future researchers.

To answer these questions, in this study we followed the guidelines of the Preferred Reporting Items for Systematic Review and Meta-analyses protocol (PRISMA) (Page et al., 2021) and selected 33 empirical studies published between 2017 and 2022 in eight different research databases. In addition, in this systematic review we use the TCCM (Theory, Context, Characteristics and Methodology) framework to suggest future research, based on the Theories, Contexts, Characteristics and Methodologies identified in the selected studies. This framework, emphasized by Paul et al. (2021) and Paul and Feliciano-Cestero (2021), can help to organize the results of systematic reviews, being useful in presenting the state of the art and identifying gaps, which makes it possible to define a precise research agenda and overcome the merely descriptive nature of traditional systematic reviews and bibliometric analyses (Sharma et al., 2020).

To date, no systematic review has been identified that examines empirical studies with concrete applications of gamification for teaching entrepreneurship and that explores the TCCM framework to propose a future research agenda. Thus, this research provides a useful set of references for researchers, educators and those interested in the subject to explore scientific evidence in this field of study. For educators, we reinforce how gamified activities add value to the experience of teaching and learning entrepreneurship. This may encourage researchers to learn about approaches identified in previous studies in order to improve the standard of future studies.

This systematic review presents the existing theoretical knowledge, corroborating the hypothesis that gamification is applicable to entrepreneurship teaching to improve the learning process and encourage interest in entrepreneurial activity, as evidenced in the literature. By compiling, analyzing and summarizing the various approaches present in the research identified, this study contributes to the advancement of knowledge, since it carries out a critical and impartial evaluation of the results available on the subject and also identifies research gaps.

METHODOLOGY

We used the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol, which provides a 27-item checklist with recommendations on how to conduct a systematic review, especially with regard to the aspects of eligibility criteria, selection and analysis, as well as a flow chart model for graphically representing the search results (Page et al., 2021). IIn addition, we analyzed the documents included in this review according to the main Theories, Characteristics, Contexts and Methodologies (TCCM). This type of analysis helps to identify gaps in studies, allowing the development of theoretical models and directions for building a research agenda (Paul et al., 2021; Paul & Feliciano-Cestero, 2021; Sharma et al., 2020).

Eligibility Criteria

We used certain eligibility criteria as filters to select the articles. In summary, the documents included in this review met the following requirements:

a. written in English, Spanish or Portuguese;
b. published in journals between 2017 and 2022;
c. applied gamification to teaching entrepreneurship; and
d. is an empirical study. Consequently, theoretical/conceptual articles, review articles, conference abstracts, books and book chapters, editorial articles and the like were excluded.

For the purposes of this study, we considered the concept of gamification used by Isabelle (2020) and Ruiz-Alba et al. (2019), who discuss this phenomenon, clarifying that it is not only represented by digital games, but by any educational activity that uses the dynamics of games, such as points and levels, rewards, challenges, feedback, leaderboards, among others.

Search and Selection Strategy

The PRISMA protocol points out that if some articles are known to the authors and have already been thoroughly read before the search begins, they can be included in the review beforehand, as long as this action is recorded in the flow diagram (Page et al., 2021). We therefore previously included four studies in this review. We carried out the initial search and export of the remaining articles on August 15, 2022 in eight online search engines: Web of Science, Science Direct, Scopus, Springer, Emerald, Wiley, Sage e Taylor & Francis.

To identify the records, we used the search terms "Entrepreneurial education" and "Gamification". In addition, the terms "Entrepreneurial learning" and "Entrepreneurial training" were included as synonyms for "Entrepreneurial education". In the case of the word "Gamification", the terms "Business simulation", "Game", "Game based education", "Game based learning", "Gamified" were used as synonyms.

Regarding the search fields indicated in the databases, we point out that the title, abstract and keywords were taken into account. In addition, the complete search string with the respective connectors was as follows: ("Entrepreneurial education" OR "Entrepreneurial learning" OR "Entrepreneurial training") AND ("Gamification" OR "Business simulation" OR "Game" OR "Game based education" OR "Game based learning" OR "Gamified").

We identified a total of 1,916 records, without eliminating duplicate documents and those that were not eligible according to the given criteria. The documents were exported in BibTeX format. All the other stages of the systematic review were conducted in a shared manner between the reviewers, using the Parsifal online tool, which contains fields to be filled in by the users, including everything from the details of the planning phase to data extraction and analysis, providing the necessary support to carry out the systematic review protocol.

Independent evaluations were carried out by the reviewers. The first screening of this study consisted of excluding documents that did not meet the eligibility criteria (language, year and type of document). We therefore removed 1,308 records and then removed 9 articles due to duplication between the databases. Thus, 599 articles were eligible for reading the titles and abstracts. During the reading of titles and abstracts, we also removed 551 articles because they did not fit the theme, i.e. although they addressed gamification, they were not empirical studies that applied game elements and analyzed their effects on variables associated with entrepreneurship.

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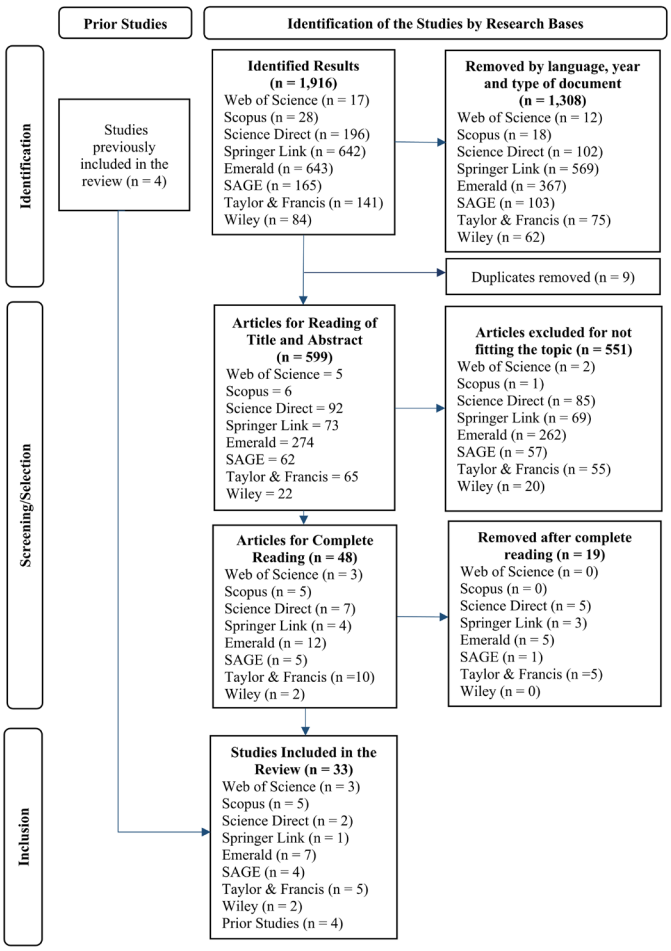
Figure 1 shows the quantitative flow diagram for each phase of the document selection process. The analysis of the results will be presented in the following section.

Figure 1

PRISMA flow diagram of the selection process



Note: Elaborated by the authors based on Page et al. (2021).

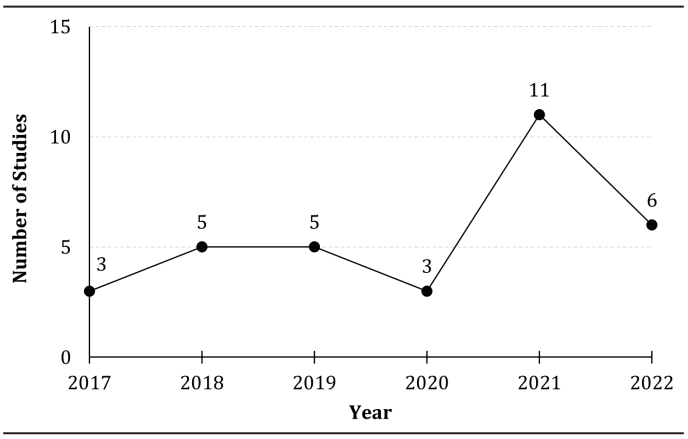
RESULTS ANALYSIS

Descriptive analysis of results

Figure 2 shows the number of publications per year between 2017 and 2022.

Figure 2

Number of publications per year



Note: Elaborated by the authors.

The publication pattern shows that from 2020 to 2021, studies were published at a faster pace, with a slight drop in 2022 (considering up to August), which indicates that this area of

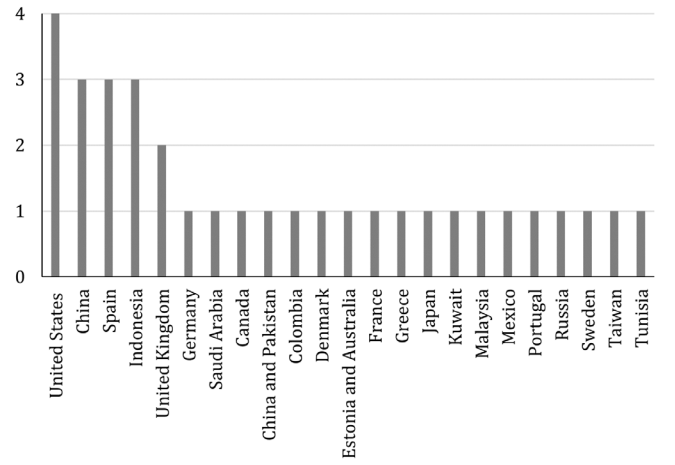
research has gained academic attention in recent years and there is still ground to be explored by researchers. We emphasize that gamification in entrepreneurship education can be applied at different educational levels and in the studies identified in this review, we observed that 67% of the research was carried out in the context of higher education at undergraduate level (22 articles); 15% in postgraduate education (5 articles); 12% in undergraduate and postgraduate education (4) and in a lower percentage (3%), there is research focusing on primary and secondary education (1 article each).

Teaching entrepreneurship through gamification has often been evaluated at undergraduate level. There are therefore opportunities for research in other contexts, especially in primary and secondary education. In the Brazilian context, it is worth highlighting the update made to the National Common Curricular Base (BNCC), which now considers entrepreneurship as one of the formative itineraries of vocational training, in accordance with the national educational curricular guidelines for vocational training (Resolution No. 3/2018, Art. 12, § 2nd). In addition, De Lourdes et al. (2017) and Pratikto et al. (2021) point to the need for research at the earliest educational levels. This is justified because it could expand the evidence on the effects of gamification on EE and demonstrate this impact on younger generations, who have not yet chosen a professional career and who, through an innovative pedagogical approach, could awaken an interest in entrepreneurship.

Figure 3 shows the countries in which the research was carried out. Although most of the studies have been carried out in the United States and Europe (Spain and the United Kingdom) and Asia (China and Indonesia), the growth of entrepreneurship education in other regions of the world (Sieger et al., 2021) suggests the need to understand this phenomenon in other contexts, since educational systems, culture and socio-economic aspects differ between nations.

Figure 3

Countries of application of the studies identified



Note: Elaborated by the authors.

Although it has received considerable attention in recent years, the literature on gamification in entrepreneurship education is still concentrated in certain regions. This can be explained by various contextual factors, such as infrastructure, access to technology, available resources and socio-economic aspects. However, due to the diversity of tools available, including free alternatives, there have been initiatives to implement gamification in educational institutions in various contexts.

In this academic discussion about the possibility of using gamification in different countries, especially in less developed regions, the study by Melo et al. (2023), carried out with data from Brazil, presents evidence that this approach is an effective strategy for stimulating the formation of students' entrepreneurial intentions. Although this study was not included in this review, as it was published after the searches for this research were carried out (August 2022), it is part of the evaluation of the use of dynamic games for EE in Brazilian secondary technical education.

To explore gamification in entrepreneurship education in Brazil, Melo et al. (2023) used a free, online game that is widely used in other countries. However, the strategy was aligned with curricula and educational objectives, considering the reality and needs of students in one of the poorest regions of the country. In addition, the instructor/teacher was trained to teach classes using the new tool. From this perspective, the following are necessary: training/qualification, adaptation of teachers so that they can properly develop and use their pedagogical resources based on game dynamics.

Therefore, Brazilian education, as in similar socio-economic and cultural contexts, has the possibility of exploring gamification in entrepreneurship education, even in regions with limited infrastructure and resources. Educators can analyze the available tools and select the most appropriate ones, whether through web-based digital games, low-tech approaches such as board games, challenges or hands-on classroom activities. These gamified strategies, when based on a solid pedagogical foundation and aligned with learning objectives, can be equally effective in motivating and engaging students, even if they do not make use of more advanced technologies such as those found in developed countries.

Table 1 shows the educational backgrounds of the sample participants. The literature points to the area of training as a moderating factor in student Entrepreneurial Intention (EI), so research that does not consider this variable may present a bias related to the field of study (Liu & Wang, 2019; Sieger et al., 2021; Zichella & Reichstein, 2022).

Table 1

Areas of training of sample participants

Area of Training	Number of articles	Author(s)
Applied Social Sciences	17	Aries et al. (2020); Capelo et al. (2021); Catalán e Martínez (2018); Chemborisova et al. (2019); Chen et al. (2022); Eggers et al. (2017); Ghani e Mohammad (2021); Isabelle (2020); Kauppinen e Choudhary (2021); Li et al. (2022); Liu e Wang (2019); Pérez-Pérez et al. (2021); Sghari e Bouaziz (2021); Solarte et al. (2021); Thanasi-Boçe (2020); Yen e Lin (2022); Zichella e Reichstein (2022).
Different fields	12	Chen et al. (2022); Fellnhofer (2018); Fox et al. (2018); Grivokostopoulou et al. (2019); ; Ruiz-Alba et al. (2019); Sudrajat et al. (2018); Takemoto e Oe (2021); Watson et al. (2017); Watson e McGowan (2018); Zulfiqar et al. (2019); Zulfiqar et al. (2021).
Engineering	1	Memar et al. (2021).
Health Sciences	1	Lara-Bocanegra et al. (2022).
No specific field	2	De Lourdes et al. (2017); Pratikto et al. (2021).

Notes: The research by De Lourdes et al. (2017) and Pratikto et al. (2021) was carried out in the context of primary and secondary education, respectively, with no specific area of training. Elaborated by the authors.

Students from different courses can benefit from gamification-based EE. In summary, with the exception of studies carried out in primary and secondary education - where there is no area of training – we carried out 54.84% of the research with students from Applied Social Sciences (Management and Business, Business Administration and specific sectors, Economics, Information

Science); 38.71% involved students from different areas, who have an entrepreneurship subject or have taken part in an entrepreneurship course/activity; 3.23% in the area of Health Sciences (physical education) and 3.23% in the area of engineering. The more expressive results for the Applied Social Sciences are relevant but reduce generalizations and suggest the opportunity for research in other areas of training. For Sieger et al. (2021), tthe field of study is crucial and business and management students exhibit more characteristics and interests linked to entrepreneurship. This argument is supported by Eggers et al. (2017), Liu and Wang (2019) and Zichella and Reichstein (2022), who highlighted the restriction to the students' course as a limitation of the sample.

Gamification is not limited to digital games and includes any task (with or without technology) that applies game elements and serves to simulate entrepreneurial practice (Chen et al., 2022; Isabelle, 2020; Ruiz-Alba et al., 2019). Table 2 summarizes the main characteristics of gamification applied in the studies, as well as its types (digital or analogue games).

Table 2

Pedagogical approaches adopted

Type	Characteristics	Number of articles	Authors
Digital	Business Simulation	21	Capelo et al. (2021); Catalán e Martínez (2018); Chen et al. (2022); Eggers et al. (2017); Fellnhofer (2018); Fox et al. (2018); Ghani e Mohammad (2021); Grivokostopoulou et al. (2019); Isabelle (2020); Kraus et al. (2021); Pratikto et al. (2021); Pérez-Pérez et al. (2021); Ruiz-Alba et al. (2019); Sghari e Bouaziz (2021); Sudrajat et al. (2018); Takemoto e Oe (2021); Thanasi-Boçe (2020); Yen e Lin (2022); Zichella e Reichstein (2022); Zulfiqar et al. (2019); Zulfiqar et al. (Zulfiqar et al., 2021).
	Quiz/games to test knowledge	2	Kauppinen e Choudhary (2021); Liu e Wang (2019).
	Product innovation game	1	Solarte et al. (2021).
Analog	Business Simulation	3	Chemborisova et al. (2019); De Lourdes et al. (2017); Memar et al. (2021).
	Entrepreneurship workshops	1	Lara-Bocanegra et al. (2022).
Analog and/or Digital	Entrepreneurship competition (creation of business plans and/or startups)	5	Aries et al. (2020); Chen, Albert e Jensen (2022); Li et al. (2022); Watson et al. (2017); Watson e McGowan (2018).

Note: Elaborated by the authors.

The literature points out that there are many ways of applying games to entrepreneurship teaching and one of the most used in the studies identified is through digital games, such as business simulations, which deal with situations in a company and allow students to solve problems and make decisions in specific business contexts, including product planning, marketing, financial, material and human resources. Additionally, researchers have also explored games to analyze creativity and product innovation skills (Solarte et al., 2021).

Traditional entrepreneurial education and gamification are not opposing methodologies (Pérez-Macías et al., 2022). With this in mind, some researchers have explored analog business simulations, demonstrating that it is possible to teach entrepreneurship in a more dynamic and playful way, with real narratives and challenges, even in the absence of a digital tool (Chemborisova et al., 2019; De Lourdes et al., 2017; Memar et al., 2021). Other studies test knowledge through question-and-answer games, which are recurrent tasks in traditional teaching, but a quiz/game can innovate these activities and generate positive results in teaching and learning (Kauppinen & Choudhary, 2021; Liu & Wang, 2019).

Various traditional EE activities can be adapted to gamification, such as the creation of business plans and startups, which can be structured in the form of a competition, with digital resources or not (Aries et al., 2020; Chen et al., 2022; Li et al., 2022; Watson et al., 2017; Watson & McGowan, 2018) and entrepreneurship workshops can also include game-based tasks (Lara-Bocanegra et al., 2022). Most of these studies suggested a positive association between gamification and entrepreneurship learning outcomes, confirming its applicability. The evidence from this research indicates that gamification in EE can be effective in three different educational objectives:

I. cognitive objectives, which are related to intellectual capacity, i.e. learning entrepreneurship content through games/simulation;
II. emotional or behavioral objectives, which portray the way in which the student experiences gamification, likes or attitudes, motivation, emotions, satisfaction; and
III. skills development, i.e. when the dynamics of the games awaken skills and competencies appropriate to the situations experienced, such as risk-taking, self-confidence, identifying opportunities, networking and others.

Table 3 summarizes these findings. The studies add variables from one or more types of educational objectives. In summary, regardless of the type of study, the literature points out that the use of gamification in EE has shown positive results in cognitive aspects such as: assimilation of concepts, assessment of business risks and decision-making (Chemborisova et al., 2019); analytical thinking (Pratikto et al., 2021); learning content through challenges and solving real issues or problems (Capelo et al., 2021; Eggers et al., 2017; Fox et al., 2018; Kauppinen & Choudhary, 2021; Kraus et al., 2021).

Table 3

Educational objectives addressed

Educational objectives addressed	Number of Articles	Authors
Cognitive	4	Capelo et al. (2021); Eggers et al. (2017); Kauppinen e Choudhary (2021); Kraus et al. (2021).
Emotional or behavioral	4	Catalán e Martínez (2018); Ghani e Mohammad (2021); Memar et al. (2021); Zichella e Reichstein (2022).
Development of skills	6	Aries et al. (2020); De Lourdes et al. (2017); Fellnhofer (2018); Li et al. (2022); Pérez-Pérez et al. (2021); Solarte et al. (2021).
Cognitive and Emotional or behavioral	1	Liu e Wang (2019).
Cognitive and skills development	3	Chen et al. (2022); Grivokostopoulou et al. (2019); Isabelle (2020).
Emotional or behavioral and Skills development	6	Lara-Bocanegra et al. (2022); Ruiz-Alba et al. (2019); Sghari e Bouaziz (2021); Yen e Lin (2022); Zulfiqar et al. (2019); Zulfiqar et al. (Zulfiqar et al., 2021).
Cognitive, Emotional or Behavioral and Skills Development	9	Chemborisova et al. (2019); Chen, Albert e Jensen (2022); Fox et al. (2018); Pratikto et al. (2021); Sudrajat et al. (2018); Takemoto e Oe (2021); Thanasi-Boçe (2020); Watson et al. (2017); Watson e McGowan (2018).

Note: Elaborated by the authors.

Considering students' emotions is important for the successful use of gamification in EE, as these feelings influence learning and acceptance (Catalán & Martínez, 2018; Ghani & Mohammad, 2021; Memar et al., 2021; Zichella & Reichstein, 2022). Regarding emotional or behavioral aspects, studies indicate that participants are more interested in learning entrepreneurship with games

(Sudrajat et al., 2018); they are more participative and feel more satisfied (Chen et al., 2022; Takemoto & Oe, 2021). On the other hand, the perception of the effectiveness of the learning decreases over time, for example, six months after a business plan competition the participants have fewer positive perceptions than before and immediately after the activity (Watson et al., 2017; Watson & McGowan, 2018). Furthermore, when they fail to achieve good results in the initial phases and/or do not feel satisfied with the game-based pedagogical approach, students experience low motivation and performance (Liu & Wang, 2019; Thanasi-Boçe, 2020).

With regard to the development of skills following the use of gamification, the following stand out: greater propensity to risk as opposed to certainty (Zichella & Reichstein, 2022); innovation (Solarte et al., 2021); self-efficacy (Chen et al., 2022; Yen & Lin, 2022; Zulfiqar et al., 2019, 2021); identification of new business opportunities (Li et al., 2022); and creation and operation of a "mini-company" through playful practices that facilitate student learning (De Lourdes et al., 2017). On the other hand, some students are afraid to take risks in gaming situations (Thanasi-Boçe, 2020). Therefore, the results of the studies are not consensual, although most of them present positive scientific evidence of gamification in EE. This will be presented in more detail in the following topic.

Gamification and Entrepreneurship Education: Approaches and Results

The PRISMA protocol recommends that individual study results be summarized. To meet this requirement, but avoid lengthy tables, the tables in this topic are divided by type of study, presenting theories, context, sample and method. Most of the studies included in this review used quantitative approaches (61%), followed by studies using mixed methods (qualitative and quantitative) (24%) and qualitative methods (15%).

Different analysis strategies were used and the methods that appeared most frequently were regression models, followed by structural equation modeling and factor analysis. Table 4 summarizes the data extracted from the quantitative studies.

Most previous studies have not verified whether the use of gamification interacts with the variables included in theories discussed in entrepreneurship literature. This gap was recently highlighted by Pérez-Macías et al. (2022) – a study that we did not include in this review, as it was published in October 2022, a period later than that of the database searches, which took place on August 15, 2022. These authors analyzed how gamification interrelates with the variables of the Theory of Planned Behavior (TPB), explaining the occurrence or not of EI.

The TPB (Ajzen, 1991) describes how a set of beliefs and considerations about a behavior influence the intentions and actions related to that behavior. This theory assumes three variables:

I. Attitude towards the behavior: refers to the individual's assessment of whether or not he/she appreciates a certain behavior;
II. Subjective norm: consists of the approval and/or social pressure perceived by the individual to perform or not perform a behavior; and
III. Perceived behavioral control: refers to the individual's perception of the ease or difficulty of performing the behavior in question, as well as being under control of its consequences.

In summary, some of the theories we used were the Technology Acceptance Model (TAM) (Zulfiqar et al., 2021), Flow Theory (Catalán & Martínez, 2018; Chen et al., 2022; Yen & Lin, 2022), TPB (Aries et al., 2020; Pérez-Pérez et al., 2021; Ruiz-Alba et al., 2019), TAM and TPB combination (Zulfiqar et al., 2019); Causation and Effectuation (Memar et al., 2021); Combination of Theory of Reasoned Action (TRA), TAM and TPB (Sghari & Bouaziz, 2021) and Shapero and Sokol's Entrepreneurial Intention Theory (1982) (Lara-Bocanegra et al., 2022).

To achieve good results in games, those involved need to combine strategic planning with adaptation to change and experimentation. This has an important relationship with the theories of Causation and Effectuation (Memar et al., 2021). According to Sarasvathy (2001), who developed these two logics, Causation assumes that it is possible to predict and control future events, having detailed planning to achieve objectives; while Effectuation is based on dealing with uncertainty and seizing opportunities with the resources available at the moment, adapting to changes and uncertainties. In addition, it is important to understand different approaches to entrepreneurship decision-making in an educational context. For example: are students adapting to the game's narrative (Effectuation)? In the initial phase of the game, are they strategically organized to define objectives (Causation)? Do they use the information (achievements, points, failures, etc.) and resources available to them to achieve these objectives (Effectuation)? Entrepreneurship requires skills linked to both logics (Sarasvathy, 2001), which is why studying them can result in insights for educators to improve their methodologies with gamification.

with game dynamics students tend to change between two behaviors: efforts and strategies to achieve the specific goal (Causation) and decisions are made according to the circumstances (Effectuation). Thus, these entrepreneurial logics can be studied with gamification resources in classes since it is necessary to face different situations when dealing with the simulation of a stable or unstable market. This research was an initial proposal on the subject, which represents an opportunity for researchers to look into these logics. Therefore, the authors suggest examining student responses and emotions towards learning when educators use gamification in their courses. Table 5 summarizes the data extracted from the mixed methods studies.

Table 5

Synthesis of mixed methods studies (qualitative and quantitative)

Author(s)	Context	Sample and Method
De Lourdes et al. (2017)	Activities on small business creation with elementary school students in Mexico.	254 students. Multiple regression models and self-reports were used.
Fox et al. (2018)	Degree programs in Mexico.	Case study, with thematic and descriptive analysis. They tested 5 games aimed at EE.
Chemborisova et al. (2019)	Master's degree from the Faculty of Economics of two universities in Omsk, Russia.	140 students (55.7% men and 44.3% women). Questionnaires were used with a likert scale, thematic analysis and descriptive statistics.
Isabelle (2020)	Experimenting with gamified undergraduate entrepreneurship in different programs in Canada.	279 undergraduates (63% male and 37% female). Experience reports and the Mann-Whitney U-test were used.
Liu e Wang (2019)	Classes for a specialization course in management and business in China.	89 students (75% female and 25% male). Before and after questionnaires and Multiple Linear Regression analysis.
Pratikto et al. (2021)	Gamified design thinking workshop with high school students in Indonesia.	Application of questionnaires after experience, thematic analysis and descriptive statistics. They do not characterize the sample.
Solarte et al. (2021)	Entrepreneurship classes in Colombia; degree in Applied Social Sciences.	189 students. They used self-reports and the Wilcoxon-Mann Whitney test.
Chen et al. (2022)	Gamified activities for the creation of innovative products in undergraduate information systems courses in the United States.	96 undergraduates. Questionnaires, content analysis and descriptive statistics were used.

Note: Elaborated by the authors.

Table 4

Summary of quantitative studies

Author(s)	Theory[1]	Context	Sample and Method
Eggers et al. (2017)		Entrepreneurship classes at the undergraduate level in the United States.	75 students (56% male and 44% female). Multiple regression was used.
Catalán e Martínez (2018)	Theory of Flow	Lessons in business decisions at the undergraduate level in management and marketing in Spain.	320 students. They used a questionnaire with a Likert scale, descriptive statistics and correlations.
Fellnhofer (2018)		Experiencing gamification as an undergraduate in different programs in Germany.	41 participants (63.4% male and 36.6% female). Exploratory Factor Analysis and regression models were used.
Grivokostopoulou et al. (2019)		Entrepreneurship course for undergraduates from different programs in Greece.	86 undergraduates (52% male and 48% female). Descriptive statistics, Cronbach's alpha and correlation were used.
Ruiz-Alba et al. (2019)	Theory of Planned Behaviour (TPB)	Online challenge for French undergraduates and postgraduates from different programs.	220 students (52.5% female and 47.5% male). They used mixed analysis of variance (ANOVA).
Zulfiqar et al. (2019)	Technology Acceptance Model (TAM)	Entrepreneurship course for different undergraduate and graduate programs in Pakistan and China.	360 students (61.11% male and 38.89% female). They used Structural Equation Modeling.
Aries et al. (2020)	TPB	Entrepreneurship classes at the undergraduate level in management and business in Indonesia.	400 students. They used multiple linear regression.
Capelo et al. (2021)		Entrepreneurship course at the Postgraduate Administration School in Portugal (Lisbon).	45 students. Multivariate regression analysis was used.
Ghani e Mohammad (2021)		Gamified activities in undergraduate engineering and management and business in Malaysia.	272 students (61.4% male and 38.6% female). Using structural equation modeling.
Kauppinen e Choudhary (2021)		Entrepreneurship course in management and business degree in Estonia and Australia.	82 students (15 women and 67 men). Multiple linear regressions were used.
Kraus et al. (2021)		Experiential gamification activity in different degree programs in the United States.	217 video game players (73.7% male and 26.3% female). Multiple regression analysis was used.
Memar et al. (2021)	Causation and Effectuation	Experiential gamification activity in the master's program in engineering and international marketing in Sweden.	126 students. They used confirmatory factor analysis and multivariate analysis of variance.
Pérez-Pérez et al. (2021)	TPB	Entrepreneurship classes at the undergraduate level in Spain.	522 undergraduates (55.38% female and 44.62% male). Principal component analysis, Kolmogorov-Smirnov statistics and Wilcoxon non-parametric analysis.
Sghari e Bouaziz (2021)	Theory of Reasoned Action (TRA), TAM, TPB and the combination of TAM-TPB	Undergraduate entrepreneurship classes in Tunisia.	57 teachers (77.2% female and 22.8% male). Using Structural Equation Modeling.
Zulfiqar et al. (Zulfiqar et al., 2021)	TAM	Online business simulation for undergraduates (various fields) in Saudi Arabia.	277 undergraduates (67.5% male and 32.5% female). Use of Structural Equation Modeling.
Chen et al. (2022)	Theory of Flow	Gamified experiential activity with Chinese undergraduates from different fields.	205 students (67% female and 33% male). They used a t-test and multiple regression analysis.
Lara-Bocanegra et al. (2022)	Theory of Entrepreneurial Intention by Shapero and Sokol (1982)	Workshop for undergraduate and postgraduate physical education students in Spain.	108 undergraduates (66.7% male and 33.3% female), using structural equation modeling.
Li et al. (2022)		EE program for different undergraduate courses in China.	12,269 students (54.59% female and 45.41% male). Correlations and regressions were used.
Yen e Lin (2022)	Theory of Flow	Classes in business administration and marketing in Taiwan.	94 students (77.7% female and 22.3% male), using structural equation modeling.
Zichella e Reichstein (2022)		Gamified experiential activity in undergraduate economics and management in Denmark.	45 undergraduates (77.7% male and 22.3% female). Logistic regression was used.

Note: [1] When the theory is applicable. Elaborated by the authors.

Finally, Table 6 summarizes the data extracted from the qualitative studies. The methods that appeared frequently were content analysis (thematic/categorical) and the authors did not highlight specific theories in their approaches.

Table 6

Summary of the qualitative studies included

Author(s)	Context	Sample and Method
Watson et al. (2017)	Business Plan Competition with undergraduates from different areas in the UK.	21 participants. Content analysis of interviews.
Sudrajat et al. (2018)	Entrepreneurship course for undergraduates at Binus University in Indonesia.	Analysis of the self-reports of 34 undergraduates.
Watson e McGowan (2018)	Business Plan Competition with undergraduates from different areas in the UK.	7 participants (4 women and 3 men). Content analysis of interviews.
Thanasi-Boçe (2020)	Entrepreneurship course for graduate students in different fields in Kuwait.	16 postgraduate students (87.5% female and 12.5% male). Self-report and content analysis.
Takemoto e Oe (2021)	Undergraduate entrepreneurship classes in different programs in Japan.	114 students interviewed; content analysis was used.

Note: Elaborated by the authors.

The evidence from the research highlighted reinforces the hypothesis that entrepreneurship teaching, based on traditional methods and theoretical lectures, can be complemented by gamification (Pérez-Macías et al., 2022). Simulations can be combined with debriefing sessions or other strategies for participants to synthesize, present and reflect on the teaching-learning process (Capelo et al., 2021). The potential of gamification is reinforced by Kraus et al. (2021), who identified a link between the classic mental models of entrepreneurship and those employed during video game play. These authors point out that different game genres can favor entrepreneurial cognitions and, above all, players of more intense games – with shots, for example – have higher performance, identify opportunities and are more prone to entrepreneurship.

Only 24% of the studies used gamification to analyze the development of Entrepreneurial Intention (Aries et al., 2020; Chen et al., 2022; Fellnhofer, 2018; Lara-Bocanegra et al., 2022; Pérez-Pérez et al., 2021; Ruiz-Alba et al., 2019; Zulfiqar et al., 2019, 2021). In addition, the studies focused on other variables related to entrepreneurial skills and competences, cognition and learning, among other aspects experienced by the student in the gamification experience.

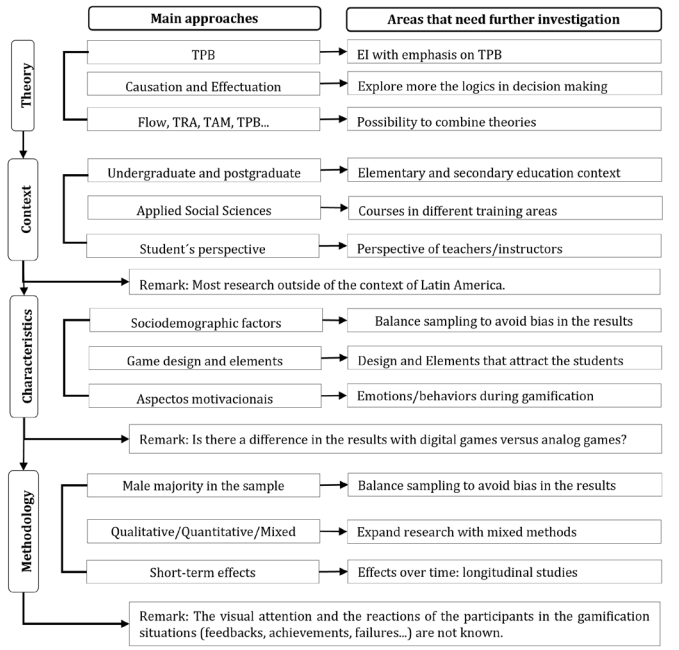
The creation of a business represents Entrepreneurial Behavior (EB), which is preceded by the intention to create (Pérez-Macías et al., 2022). Thus, these studies support their research objectives with the position that because it is a training process, gamified approaches can precede EI. Consequently, the intention identified can predict behavior. However, whether this willingness to undertake, after gamification, led these students to start companies is an unknown hypothesis, thus becoming a research gap. When analyzing the effect of gamification on EI, no research has used longitudinal data to verify whether this intention has in fact been converted into EB.

Based on the theoretical context presented in this results section, we were able to design a conceptual research model (Figure 4). Based on this model, we came up with directions for future research (Table 7).

The model shows the main approaches identified in the literature in terms of TCCM and highlights aspects that require further research. Based on this representation, we arrived at directions for future research, as shown in Table 7.

Figure 4

Research model



Note: Elaborated by the authors.

DIRECTIONS FOR FUTURE RESEARCH

Based on the analysis of the articles included in this review, Table 7 points to some directions for future research. To do this, we used the framework of Theory, Context, Characteristics and Methodology (TCCM). Below is a brief explanation of the TCCM structure in Table 7, which suggests directions for researchers, following the guidelines provided by the identified studies.

Theory

This study revealed that the majority of articles in the current literature have not analyzed gamification in relation to Entrepreneurial Intention, which may explain the fact that the theories underpinning some of the research analyzed tend to be dedicated to the learning and performance process, such as Flow Theory (Catalán & Martínez, 2018; Chen et al., 2022; Yen & Lin, 2022) and theories of technology acceptance (Sghari & Bouaziz, 2021; Zulfiqar et al., 2019; 2021). However, empirical evidence of gamification has also been identified with theories generally associated with entrepreneurial behavior (Aries et al., 2020; Lara-Bocanegra et al., 2022; Memar et al., 2021; Pérez-Macías et al., 2022; Pérez-Pérez et al., 2021; Ruiz-Alba et al., 2019).

Overall, there is a deficit in the use of theories to support each piece of research. In future studies, new theoretical points of view are recommended, i.e. other theories or a combination of theories used in entrepreneurship. It is suggested that research be carried out that analyzes how gamification interacts with TPB variables and how this interaction affects the development of EI. This is justified by the scarcity of studies in this field and because all entrepreneurial behavior is preceded by intention, which makes EI one of the best predictors of entrepreneurship (Pérez-Macías et al., 2022). Future research proposals could also corroborate Memar et al. (2021) and make use of Causation and Effectuation logic to better understand how different game situations explain decision-making, i.e. how gamification-based learning stimulates these two behaviors in students.

Table 7

Directions for future research based on the studies analyzed

Category	Gaps	References
Theory	Research with an emphasis on TPB.	Aries et al. (2020); Pérez-Pérez et al. (2021); Ruiz-Alba et al. (2019).
	Explore Causation and Effectuation logic.	Memar et al. (2021).
	Combining theories.	Sghari e Bouaziz (2021); Zulfiqar et al. (2019).
Context	Primary and secondary schools, where the majority of students have not yet decided on a professional career.	De Lourdes et al. (2017); Pratikto et al. (2021).
	Courses in different areas, as the studies are concentrated in the area of Applied Social Sciences.	Eggers et al. (2017); Liu e Wang (2019); Zichella e Reichstein (2022).
	Research in the context of Latin America.	
	Teachers' perspectives on gamification, the challenges and potential of adapting the methodology to this new paradigm.	Fellnhofer (2018); Solarte et al. (2021); Sghari e Bouaziz (2021); Zulfiqar et al. (Zulfiqar et al., 2021).
Characteristics	Check for differences in effects between gamification based on digital games and other gamified activities (which use game dynamics, but without technology support).	
	Analyze factors that moderate the effects: gender, type of game, age and various sociodemographic aspects.	Liu e Wang (2019); Ghani e Mohammad (2021); Ruiz-Alba et al. (2019).
	Elements of games that most appeal to students.	Fox et al. (2018).
	Analyze emotions and behaviors in situations of success and failure in activities.	Memar et al. (2021).; Thanasi-Boçe (2020).
Methodology	Gender balance in the samples to avoid biased results.	Ruiz-Alba et al. (2019).
	Use of mixed methods for analysis.	Chemborisova et al. (2019); Chen, Albert e Jensen (2022); De Lourdes et al. (2017); Fox et al. (2018).
	Experiments and longitudinal studies.	Fellnhofer (2018); Yen e Lin (2022); Ruiz-Alba et al. (2019).
	Psychophysiological studies - using neuroscience techniques - to verify participants' reactions during the gamification-based learning process.	

Note: Elaborated by the authors.

Context

Given that less than 4% of studies have been carried out in the context of primary and secondary education (De Lourdes et al., 2017; Pratikto et al., 2021), we recommend carrying out research at these early educational levels, where students are younger, not yet linked to a training area and generally not at the age of choosing a professional career. It is therefore important to test whether gamification in EE increases EI for this target group and could lead them to choose entrepreneurship as a career. In addition, it is advisable to study this phenomenon in different training areas and even check the perspective of teachers/instructors.

In this context, it is important to consider the perception of teachers, since it can broaden the understanding of the subject, highlighting teacher training as a possible obstacle to the implementation of gamification. Furthermore, it is important to note that this research did not address programs, public policies or public-private partnerships related to the development of accessible games for public educational institutions. Therefore, there is no information available on such actions and their availability of resources. However, research in this field can provide valuable insights for policymakers and government bodies, informing about the possibilities of using gamification and guiding the development of strategies to encourage the use of pedagogical games, as well as teacher training.

Additionally, although this study has highlighted the need for more research in the field of basic, vocational and technological education at secondary level (Melo et al., 2023), we suggest that future studies also focus on the concept of lifelong learning. In view of the growing interest in gaming in modern society, this approach becomes particularly relevant, as individuals can constantly seek knowledge and skills related to starting a business, even outside the formal education environment. As entrepreneurial education expands into lifelong learning, factors similar to or different from those identified in the conventional educational environment may emerge. However, this issue deserves the attention of researchers in order to provide evidence to drive new academic discussions.

Finally, we highlight the crucial role of entrepreneurship in developing countries, where entrepreneurial activity is sometimes the only way for minority groups to access employment and support themselves (Sieger et al., 2021). Therefore, gamification in EE can receive special attention in these economies. The Global University Entrepreneurial Spirit Students' Survey, GUESSS 2021, confirms the growth of nascent entrepreneurs in developing countries and especially in Latin American countries (Sieger et al., 2021). Thus, future researchers can uncover evidence in the context of emerging markets in Latin America and developing countries.

Characteristics

Instructors/teachers should choose gamification resources carefully to achieve the best learning results (Fox et al., 2018; Thanasi-Boçe, 2020; Sudrajat et al., 2018). According to Liu and Wang (2019), this adequacy of choice is necessary so that gamification in education does not become a choice for any game, but that its elements and purposes must be established before implementation, since it is a system that can even demotivate participants and hinder learning. We therefore suggest that future researchers investigate the influence of the types of games (digital or analog), as well as the elements that most attract students' attention during the gamification experience. Furthermore, it is important to analyze whether the games used to teach entrepreneurship consider the reality and needs of students. It is essential to ensure that these games promote inclusion and accessibility for all groups involved in the teaching and learning process.

The immediate feedback from the games is relevant, but it should be noted that they present results related to points, rewards, achievements and various aspects of success or failure in the dynamic (Memar et al., 2021). Thus, students experience various emotions that are part of the learning process and can be studied more extensively. Analyzing participants' attention behaviors could exploit neuroscience techniques to capture psychophysiological reactions during games. The use of neuroscience techniques, which are currently widely used in neuromarketing - such as eye-tracking

to map visual patterns and on which points of the screen attention is fixed - as well as Electroencephalography (EEG) and others, could be useful for capturing and analyzing students' reactions during the game.

Digital games allow students to experience various emotions and motivations through gamified activities, in scenarios of success and failure (Memar et al., 2021),), which are integral parts of the learning process. But what attracts students' attention in a business game or simulation? To what extent is engagement maintained? How do students react to progress in the dynamic, points, achievements and rewards? And are failures in the game demotivating? Questions like these remain unanswered and the literature on these psychophysiological reactions in different gamification situations is practically non-existent.

Furthermore, these emotions can be moderated by the characteristics of the participants. Pérez-Pérez et al. (2021) argue that a limitation of studies relating gamification to EE is that they do not consider the direct or indirect impact of moderators, such as whether the individual has any previous training in entrepreneurship, gender, course, age, among others. In this way, research generally considers the short term, although the impacts produced by game-based training could have an effect later on (Pérez-Pérez et al., 2021; Yen & Lin, 2022). Therefore, another opportunity for further studies is to analyze moderating factors of the effects.

Methodology

The methods we used were predominantly quantitative, followed by qualitative and a small number of studies (three) used a mixed method (qualitative and quantitative). Researchers are advised to use mixed methods approaches in their future studies for a broader understanding of the phenomenon. Additionally, there is a gap in experimental research to measure causal behavior, given that some studies are based on a quasi-experimental design, but do not randomly allocate treatment and control groups (Capelo et al., 2021; Liu & Wang, 2019; Pérez-Pérez et al., 2021). In addition to experimental research, it would be interesting to conduct studies with longitudinal data to monitor whether the entrepreneurial intention resulting from gamification is converted into entrepreneurial behavior.

Another problem is the convenience sampling still used in some studies (Yen & Lin, 2022) and self-selection of the sample (Chen et al., 2022; Li et al., 2022; Watson & McGowan, 2018). For example, some samples are made up of participants in entrepreneurship courses or short-term activities, where students sign up to take part in such activities. In this way, the results may be biased, because if they choose to participate in the course, they may be more inclined to entrepreneurship and show more knowledge and interest in this field, which requires caution when analyzing the results with this type of group.

Sample size limitations were mentioned in many of the studies analyzed. It would be interesting for future studies to state and justify the sampling technique chosen, as many analysis strategies are not appropriate for small samples. Finally, the study by Ruiz-Alba et al. (2019) demonstrates that, although it is not yet an investigated issue, gender is a factor that can alter the results of gamification research, since the literature points to evidence that male students are more prone to entrepreneurship than their female counterparts, and this discrepancy can somehow affect the returns of gamification in EE.

We can see that the samples in most of the studies analyzed have more male participants and this can cause biased results. Thus, researchers need to be concerned about the disparity between the number of male and female (or multi-gender) samples. Therefore, to guarantee more rigor and relevance to this type of research, we recommend that the samples be more balanced.

FINAL CONSIDERATIONS

The purpose of this study was to understand how current research has approached the topic of gamification in entrepreneurship education and to propose future directions for researchers by systematizing the Theories, Contexts, Characteristics and Methodologies (TCCM) used in the empirical studies analyzed. Thus, following the PRISMA protocol guidelines, 33 articles published between 2017 and 2022 were included in this systematic review.

In summary, we found that most of the studies identified positive results and suggest that gamification plays an important role in entrepreneurial education, meeting cognitive, emotional, or behavioral educational objectives and developing entrepreneurial skills. Most of the studies were carried out in the context of the United States and in some European and Asian countries; quantitative methods were predominantly used; there are few articles that focus on gamification in relation to Entrepreneurial Intention; the use of theories to support research is still low and the work is concentrated in higher education.

The set of articles selected in this systematic review shows that gamification has been recognized as an innovative pedagogical resource for teaching entrepreneurship in various educational contexts. Notable benefits of using games include increased EI, engagement, motivation, the development of information-based decision-making skills and the ability to take risks, among other competencies. However, it is important to note that more studies are needed to deepen knowledge in this area. Furthermore, gamification should not be considered an isolated solution, but rather a complement to traditional teaching approaches, without replacing them. It is therefore crucial to analyze which pedagogical strategies can be combined to achieve comprehensive training, integrating theory, practice, and critical reflection on the challenges of entrepreneurship.

This study expands on what has already been done in theoretical terms by corroborating the hypothesis that gamification can be applied in entrepreneurship teaching to energize the learning process and arouse interest in entrepreneurial activity, as identified in the literature. By collecting, analyzing, and synthesizing the approaches used in the research identified, this study contributes to the advancement of knowledge, since it carries out a critical and impartial evaluation of the existing results on the subject and reveals gaps in the literature, allowing researchers to identify areas that need further investigation.

In addition to understanding how researchers have approached the topic of gamification in entrepreneurship education, we suggest that future systematic literature reviews and/or content analyses seek to identify, evaluate and synthesize, among other aspects, the available evidence on how gamification can be used to develop the social and emotional skills so necessary for entrepreneurship (e.g. teamwork, communication, negotiation), in both educational and business environments. Furthermore, identifying best practices for the application of gamification in entrepreneurship education - including, but not limited to, game design and the selection of learning objectives - could provide insights for educators.

Despite the rigorous search, selection and analysis process, this research is not without its limitations. Firstly, by including only documents published in journals – excluding conference papers, theses, dissertations and the like – it is possible that some work on the subject was not analyzed due to the criteria established. In addition, due to the heterogeneity of the studies identified, we were not able to carry out in-depth statistical analyses and group the results of the research together. However, these limitations do not compromise the value of this systematic review. We therefore hope that the academic discussions presented will contribute to the advancement of knowledge in this field.

Conflit of interest statement

The authors declare that there is no conflict of interest.

Authors' statement of individual contributions

Roles	Contributions				
	Soares, A. M. J.	Melo, F. L. N. B. de	Dantas, S. de T. A	Silva, M. P. da	Genuino, S. L. V. P .
Conceptualization	■	■	■		
Methodology	■	■	■	■	■
Software			N.A.		
Validation	■	■			
Formal analysis	■	■	■		
Investigation	■	■	■	■	■
Resources			N. A.		
Data Curation	■	■			
Writing - Original Draf	■	■	■	■	■
Writing - Review & Editing	■	■			
Visualization	■	■	■	■	■
Supervision	■	■			
Project administration	■	■			
Funding acquisition			N. A.		

Note: Acc. CRediT (Contributor Roles Taxonomy): https://credit.niso.org/

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