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REVIEW

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Serious games research streams for social change: Critical review and framing

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The number of scientific publications about serious games has exponentially increased, often surpassing human limitations in processing such a large volume of information. Consequently, the importance of frameworks for summarising such fast-expanding literature has also grown. This paper draws a panorama of serious game research streams, focusing on higher education in engineering and management. The research design involves a systematic review using PRISMA guidelines, along with bibliometric and content analyses. The sample comprises 701 documents collected from both Scopus and Web of Science databases. For supporting bibliometric analyses, *Bibliometrix* and *Biblioshiny* tools are employed. In addition, a coding schema is developed for in-depth analysis of 701 documents selected according to the inclusion criteria. In short, the literature on serious games for engineering and management education grows more rapidly than modern science, following a globalised, collaborative and context-based trajectory. The results reveal five main research streams: *game design guidelines, game design cases, game experiment guidelines, game experiment cases and generalists*. These streams are summarised in a proposed framework. Cross-tabulation and statistical analyses conducted in *SPSS Statistics* identify the key relationships amongst the research streams. Finally, opportunities to investigate serious games for sustainable development education arise, and there is a need for future efforts to formalise the framework classification algorithm.

KEYWORDS
engineering and management higher education (EMHE), serious games (SGs), systematic literature review (SLR)

Practitioner notes

What is already known about this topic

- Scientific production related to Serious Games (SGs) has grown exponentially in a globalised manner. It reflects the interest from various domains, particularly the field of sustainability in management.
- Literature reviews on SGs have emphasised various topics, including the acceptance of simulations and games as effective methods of teaching and learning. The role of technology-enhanced games and simulations in the context of digital transformation in education and the emergence of sustainability as a promising field for future SGs research are also highlighted.
- The literature has introduced three categories for empirical research on SGs: (1) game presentation, (2) game evaluation and (3) game effectiveness. It has also highlighted methodological rigour as a common challenge across studies.

What this paper adds

- Scientific research on SGs in Engineering and Management Higher Education (EMHE) experiences exponential and significantly faster growth compared to modern science in a globalised and collaborative manner. This growth reveals the scarcity of experts in this area and attracts the attention of various fields, particularly in the realm of sustainability.
- Thematic trajectories indicate a decline in discussions regarding users' perceptions of SGs and their validity as educational tools. They also demonstrate consistency in discussions about SGs design, and the potential of sustainability emerges as a promising area for future SGs in EMHE.
- A comprehensive framework composed by five primary research streams connects *game design cases and guidelines, game experiment cases and guidelines and generalists.* This framework can serve as a lens for future context-based literature reviews, and the relationships amongst its streams reinforce the idea that the field can benefit from increased methodological rigour in experiments.

Implications for practice and/or policy

- This review offers categorised supplementary material in which educators can discover a variety of artefacts for application in their specific educational contexts. Designers can access guidelines for enhancing the design of innovative games. Researchers can access guidelines for more effective evaluation of their artefacts across various contexts. Finally, policymakers can explore numerous experiments to inform decisions related to technology-enhanced innovations in the classroom.

INTRODUCTION

Serious Games (SGs) have emerged as pervasive and versatile educational tools, finding applications in diverse Higher Education (HE) contexts such as medical and nursing (Wong et al., 2022), accounting (Carvalho & Neto, 2022), engineering (Castronovo et al., 2022;

Gordillo et al., 2022), business (Beranič & Heričko, 2022), management (Afthinos et al., 2022; Whalen et al., 2018), amongst others. By blending entertainment and education, these interactive and immersive learning artefacts have garnered considerable attention from educators and researchers alike, especially from the field of Engineering and Management Higher Education (EMHE). The potential positive impacts of SGs on cognitive, affective and behavioural learning outcomes (Vlachopoulos & Makri, 2017) reinforce the ability of games to cultivate effective educational environments. SGs have the capacity to bridge the gap between theoretical understanding and practical application by providing immersive learning experiences within risk-free simulated real-world scenarios and challenges. This capability can empower students to apply theoretical knowledge and acquaint them with cutting-edge technologies relevant to their fields. Moreover, SGs in EMHE can facilitate the development of leadership skills for collaborative teamwork, enhancing mutual comprehension amongst team members and fostering a grasp of varying perspectives. They can also nurture the ability to make decisions by comprehending the ramifications of choices and leveraging failure as a learning opportunity devoid of real-life repercussions, alongside other benefits.

As the interest in this field continues to surge, research pertaining to SGs for EMHE—which is the focus of this paper—has experienced exponential growth, with thousands of documents published yearly and numerous released reviews, indicating a high demand for knowledge condensation. However, to effectively manage this overwhelming influx of information and summarise the vast knowledge landscape, researchers in this field have tackled the synthesising challenge mostly through context-based stratifications. For instance, Rumeser and Emsley (2018) and Rodríguez et al. (2021) examined the literature from the perspective of project management education. Hallinger et al. (2020) and Stanitsas et al. (2019) investigated SGs research in terms of sustainability education. Rumore et al. (2016) explored such publications through the lens of climate change education. Along, some authors have focused on specific management topics. Solinska-Nowak et al. (2018), for example, reviewed SGs for disaster risk management. Carenys and Moya (2016) targeted the accounting and business literature on digital-game-based learning. Lane (1995) and Wolfe (1993) offered historical backgrounds and developments for business simulation games. Furthermore, others have concentrated on a particular engineering category. Alanne (2016) overviewed game-based learning in building services engineering, Menandro and Arnab (2020) reviewed game-based teaching and learning in mechanical engineering, and Garcia et al. (2020) investigated the effects of game-based learning in software engineering courses.

Only a few comprehensive reviews have embraced the challenge of screening a large body of knowledge in EMHE. Behl et al. (2022), for instance, classified SGs in the learning approaches cluster, highlighting four major themes for research in gamification and e-learning for young learners. Deshpande and Huang (2011) offered a taxonomy for SGs applications in the education of multiple engineering disciplines, a classification of production planning and control simulation games and a summary of 50 simulation games and their characteristics. Bodnar et al. (2016) classified records according to both engineering disciplines and topics, and cognitive or learning outcomes as positive, negative or neutral. In their turn, Hallinger and Wang (2020) identified four schools of thought in the literature on simulation-based learning in management education: (1) theoretical foundations of simulation-based learning, (2) simulation-based learning in business education, (3) organisational theory and complex systems, and (4) simulation-based learning in the professions. Finally, Udeozor et al. (2022) listed engineering disciplines and games, along with considerations about the design studies, performance assessments and outcomes, and identified three main streams for SGs empirical research in engineering: game presentation, game evaluation and game effectiveness.

However, existing reviews in this field tend to be either empirically focused, concentrating solely on the *applications* of SGs in engineering or management education, or they lack a comprehensive perspective particularly regarding the potential uses of SGs in scientific

research. Thus, a broader framework for the research streams of SGs in EMHE research is a literature gap. To narrow this gap, this study addresses the following research questions (RQs):

- **RQ1:** What are the main characteristics of the literature about serious games for engineering and management higher education?
- **RQ2:** What main topics have been discussed in the literature about serious games for engineering and management higher education?
- **RQ3:** What are the main research streams of the literature about serious games for engineering and management higher education, and what are the relationships amongst them?

To answer these questions, this research uses a Systematic Literature Review (SLR) design following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). Additionally, it employs *Bibliometrix* and *Biblioshiny* tools (Aria & Cuccurullo, 2017) to synthesise the existing knowledge and identify research opportunities within the field.

As a result, this paper offers the following four main contributions. First, it characterises literature on SGs for EMHE and demonstrates that the field under investigation grows at a faster rate than modern science. Second, it analyses the primary research topics that have been commonly discussed in the literature on SGs for EMHE. Third, drawing from how SGs are utilised in research, this paper presents a framework for synthesising the literature. This framework will serve as a guide for future works, particularly for researchers who are relatively new to the field. Lastly, as a practical contribution, this review can assist program directors, educational professionals and designers in discovering various SGs initiatives in EMHE through the categorised supplementary materials offered.

The structure of the SLR is as follows: The background section introduces the two main constructs of this work. The methods section outlines the steps of the review. The results section reports the findings. The discussion section examines the implications of this work. Finally, the last section presents the conclusions and highlights the limitations.

BACKGROUND

The first construct that is central to this SLR is SG. The SG concept has received multiple definitions. Zyda (2005), eg, defined SG as “a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives”. Other similar definitions presented by Susi et al. (2007), Ritterfeld et al. (2009) and Alvarez (2007) also limited the notion of SGs to computer-based games. Per these definitions, however, interesting board games are not considered SGs. Thus, this paper adopts the term as it was initially coined, by Abt in 1970, ie: SGs were defined as games that “have an explicit and carefully thought-out educational purpose and are not intended to be played *primarily* for amusement” (Abt, 1987). In other words, the concept adopted in this review is not restricted to the game format, encompassing various platforms such as computer, mobile, virtual or board games. However, it is delimited by the intended purpose of the artefact, specifically games for education.

Furthermore, there is a need to make conceptual distinctions between the terms Gamification and Game-Based Learning (GBL). In the words of Deterding et al. (2011), Gamification refers to “the use of game design elements in non-game contexts”. While SGs are fully-fledged games, Gamification consists of the adoption of game design parts. Only

completely developed games compose the scope of this review. Now, in the words of Krath et al. (2021), GBL "refers to the achievement of defined learning outcomes through game content and play", that is, GBL relies on SGs to happen. GBL, however, denotes not the artefact, but one of the goals to be achieved with its application, ie, the goal of learning. To maintain coherence and rigour in its aim to investigate the scientific affordances of SGs as artefacts, this study deliberately excludes the closely related concepts of GBL and Gamification.

Finally, concerning HE, the second primary construct of this review, not every educational level is examined. The International Standard Classification of Education (ISCED), developed in the early 1970s by the United Nations Educational, Scientific and Cultural Organization (UNESCO), is adopted. Four aggregate levels of education comprise the ISCED. The four levels are (i) less than basic, (ii) basic, (iii) intermediate and (iv) advanced. Only the advanced level integrates the scope of this review. The advanced level includes (a) short-cycle tertiary education, eg, technical education, community college education, vocational training etc.; (b) bachelor's or equivalent level, eg, undergraduate, bachelor's programmes, first university cycle etc.; (c) master's or equivalent level, eg, postgraduate master programmes, magister etc.; and (d) doctoral or equivalent level, eg, postgraduate PhD, DPhil, D.Lit., D.Sc., LL.D, doctorate programmes etc. (ILOSTAT, n.d.; UNESCO, 2012).

"Serious games" and "advanced education" were the two central constructs employed as starting points for this review, as described in the following section.

METHODS

To address the RQs transparently, the PRISMA 2020 guidelines were adopted (Page et al., 2021). Therefore, identification, screening and assessment phases were carried out in seven detailed steps (Figure 1).

Data collection

Initially, high-quality research documents in sufficient quantity were identified. Scopus and Web of Science databases were selected because of their abundance of evidence, their independent and thorough editorial process, and their unique and complete indexing system (step 1 in Figure 1).

Next, the search string was defined through an iterative process ensuring the most frequent synonyms for the two central constructs were found. The first central keyword (*"serious game"*) was used to search the "author keywords" field in Web of Science. Synonyms were identified from the output file, expanding the initial string (eg, from *"serious game"* to *"'serious gam*' OR 'serious-gam*' OR 'educational gam*'"*). The expanded string was used to search for synonyms iteratively until the most frequent were encountered. The process was repeated with the second central construct (*"undergraduate education"*). Finally, the two sets of terms were united by the logical operator *"AND"* generating the final search string. Three iterations were necessary to find the 26 most frequent synonyms for "serious game", and other three to find the 49 most frequent related terms for "undergraduate education" (step 2 in Figure 1, and supplementary materials A and B).

Then, publications were searched and selected. The identified string was used to search the "topic" field in Web of Science, and the "article title, abstract, keywords" field in Scopus. 3897 publications were found, and filters were applied to select only articles, reviews and early access in English from the subject/research areas of engineering, management and education. 2919 records were filtered out. No temporal cut-off was employed in the sampling process, meaning the articles in the sample encompass all the

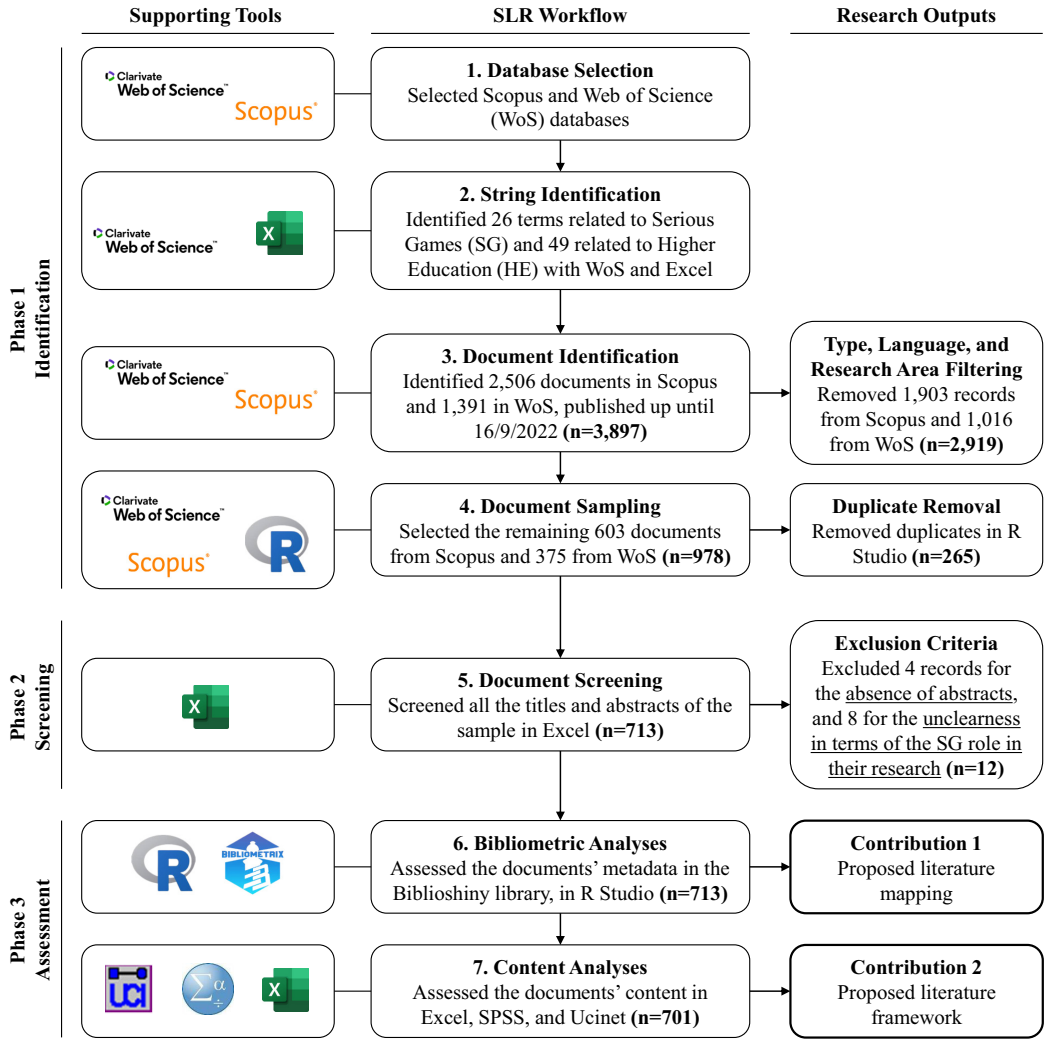


FIGURE 1 Systematic literature review workflow.

works published until the data collection date: 16/9/2022 (step 3 in Figure 1, and supplementary material C).

The 978 remaining documents were exported from both databases and imported into *RStudio*. 265 duplicates were removed, and a sample of 713 articles was generated for bibliometric analysis with *Bibliometrix* and *Biblioshiny* (step 4 in Figure 1).

Finally, titles and abstracts were screened in Microsoft Excel, and 12 articles were excluded: 4 that did not provide an abstract for their work, and 8 that offered an abstract in which the SG use was not clear (step 5 in Figure 1). 701 documents composed the final sample for content analysis.

Data analysis

Bibliometric analysis, supported by Bibliometrix and Biblioshiny tools, provided the literature panorama. In Biblioshiny software, conceptual structure and intellectual structure

analyses were performed (Ramos-Rodríguez & Ruíz-Navarro, 2004). In brief, the selection of Bibliometrix and Biblioshiny tools stemmed from their capability to incorporate a range of diverse software applications necessary to address the intricacies of conducting science mapping within an open-source framework (Aria & Cuccurullo, 2017). This choice also facilitates the reproducibility of the research (step 6 in Figure 1).

For content analysis, a coding scheme was developed through an iterative process, looking for a higher level of understanding (Auerbach & Silverstein, 2003), identifying relevant codes and applying Webber protocol (Duriau et al., 2007). The codebook assessed and inductively categorised in *Microsoft Excel* is provided as supplementary material. For building the framework, the relationship amongst codes was depicted through cross-tabulation and significance analysis in *IBM SPSS Statistics* and network analysis in *UCINET6* software (Borgatti et al., 2002) (step 7 in Figure 1, and supplementary material D).

RESULTS

Literature characterisation

From the earliest work of Philippatos and Moscato (1971) to the latest of Zarraonandia et al. (2022), 713 articles were produced by 2091 authors in 326 sources from 60 countries in the field of SGs for EMHE. Those numbers show an exponential growth pattern with an annual growth rate of 7.75%. Considering the annual growth rate of 4.1% of modern science (Bornmann et al., 2021), the investigated field has an expressive growth rate. Such exponential increase was fostered by researchers from every continent, revealing an important literature characteristic: global presence. Historically, the 10 most notable countries were the United States (US) (162 articles), Spain (99), the United Kingdom (UK) (87), Ukraine (46), Australia and China (36 each), the Netherlands (33), Germany (30), Portugal (27), and Brazil and Turkey (24 each). These countries accounted for 84.7% of the sample. Also, stronger collaboration ties were observed between UK-Australia, UK-Brazil and Spain-Colombia (Figure 2).

In fact, collaboration emerged as another preeminent characteristic. Each article was produced, on average, by more than three researchers (3.26 per document), and only 100 authors (4.77%) produced single-authored articles. Moreover, 326 sources in a sample of 713 articles might also indicate openness and interest from multiple fields with respect to SGs research.

As expected outcomes, on the one hand, journals in the field of serious games, as illustrated by (i) Simulation and Gaming and (ii) JMIR Serious Games, and in the field of education, as illustrated by (iii) Computers and Education, (iv) British Journal of Educational Technology, and (v) International Journal of Engineering Education, comprised the group of main journals of the sample, according to Bradford's Law and h-index. Surprisingly, on the other hand, journals from the fields of sustainability and sustainable development, as illustrated by (vi) Sustainability and (vii) Journal of Cleaner Production, were also part of this group, drawing attention to a growing interest in SGs for sustainability and sustainable development in EMHE. The sample core sources accounted for 33% of scientific production; the other 67% was dispersed in multiple fields.

While detected in the analysis of main sources, the topic of sustainability did not emerge in the investigation of the most relevant authors and their respective mastery themes. This fact indicates open positions for future experts in SGs for EMHE related to sustainable development. Table 1 presents the 10 most productive authors in the sample and their areas of expertise.

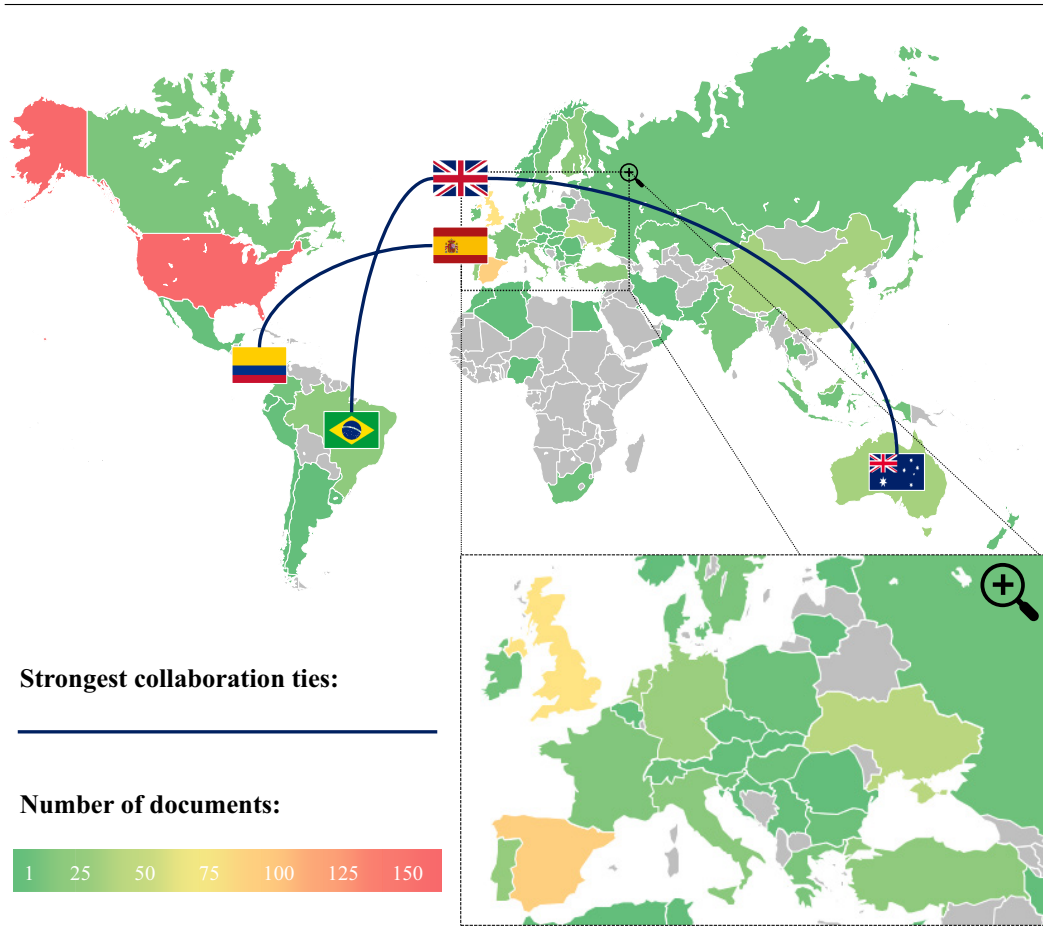


FIGURE 2 Collaboration WorldMap.

Again, collaboration emerged as an important characteristic, since the top positions were occupied by research partners, instead of single authors. Similar to previous analyses, these publications accounted for a small fraction of the total scientific production of the sample (6%). Other 94% were written by multiple authors, displaying an absence of central specialists in the field: 92.7% of authors published one article, 5.3% published two articles and 1.3% published three articles. In conclusion, Table 2 summarises what has been articulated in the preceding paragraphs of this section, highlighting which supporting analysis resulted in which literary characteristic and answering RQ1.

Thematic evolution

The main authors from Table 1 emerged from 2008 forward, except for Wolfe who contributed to the field from 1991 to 2009 (Figure 3).

Comprehensively, Table 1 and Figure 3 allow a first evolutionary description of the main topics. In short, exponents were found in relation to (1) SGs and simulations for education in business and entrepreneurship (Wolfe, Almeida, & Buzady, 1991–2022); (2) SGs design and assessment (Hummel & Nadolski, 2008–2021); (3) game-based

TABLE 1 Main authors and topics.

Authors (publications)	Topics per top ten author's keywords (word frequency)
Almeida and Buzady (10)	Serious games (8); fligby (5); higher education (4); entrepreneurship education (3); entrepreneurship (2); flow (2); flow theory (2); leadership development (1); positive psychology (1); active methodologies (1)
Martí-Parreño and Sánchez-Mena (7)	Higher education (6); educational video games (5); attitude (2); behavioural intention (2); gamification (2); tam (technology acceptance model) (2); teachers (2); acceptance (1); age (1); barriers (1)
Hummel and Nadolski (6)	Serious games (4); higher education (2); assessment of learners (1); authoring environment (1); communication skills (1); complex skills (1); content validation method (1); design framework (1); development process (1); emergo (1)
Messner (6)	Engineering education (5); construction education (3); simulation game (3); augmented reality (2); problem-solving (2); serious games (2); construction management (1); development framework (1); ecocampus (1)
Hainey (5)	Empirical evidence (4); games-based learning (3); evaluation (2); serious games (2); adaptative games-based learning (1); comparative study (1); computer games (1); digital games for learning (1); education (1); felder-silverman (1)
Ifenthaler (5)	Causal representation (1); complex problem-solving (1); digital transformation (1); digitalization (1); distance learning (1); himatt (1); school development (1); vocational school (1)
Wolfe (5)	Business games (3); management education (3); simulation (2); business education (1); business/management games (1); computerised simulations (1); entrepreneurship (1); evaluation methods (1); experiential learning (1); logic model (1)

TABLE 2 Literature characteristics.

Literature characteristics	Supporting analyses
A. Scientific production related to SGs for EMHE grows faster than modern scientific production in general	1
B. Scientific production related to SGs for EMHE is global	2
C. Scientific production related to SGs for EMHE is collaborative	3, 4, 8
D. Research on SGs for EMHE is appealing	4
E. Research on SGs for EMHE is appealing, particularly to the field of sustainability	5, 6, 7
F. Scientific production related to SGs for EMHE lacks experts	9
G. Scientific production related to SGs for sustainability in EMHE lacks experts	10

Note: (1) Annual scientific production. (2) Country scientific production. (3) Collaboration world map. (4) Main information. (5) Most relevant sources. (6) Bradford's law. (7) Source impact. (8) Most relevant authors. (9) Lotka's law. (10) Most relevant authors and most frequent words and word clouds.

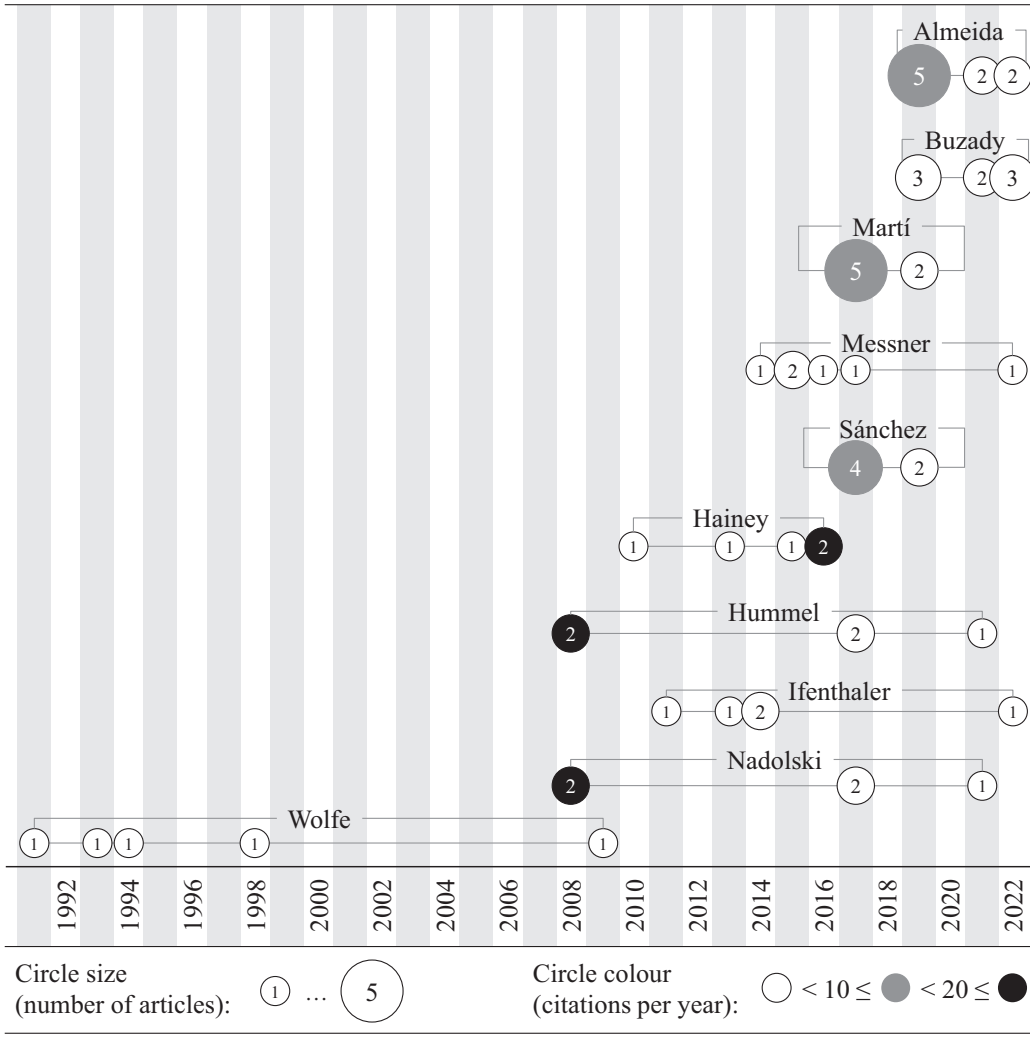


FIGURE 3 Top-authors' production over time.

learning supporting evidence (Hainey, 2010–2016); (4) digital transformation in education (Ifenthaler, 2011–2022); (5) SGs for education in construction (Messner, 2014–2022); and (6) teachers' acceptance of educational video games and gamification (Martí-Parreño & Sánchez-Mena, 2017–2019).

A second evolutionary description emerged from the analysis of the most relevant documents. Table 3 ranks the most cited articles of the sample according to both the number of citations in all years (ranking 1) and the average citations per year (ranking 2).

The two top 25 rankings of most cited papers shown in Table 3 are composed of 35 unique documents. So, 16 papers appear in both rankings, 9 articles exclusively in the total citations ranking (on the left) and 10 articles exclusively in the average citations ranking (on the right). The papers in Table 3 accounted for 43.4% of total citations in the sample. In order to examine the topics covered by those articles, they were clustered in three groups as shown in Table 4. Table 4 displays the main topics for each of these groups.

From Table 4, slight differences amongst relevant topics are highlighted in bold and reveal that research on: (a) the perception regarding the educational use of SGs appeared in the total citations group only; (b) SGs design for education continues to be highly cited; and (c) SGs for sustainability education have recently been disseminated.

Finally, a third evolutionary description developed from *Biblioshiny* thematic analysis. Figure 4 shows the thematic map generated automatically with the top 500 keywords from the sample "keywords plus" data field.

Figure 4, built from the word co-occurrences network, distributes the literature themes in four quadrants, defined and named by *Biblioshiny* as motor themes (MTs), niche themes (NTs), emerging or declining themes (EDTs) and basic themes (BTs).

MTs, in the top-right corner, are topics with both high-density and high-centrality values in the network. They are highly developed and importantly positioned. Three MTs were identified. MT1 congregated studies about games for education associated with healthcare (eg, medicine, care, nursing, pharmacy, medical school, covid-19, mental health, health knowledge, anxiety, attitude to health, clinical article), and with experiments (eg, human experiments, controlled studies, and randomised controlled trials). MT2 gathered research on educational games connected with technology and engineering (eg, construction industry, quality assurance, engineering and mathematics, agile, manufacturing systems, software engineering, programming course), and with educational technology (eg, learning systems, e-learning, education computing, curricula and technology-enhanced learning). MT3 joined studies on SGs for education and SGs design (eg, user acceptance, challenges, learning outcomes, tool, validation and engagement).

Next, NTs, in the top-left corner, are themes with high-density and low-centrality values in the network. They are highly developed, but isolated. Two NTs were identified. NT1 comprehended studies on SGs for education related to special educational needs and disabilities, and to social relationships (eg, social adaptation, human relations and peer groups). NT2 brought together studies on games for education connected with design and pedagogy (eg, bloom, taxonomies, teaching methodologies and teaching approaches).

Then, EDTs, in the bottom-left corner, are the themes with both low-density and low-centrality values. They are not highly developed, and isolated. Three themes appeared in this quadrant. EDT1 gathered works associated with climate change, sustainable development goals and assessment methodologies (eg, assessment method, research work and questionnaire survey). EDT2 congregated studies associated with acceptance, technology (eg, information-technology, 2nd life, system) and education (eg, instruction and competence). EDT3 comprehended research associated with mathematical modelling (eg, personnel testing and empirically allocated models).

TABLE 3 Rankings of most cited articles.

RANKING 1—Top 25 papers in number of citations	Total citations in all years	RANKING 2—Top 25 papers in number of citations per year	Average citations per year
Neck and Greene (2011)	644	Neck and Greene (2011)	53.7
Ebner and Holzinger (2007)	452	Erhel and Jamet (2013)	32.8
Erhel and Jamet (2013)	328	Xu et al. (2017)	31.7
Squire and Klopfer (2007)	277	Hainey et al. (2016)	28.4
Westera et al. (2008)	222	Ebner and Holzinger (2007)	28.3
Virvou and Katsionis (2008)	211	Vlachopoulos and Makri (2017)	25.7
Hainey et al. (2016)	199	Chen et al. (2020)	20.7
Guillén-Nieto and Aleson-Carbonell (2012)	197	Gorbanev et al. (2018)	20.0
Xu et al. (2017)	190	Mayer et al. (2014)	18.4
Kiili (2007)	190	Lameras et al. (2017)	18.2
Mayer et al. (2014)	166	Guillén-Nieto and Aleson-Carbonell (2012)	17.9
Vlachopoulos and Makri (2017)	154	Squire and Klopfer (2007)	17.3
Pasin and Giroux (2011)	154	Bodnar et al. (2016)	17.0
Deshpande and Huang (2011)	152	Gatti et al. (2019)	16.3
Tao et al. (2009)	145	Stanitsas et al. (2019)	15.8
Dieleman and Huisingh (2006)	144	Almeida and Simões (2019)	15.5
Lane (1995)	132	Rutledge et al. (2018)	15.2
Bellotti et al. (2010)	123	Tejedor et al. (2019)	15.0
Kiili (2005)	122	Westera et al. (2008)	14.8
Bodnar et al. (2016)	119	Virvou and Katsionis (2008)	14.1
Lameras et al. (2017)	109	Solinska-Nowak et al. (2018)	13.6
Lawrence (2004)	104	Pasin and Giroux (2011)	12.8
Nadolski et al. (2008)	103	Deshpande and Huang (2011)	12.7
Hwang et al. (2014)	102	Romero et al. (2015)	12.3
Gorbanev et al. (2018)	100	Fox et al. (2018)	12.0
		Castronovo et al. (2022)	12.0

TABLE 4 Topics in the most cited papers.

Main topics **per top 10 abstracts unigrams (word frequency)**		
GROUP 1: Topics covered by papers in ranking 1 only	**GROUP 2: Topics covered by papers in both rankings**	**GROUP 3: Topics covered by papers in ranking 2 only**
Game(s) (51)	Game(s) (91)	Game(s) (42)
Learning (25)	Learning (47)	Learning (28)
Students (16)	Students (30)	Education (24)
Research (15)	Education (23)	**Sustainability (18)**
Educational (11)	Research (17)	Research (17)
Paper (10)	Studies (14)	Skills (12)
Development (9)	**Design (13)**	Study (12)
Perceived (9)	Intercultural (12)	Development (11)
Education (7)	Paper (12)	Gamification (11)

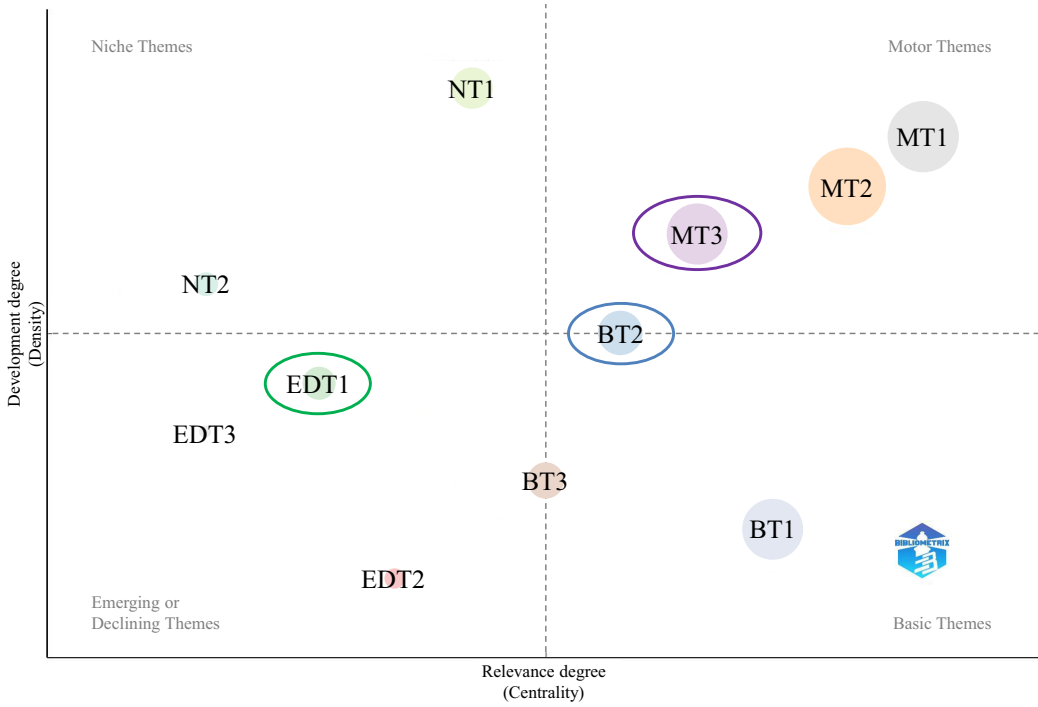


FIGURE 4 Thematic map (keywords plus field, 500 number of words and walktrap clustering algorithm).

Finally, BTs, in the bottom-right corner, are topics with low-density and high-centrality values. They are not highly developed, but importantly positioned. BT1 was revealed as a basic theme and joined research on games for education associated with motivation, business (eg, business games, communication and computer-mediated communication) and simulation (eg, simulators and computer simulations). Also, between the basic and the motor quadrants, BT2 emerged. It gathered works on SGs for education connected with sustainability (eg, sustainable performance, ecodesign, sustainable design education), with technology (eg, augmented reality, augmented reality gaming) and with construction (eg, civil engineering students, architectural design and architectural engineering). Lastly, between the basic and the emerging or declining quadrants, BT3 brought together studies on SGs for education associated with business simulation games, undergraduate students, skills development and behavioural research.

Overall, three themes mainly drew attention from Figure 4. First, a design purple cluster (MT3) appeared as a motor theme since both its density and centrality in the word co-occurrences network were high. MT3 reinforces the observation from Table 4 in which SGs design for education has been a developed and relevant theme discussed in the literature. Second, a sustainable development blue cluster (BT2) emerged between the basic and the motor quadrants, appearing as a moderately developed and reasonably relevant topic. BT2 supports considerations from frequent sources analyses and from Table 4 in which SGs for sustainability education emerge to be an important field for future research. Third, a climate change green cluster (EDT1) reassured such observation, as it surfaced in a top central position on the emerging quadrant.

In conclusion, Table 5 synthesises what has been articulated in the preceding paragraphs of this section, highlighting which supporting analysis resulted in which evolutionary description and answering RQ2.

TABLE 5 Thematic trajectories.

Thematic trajectories	Supporting analyses
A. (Phase 1) SGs and simulations for education in business and entrepreneurship; (Phase 2) SGs design and assessment; (Phase 3) Game-based learning supporting evidence; (Phase 4) Digital transformation in education; (Phase 5) SGs for education in construction; and (phase 6) Teachers' perception and acceptance of educational video games and gamification	1, 2, 3, 4
B. (Phase 1) Research about the perception regarding the educational effectiveness of SGs tends to be less frequent in the future; (Phase 2) Research on SGs design for education has been and continues to be important; and (Phase 3) Research on SGs for sustainability education continues to gain traction in next years	4, 5, 6
C. (Phase 1) Research on SGs design for education has been and continues to be important (ie, highly developed and highly relevant); and (Phase 2) Research on SGs for sustainability, sustainable development, and climate change education points to become an important research field in the future	7

Note: (1) Most relevant authors. (2) Wordclouds. (3) Author's production over time. (4) Most frequent words. (5) Most global cited documents. (6) Most global cited documents per year. (7) Thematic map.

Research framework

Finally, in terms of RQ3 and the uses SGs afford in science, five research streams (RS) were inductively identified from content analyses. RS1, or game design guidelines, comprised works that inform on how to design SGs for education. RS2, or game design cases, contained articles that report on specifically designed SGs. RS3, or game experiment guidelines, encompassed papers about how to employ SGs in research experiments. RS4, or game experiment cases, comprehended records that report on empirical research carried out with SGs, and RS5, or generalists, involved publications fostering generic discussions on SGs multiple topics, such as the general effectiveness, usefulness and implications of SGs; perceptions on the use of SGs; opportunities to apply SGs; adoption of SGs in the educational curriculum; personal experiences with SGs; the past and the future of SGs; etc.

Table 6 exemplifies the five proposed research streams with illustrative identification sentences.

Supplementary material D displays the complete table with inductive classifications for all 701 abstracts, along with their respective main sentences responsible for inducing identification. In short, 173 articles in RS1 (24.7%) informed design. 236 in RS2 (33.7%) presented a designed SG. In RS3, 102 (14.6%) informed on how to apply SGs in research. 412 in RS4 (58.8%) employed SGs in their research. And 204 articles in RS5 (29.1%) approached SGs from general perspectives.

Additionally, 321 articles (45.8%) described employment of two or more SGs affordances in their research. For instance, González-González and Blanco-Izquierdo (2012) analysed the evolution of educational video game design methodologies (RS1) and presented a SG prototype to teach human-computer interaction (RS2). Thavikulwat (1995) described a computer business gaming simulation for entrepreneurship education (RS2) and contended that "a gaming simulation should be evaluated on the extant it games defining processes with administrative ease" (RS3). Neset et al. (2020) presented a game for climate education (RS2) and applied their artefact with students to evaluate it (RS4). Andrés and Casas (2011) performed an experiment to collect students' perceptions of gaming as experiential learning (RS4) and reviewed the general advantages and drawbacks of using games in education (RS5).

Table 7 presents all these numbers in detail, cross-tabulating documents according to proposed streams. It presents the frequency of papers in each stream and in each intersection

TABLE 6 Research streams' identification sentences.

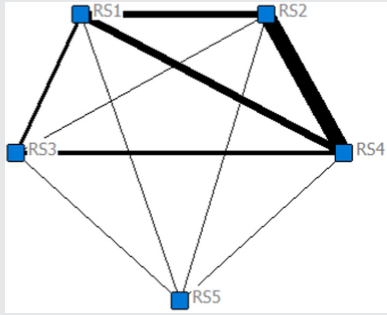
Stream	Sentence
Game Design Guidelines (RS1)	"We present a framework for the design of serious games in engineering education, with a specific focus on the definition of intended learning outcomes and the development of the corresponding game activities" (Urgo et al., 2022) "This paper presents a framework for serious game design, which aims to reduce the design complexity at conceptual, technical and practical levels" (Westera et al., 2008)
Game Design Cases (RS2)	"This study describes the design of a serious game for social change ('Fact Finders') that presents intergroup conflicts through historical inquiry and multiperspectivity" (Nicolaidou et al., 2022) "In the Loop was developed to provide an experiential learning situation for educating about material criticality and [Circular Economy] CE" (Whalen et al., 2018)
Game Experiment Guidelines (RS3)	"The evaluation of the performance of participants is generally subjective and is based on the trainer's perception of the importance of several evaluation criteria. In this paper, data envelopment analysis (DEA) is proposed for such evaluation. Input-oriented constant return-to-scale DEA models are used for evaluating the performance of teams participating in business simulation games" (Koltai & Tamás, 2022) "The [multivocal literature review] MLR allowed software practitioners and teachers to identify cutting-edge methods for evaluating SGs, application domains in which the assessments were carried out, and the main features considered for assessing the educational benefits of SGs" (Rodríguez et al., 2021)
Game Experiment Cases (RS4)	"The experiment has been conducted through the introduction of two simulators, Gestionet, in the undergraduate classroom, and Global Management Challenge (GMC), in the master's degree classroom" (Grijalvo et al., 2022) "In this paper, the experiences of university students ($n = 18$) playing an educational game, IT-Emperor, which was designed to facilitate flow experience, are studied through questionnaires and interviews" (Kiili, 2005)
Generalists (RS5)	"The main objective is to study the impact of games and simulations with regard to achieving specific learning objectives" (Vlachopoulos & Makri, 2017) "In this essay, the author looks back on 20 years of experience in simulation/gaming" (Ellington, 1994)

and displays the statistical significance of each relationship for every pair of streams in square brackets. Darker cells indicate a higher frequency, green figures denote statistically significant relationships, and red values signify relationships that lack statistical significance.

Nine main results emerged from Table 7, and based on them, three propositions can be suggested. First, the two most frequent streams were RS2 and RS4, with 412 and 236 articles, respectively. Second, RS2 and RS4 are context-dependent streams. Third, the RS2-RS4 relationship, which appeared in 185 articles, was the most common in the sample. It was also statistically significant. Therefore, this SLR suggests that (1) the examined literature is heavily context-based and mostly centred on designing SGs and using them as research tools.

Fourth, RS5 emerged as the third most frequent stream, with 204 articles. Fifth, RS5 exhibited significant relationships with all streams except RS3. Sixth, it is worth noting that the RS3-RS4 relationship was not statistically significant due to their correlation coefficient of 0.837. Seventh, RS3 was the least frequent stream, comprising 102 articles. In light of these findings, this study suggests that (2) research on SGs for EMHE could benefit from

TABLE 7 Cross-tabulation, network and statistical significance.

Count[sig.]	RS1	RS2	RS3	RS4	RS5
RS1	173	77 [0.000**]	44 [0.000**]	95 [0.235]	21 [0.000**]
RS2		236	22 [0.005**]	185 [0.000**]	4 [0.000**]
RS3			102	59 [0.837]	23 [0.115]
RS4				412	10 [0.000**]
RS5					204
Network					

**Correlation significant below 0.01 level (2-tailed).

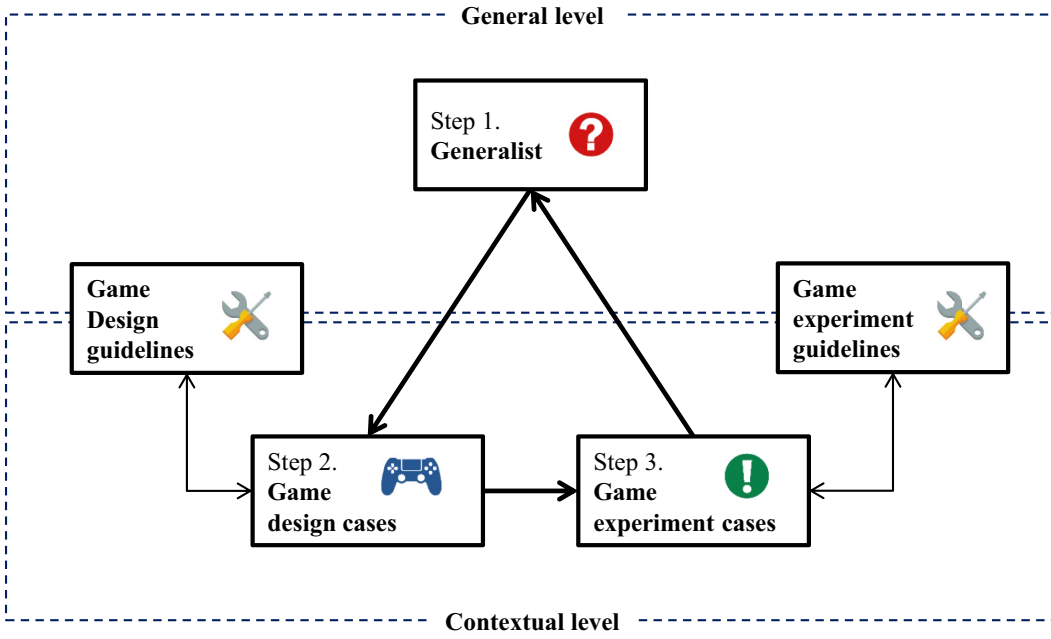


FIGURE 5 Serious Game research framework.

a stronger emphasis on methodological rigour in evaluation, which is currently an area of weakness in the existing literature.

Eight, Table 7 reveals that 7 out of 10 relationships in the data were statistically significant, with correlation values below the 0.01 level. Ninth, it is noteworthy that a discernible logical order can be inferred amongst the five proposed streams. This observation allows for the proposal of (3) a comprehensive SGs research framework, as depicted in Figure 5.

In short, SGs research can be synthesised by the proposed framework (Figure 5). The scientific processes using SGs can start with general problems to be investigated. These questions reside at the general level and can be found in publications from the generalist stream (RS5). Second, a SG can be contextually and purposefully designed (RS2), considering tools from the game design guidelines stream in the intersection between general and contextual levels (RS1). Third, a designed serious game can be employed as a research tool (RS4), guided by methodologies available in the game experiment guidelines stream in the intersection between general and contextual levels (RS3). In the end, once the experiment is rigorously performed, new knowledge can flow up to close de cycle, back to RS5.

The framework can also be applied to guide future research on SGs for EMHE comprehensively. To illustrate, a scholar aiming to advance the domain of SGs for an emerging and promising research area within EMHE, such as circular economy education, can apply the framework to formulate research questions. A question for the application of the generalist stream (RS5) in this hypothetical case could be: *What are the key general competencies to be developed through SGs in circular economy education?* Other questions that highlight the utility of the game design cases stream (RS2) and the game design guidelines stream (RS1) can be as follows: *What SGs have been created and employed to teach circular economy in EMHE? And what guidelines were used in their creation?* Lastly, questions that demonstrate the applicability of the game experiment cases stream (RS4) and the game experiment guidelines stream (RS3) can be: *What experiments have been carried out using SGs for circular economy education? And what guidelines were followed to conduct them?* Clearly, several other research questions can emerge from each stream. This short hypothetical scenario serves to illustrate how the proposed framework helps scholars to design their research within the identified themes. Table 6 and supplementary material D can also be referred to as sources that can inspire practitioners in terms of future research per each stream.

The next section revisits the research questions of this review and discusses the main findings considering previous related publications.

DISCUSSION

Theoretical implications

Regarding RQ1, seven main characteristics were identified (Table 2). Udeozor et al. (2022), Hallinger and Wang (2020) and Bodnar et al. (2016) also observed an increase in SGs scientific production. Hallinger and Wang (2020) also documented the global span of research, pointed to the multiple contexts of SGs research and to the diverse domains of management education interested in SGs and identified sustainability as an emerging topic in their field. Moreover, despite major differences from the work of Hallinger and Wang (2020), one of the most important identified authors, Wolfe, also converged. What this review added to RQ1 is the fact that, while the overall modern science—as represented by Bornmann et al. (2021) and including multiple knowledge areas from physical, technical, life, and health sciences—grows exponentially at an annual rate of 4.1%, the field of SGs for EMHE, investigated in this study, grows exponentially at an annual rate of 7.7%. Since modern science in general is exponentially growing, one could not argue that a specific field of the literature is significantly expanding without such comparison. In other words, the comparison demonstrates that the growth of scientific publications in the sample is higher than the growth of scientific publications in general. Thus, the interest in research within the investigated field is indeed prominent.

Considering RQ2, three thematic trajectories were offered (Table 5). The main convergent topics with previous works were: (1) acceptance of simulation and games as a valid method of

learning, ie, works on the acceptance of SGs and gamification from the perspective of students and professors (Hallinger & Wang, 2020); (2) digital transformation in education, including technology-enhanced games and simulations, eg, e-learning, computer games, virtual reality, virtual worlds, virtual learning environments, augmented reality (Hallinger & Wang, 2020; Udeozor et al., 2022); and (3) the emergence of sustainability as a contemporary and promising topic for future research in management (Hallinger & Wang, 2020). This SLR contributed to RQ2 by strengthening the presence of SGs design for education. Such contribution is important since design and evaluation appeared as the strongest activities in the investigated sample. Also, this SLR revealed the theme of sustainability as a trend in the field of EMHE.

Concerning RQ3, five research streams were identified (Table 6). *RS1 (game design guidelines)*, *RS2 (game design cases)* and *RS4 (game experiment cases)* converged to previous works. Udeozor et al. (2022) identified similar categories, ie, (1) "game presentation", including studies that presented design frameworks, design prototypes, and some evaluation of the games, which is similar to RS1, RS2, and RS2-RS4; (2) "game evaluation", including studies that evaluated "the usability of the game and the perceptions and experiences of students with games", which is similar to RS4; and (3) "game effectiveness", including studies that "measured the effectiveness of digital games for knowledge and skill acquisition", which is also similar to RS4. Furthermore, this SLR confirmed a gap indicated before, the RS3 gap. In Udeozor et al. (2022)'s words, "there is a need to go beyond evaluating usability to assessing the effectiveness of digital games for engineering education", and in Bodnar et al. (2016)'s words, "only a relatively small subset of the literature demonstrates *a systematic, validated approach in assessment*". Undetailed measures (Udeozor et al., 2022), lack of uniformity (Bodnar et al., 2016) and small sample sizes (Bodnar et al., 2016; Udeozor et al., 2022) of the assessment studies harm the replication and generalisation of results. In other words, the RS3 gap verified in this SLR confirmed the research limitations indicated previously. In Bodnar et al. (2016)'s words, "we also hope that guidelines and metrics are developed to help implement game-based learning and to measure and report the outcomes of this pedagogical tool". Finally, this SLR added a research framework as a contribution, extending previously identified streams and, most importantly, congregating them to offer a holistic view of the scientific process with SGs in EMHE. The proposed framework can be used by researchers as a lens to review SGs literature in different educational settings (Graphical Abstract) and as guiding steps to conduct comprehensive research in their fields (Figure 5).

Practical implications

Practitioners can benefit from this SLR. Designers and educators have access to supplementary materials where they can find categorised information on how to design SGs and encounter designed artefacts that can be applied in different educational contexts. Moreover, as SGs research is primarily applied, theoretical contributions, such as the proposed framework (Figure 5), also hold significance for practitioners. Unlike entertainment games, SGs inherently need to combine pedagogical and entertainment elements and objectives. Therefore, practitioners should always monitor theory development to enhance their tasks. Overall, seriousness and entertainment are two sides of one coin in SGs research, development and practice.

CONCLUSIONS

This paper presented an in-depth analysis of 701 documents related to SGs for EMHE. Through bibliometric analysis, a panorama of the literature was drawn, depicting the

conceptual and intellectual structures of the field. In short, the investigated literature has grown faster than modern science and is characterised as global, collaborative, appealing and highly context-dependent. Three thematic trajectories were provided. They reinforced the presence of design as a strong research topic and highlighted opportunities to investigate SGs for sustainability education. Through content analysis, the uses SGs afford in science were clarified. Results revealed five main research streams. The first one was *game design guidelines*, which comprised works that inform on how to design SGs. The second included *game design cases*. This stream contained reports on specifically designed SGs. The *game experiment guidelines stream* was the third, which encompassed papers about how to employ SGs in research. Finally, *game experiment cases* and *generalists* were the fourth and fifth streams that included, respectively, records on empirical research with SGs, and publications fostering generic discussions on SGs multiple topics. Cross-tabulation and network analyses supported the development of the research framework that can be used as a lens for specific contextual reviews and as a guide for future works in the field. Overall, an exploration of which sub-domains of sustainability can be more effectively addressed using SGs, and designs and evaluations of technologically enhanced SGs dedicated to sustainability in EMHE are indicated for future research. This should preferably be done following rigorous methodological procedures.

Finally, limitations must be indicated: First, the iterative process employed to identify synonyms was limited to the analysis of the top thousand positions of each output file. Future research can analyse more than a thousand keywords per iteration. Second, this review was limited to the choices of synonyms and related terms. It focused on Serious Games as artefacts, deliberately ignoring Gamification, Game-Based Learning, Simulation-Based Learning, Game-Based Teaching etc. A more comprehensive review can include these and other terms. Third, this review was limited by its filters. Publications from fields other than engineering, management and education can widen the scope, and possibly reveal new insights from other research areas. Other document and source types, and other languages can also be beneficial. Fourth, this investigation was bounded by the subjective process employed to read, analyse and classify articles. Lastly, this SLR utilised abstracts to induce categories. Since abstracts may not be complete, classifications can be enhanced if the full paper is analysed instead. Still, the careful analysis of 701 documents allowed in-depth identification of the affordances SGs have in scientific research.

ETHICS STATEMENT

This study followed all the ethical requirements set forth by the Polytechnic School of the University of Sao Paulo (USP) and by Aston University for a Systematic Literature Review.

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CONFLICT OF INTEREST STATEMENT

None.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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