Research on Serious Games: Bibliometric Study of Current Status and Future Trends

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Abstract **– Serious games are digital software for learning rather than for entertainment. They have been effective in different environments. Research on serious games has increased in the last decades; however, there is lack of studies on serious games scientific production. This study aims to determine research current and future trends regarding serious games. Specific objectives are: (1) To analyze the performance of literature, (2) To analyze collaboration networks, and (3) To analyze science mapping of serious games. It is a bibliometric study exploring the database Scopus. The authors used the specialized software VosViewer, Bibliometix, and ggplot2 in RStudio to process and visualize the data. Results show that scientific production is mainly addressed to using serious games in formal education. The fields with higher production were Environmental Sciences, Business, Management, Mathematics and Arts and Humanities. There is growing interest for research on serious games use and effectiveness; however, in some contexts, like Latin American countries, this production is scarce and must be enhanced. Areas for further research were identified; for example, the use of serious games to improve the employees' skills and decision-making. This paper contributes to better knowledge on the topic and sheds light on potential new topics for researchers.**

Keywords **– Bibliometrics, serious games, education, research trends, science mapping.**

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1. Introduction

Serious games are particularly designed for educational or skill-training purposes. Those purposes are achieved while the player enjoys them in the education context or during leisure time [1], [2], [3], [4]. They have also been defined as digital software for learning rather than for entertainment [5]. The use of serious games and their effectiveness has been studied across disciplines [5], [6], [7], [8]. Some authors affirm that serious games success is related to their influence on learners' mood and motivation [4], enhancing chances for learning [3] and because they offer opportunities for active exploration without real risks in case of making mistakes [9].

Serious games design and use rely on sound theoretical foundations. Cognitive psychology, social psychology, and human-computer interaction theories are outstanding frameworks in serious games research [10]. Besides, serious games design implies multidisciplinary work. The ideal context for serious games production includes experts in game design and development, experts in pedagogy, and subject-matter experts [11].

Serious games have spread across different disciplines, and they have been used to teach specific contents in formal education settings [7], to address social issues in vulnerable or problematic populations [12], [13], [14], and for the development of skills in the academic and professional environments [2], [8], [15]. However, in the last years, fast-changing information technologies have contributed to accelerated growth of serious games development in different fields and contexts [3], [13], [16]. In this sense, an updated view of the scientific production of serious games is helpful for showing the most exploited themes and identifying potential gaps in the development and study of serious games.

There is lack of research on serious games scientific production. Recently, [17] analyzed the scientific production on serious games in science education in the Web of Science (WoS) from 2016 to 2020. Kara's study limitation was the emphasis on just one subject area (i.e., social sciences education).

Also, [18] published an article based on the analysis of publications in Scopus from 1884 to 2019; however, they did not include science mapping analysis which was important for researchers to identify research opportunities.

Hence, this bibliometric study aims to map the production of research articles on serious games in the last five years in the Scopus database revealing current production and trends. Then, three specific objectives are proposed: (1) To analyze the performance of literature production of serious games; (2) To analyze collaboration networks; and (3) To analyze science mapping of serious games. The findings would help researchers and practitioners to have a current view of the field. They also identify gaps and future trends to propose new sound research on the use and effectiveness of serious games.

1.1. Serious Games

Serious games are the result of evolution in decades. In fact, [19] explains that serious games are the current expression of centuries of classic theories and practices. Serious games may combine traditional tools and technology [4], including Virtual and Augmented Reality.

Authors have proposed different classifications of serious games. For instance, [20] classified them in three types, namely: Role-playing games without required simulation of real situations, business games with simulation like a model of reality, and games that simulate reality. [4] classified them according to their therapeutic modality. They found exergames, computerized cognitive behavioral games, cognitive training games, and biofeedback games.

Some benefits of serious games are: An increased level of interactivity, adaptation to the users in terms of levels of competence, repeatability and constant feedback, enhancement of competitiveness, motivation through a sense of achievement [2]. Also, researchers have shown the need for understanding and integrating the serious game mechanics; that is, the relationship between pedagogy and game design [8].

Serious games must be designed to accomplish specific goals. Those goals determine most of their features, mainly their dynamics and aesthetics. For instance, games aiming to trigger and develop creativity need to include expressive choices, but if the goal is to develop critical thinking skills, the game should include the chance to make tactical choices [21]. Further, some games trigger motivation through competition while others enhance collaboration and team work [22].

Serious games are the product of a careful processes and rely on solid theoretical foundations.

Their development depends on several, namely: target audience, teaching topic and genre of the game [20]. A well-designed serious game needs to prove usability, utility and acceptability. These kinds of games are expected to have a good design to be pedagogically useful and attractive for the player and to fulfil the institution requirements [23]. Also, a serious game needs to motivate students to use it [4].

1.2. Serious Games Theoretical Cornerstones

Serious games differ from just videogames because the former rely on pedagogical theoretical foundations. There systematics reviews that have provided evidence on the preferred use constructivism (Piaget's theory or Vigostky's Social Constructivism) as the core theory underlying serious games [24], [25]. Constructivism-based approaches claim that students construct knowledge based on previous knowledge and through social interaction [24].

Constructivism theories are student-centered learning ones. It means that students play an active role in the learning process [26]. Constructivism states that experience and experimentation are essential to construct knowledge from the experience. Constructivism-based learning focuses on providing environments helpful for learners to actively explore complex topics and settings and to think as an expert in a specific area [27]. Serious games offer learners the chance to experience situations that enhance learning and knowledge construction in a motivating and enjoyable way.

Constructivism has served as base for the emergence of specific teaching approaches relevant for supporting serious games design and use in the classroom. The literature shows Constructive Alignment as a teaching framework combining students-centered activities for the construction of knowledge and teachers' actions to promote the achievement of appropriate learning activities to reach pedagogical goals [28].

Serious games use may also be supported by game-based learning which is a theoretical base for gamification and refers to the accomplishment of clearly stated learning outcomes through game content and play. This theory supports the presence of problem-solving situations to promote learning who are expected to experiment a sense of achievement [10] and it is compatible with constructivism because it creates an environment for the student to construct knowledge through experiencing challenges and solving problems on their own or in groups.

2. Methodology

This bibliometric study followed the methodological criteria suggested by [29] and [30] regarding data collection procedures and techniques for bibliometric analysis. The Scopus database was selected to gather the data because it includes journals worldwide under strict high-quality standards and very precise information to process for a reliable analysis [31].

2.1. Data Source and Collection

The search was performed in May 2023 and included only the production of research articles like in previous studies [32], [33]. The search was based on the following inclusion criteria:

- Presence of the keyword "serious games" in the title. The selection of this keyword was made considering results in previous bibliometric studies in which it showed the highest presence [18].
- Document type (research article). Peer-reviewed scientific articles have been considered the main vehicle to share scientific information [34], [35], [36], [37]. They have resulted in the most frequent document type in scientific production [5], [32] and unit of analysis in previous bibliometric studies of serious games [33].
- Source type (journal).
- Year of publication (2019-2023). To avoid bias, production for 2024 was not considered because the year has not ended.

Then, the search string was:
TITLE-ABS-KEY ("serious games")
AND (LIMIT-TO (PUBYEAR, 2023)
OR LIMIT-TO (PUBYEAR, 2022)
OR LIMIT-TO (PUBYEAR, 2021)
OR LIMIT-TO (PUBYEAR, 2020)
OR LIMIT-TO (PUBYEAR, 2019))
AND (LIMIT-TO (DOCTYPE, "ar"))
AND (LIMIT-TO (SRCTYPE, "j")).

This search resulted in 1,924 papers. To avoid bias for duplicated information, initially, all titles were analyzed with the software Rayyan™. No duplicates were observed. To avoid content bias, abstracts were read to confirm that they directly reported research on serious games study. After this revision, all the 1,924 research papers were considered for the analysis.

2.2. Data Visualization and Analysis

The information was processed with VosWiewer (version 1.6.19) and the bibliometric package Bibliometrix Biblioshiny for RStudio (version 4.2.3).

That software combination offers a comprehensive view (both qualitative and quantitative) of bibliometric information, including tracking the evolution of themes across time [30], [38]. Three bibliometric analysis techniques were used: Performance analysis (to know details on contributions; e.g., authors, affiliations), network analysis (e.g., collaborations between authors and institutions), and science mapping (for citations and thematic trends) [29].

3. Results

Details on the scientific production analyzed are shown in Table 1. It can be observed that a total of 1,924 research papers published between 2019 and 2023.

Table 1. General information regarding sources, authors, and collaborations

Description	Results
Sources (Journals)	772
Period	2019-2023
Documents	1924
Document Average Age	2.17
Average citations per doc	5.89
References	99362
Authors	7350
Authors of single-authored docs	107
Single-authored docs	119
Co-Authors per Doc	4.67
International co-authorships %	28.95

The analysis yielded growing interest in serious games since 2019. That increase has not been constant. It was lower between 2020 and 2021, but increased again between 2021 and 2022. A projection indicated that the growth in 2023 seems similar to 2021 (n= 217). This indicates that the interest of researchers on the topic is still growing.

3.1. Most Influential Sources and Fields

Performance analysis started with the analysis of the most representative sources. The analysis showed 25 journals that have published research articles about serious games in the last five years. The top ten sources are presented in Figure 1. *Jmir Serious Games* is the journal with more publications (90 papers over the closest).

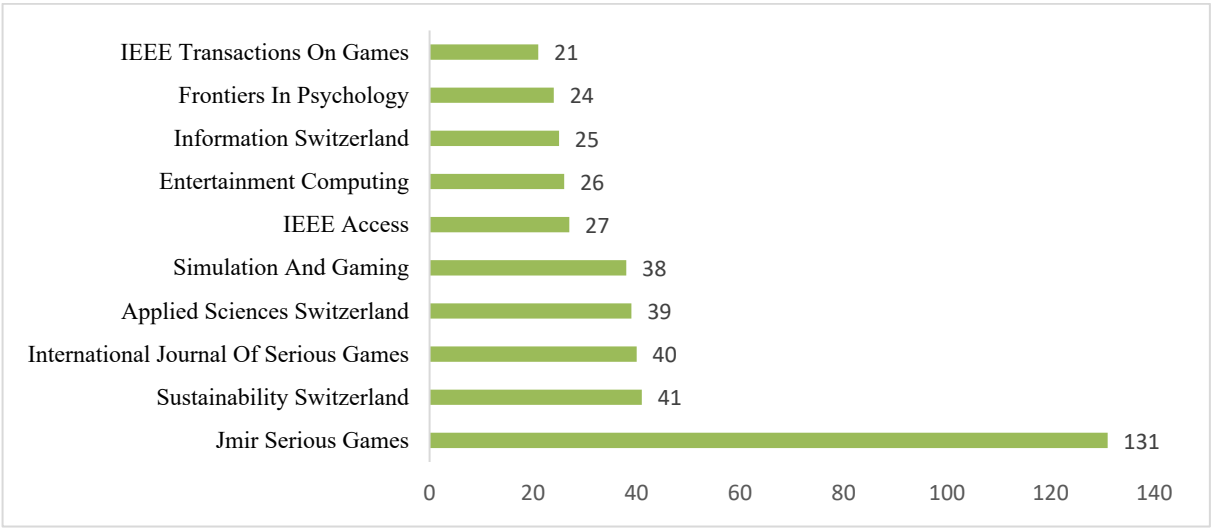

Figure 1. Overall production by journal (January 2019- March 2023) (own elaboration)

The analysis of the increase in publication over time was performed for the top five journals from Figure 1. All of them have strongly influenced the field and show a constant average increase in papers published per year: JMIR Serious Games (n= 35), Sustainability (n= 12), International Journal of Serious Games (n= 13), Applied Sciences (n= 11), and Simulation and Gaming (n= 8).

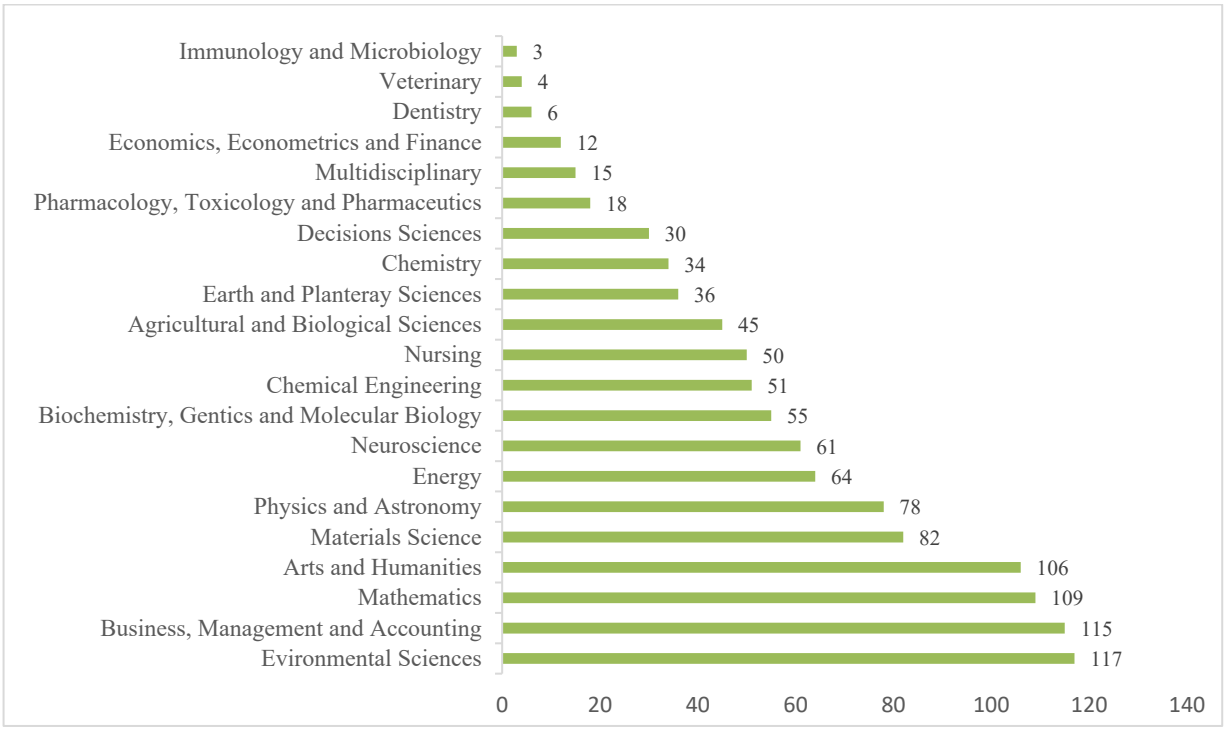

Figure 2. Publications per field or area (own elaboration)

Serious games have been proposed in different scenarios. Then, it is not surprising that researchers have published studies on their use and effectiveness in 27 subject areas (Figure 2). The highest production was found for science (n= 840), social sciences (n=701), engineering (n= 564), and medicine (n= 482).

3.2. Most Influential Authors and Institutions

The analyzed papers showed 7350 authors. Most of them have published one (n= 6196) or two (n= 686) papers. The ten most influential authors were identified and their production rate and impact were analyzed. Five of them published 10 or more papers since 2019 (average of 2-2.5 papers a year). Details on citations and bibliometric indexes for the top ten authors are shown in Table 2.

Table 2. Ten most influential authors

	Index				
Author	**h**	**g**	**m**	**TC**	**Papers**
Fernández-Manjón B	7	12	1.4	230	12
Alonso-Fernández C	6	12	1.2	217	12
Calvo-Morata A	6	11	1.2	206	11
Freire M	6	10	1.2	207	10
Martínez-Ortiz I	6	10	1.2	220	10
Almeida F	5	9	1	135	9
Booth L	5	5	1.25	67	5
Liu L	5	5	1	68	5
Xinogalos S	5	9	1	83	11
Abad J	4	4	1	61	4

Note: TC (total citations)

All the authors in Table 2 showed a stable production. The most cited author registered 12 papers and 230 citations (h index= 7). The 89 papers published by these ten authors are 4.6 % of the total. Apart from these authors, other 7340 published either single or co-authored documents, with 28.95 % of international co-authorship.

The analysis of co-authorship by country revealed only seven countries that formed team works with others. VosViewer analysis showed two clusters. The first one included the United States, South Corea, Singapore, and Belice; whereas the second showed collaboration between Australia, Colombia, and France.

Only one country from the first cluster (USA) showed one collaboration with another from the second (Australia).

The authors represented 2577 organizations. Among them, 66.39 % institutions (n= 1711) reported just one paper and only 2 % (n= 52) has produced ten or more. Table 3 shows the ten most influential institutions.

Table 3. Affiliations reported by authors in single and co-authored papers

Affiliation	**Country**	**Papers**
Aristotle University of Thessaloniki	Greece	27
Mcmaster University	Canada	21
University of Groningen	The Netherlands	21
Complutense University of Madrid	Spain	19
Mcgill University	Canada	19
University College London	United Kingdom	19
University of Alberta	Canada	19
University of Twente	The Netherlands	19
Delft University of Technology	The Netherlands	18
The University of Auckland	New Zealand	18

The top five institutions showed an increase in publications which indicates a growing interest in the topic (Figure 3). This revealed a trend for those institutions and shows a path for researchers aiming potential interinstitutional collaborations.

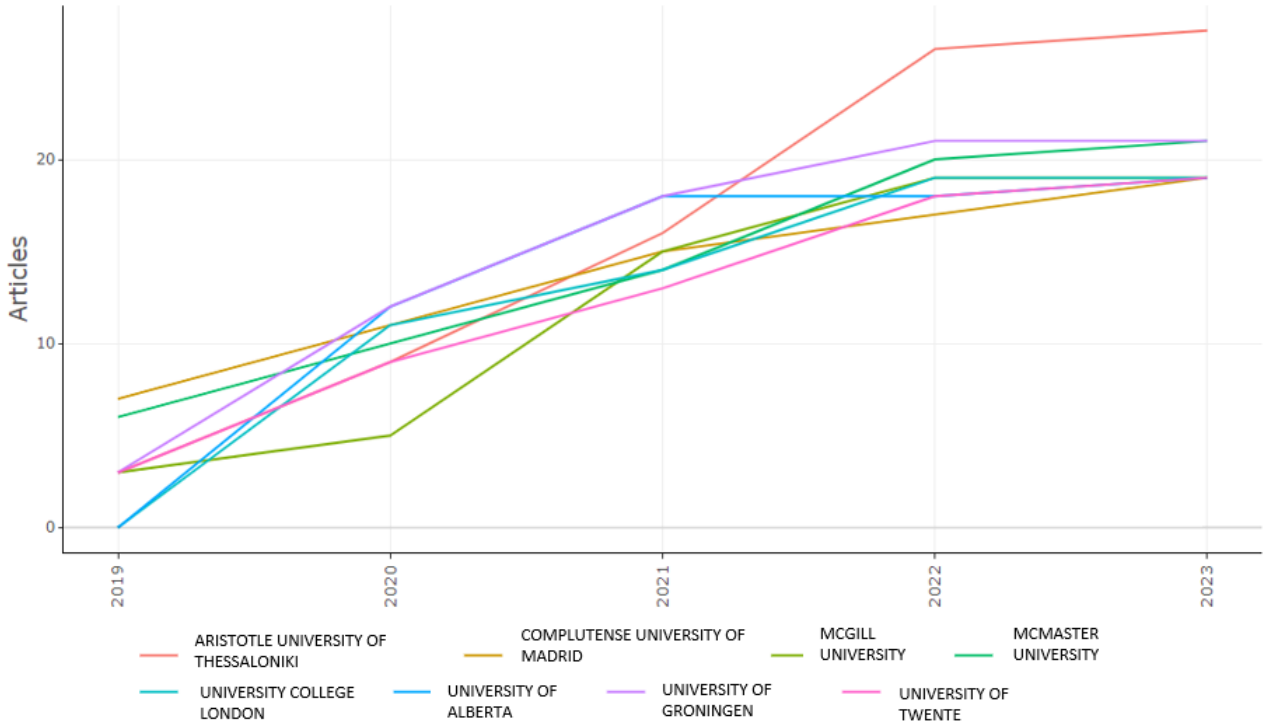

Figure 3. Production of institutions over time (own elaboration).

Regarding citations, 1440 papers were cited, with an average of 7.87 citations per document (ranging from 1-205). Even when Spain is not the country with more publications among all, it showed the highest citation scores (1239), followed by the USA (873), Italy (709), and the Netherlands (684).

The overall four most cited articles were systematic reviews of serious games in the context of education. Details for the ten most relevant documents worldwide are presented in Table 4.

Table 4. Ten most cited papers

DOI	TC	TC/ Year	Norm TC
10.1007/s11042-019-08348-9	205	51.25	22.02
10.30935/cet.554469	86	17.20	7.49
10.1016/j.chb.2021.106963	84	28.00	16.28
10.1016/j.compedu.2019.05.003	84	16.80	7.32
10.1016/j.ecns.2019.02.002	78	15.60	6.79
10.3389/fneur.2020.00926	73	18.25	7.84
10.1016/j.compedu.2019.103612	70	14.00	6.10
10.1016/j.enbuild.2019.05.009	61	12.20	5.31
10.1109/ACCESS.2019.2916324	61	12.20	5.31
10.1016/j.culher.2019.12.004	56	14.00	6.01

Note: TC (total citations)

3.3. Author's Keywords and Co-Occurrences

The term 'serious games' was the most common keyword (n= 521, 9 %) followed by 'human' (n= 440, 7 %), 'female' (n= 378, 6 %), and 'male' (n= 376, 6 %).

The software VosViewer helped to analyze keywords co-occurrence (Figure 4). Three main clusters were observed. However, few words co-occur with all from the other cluster. Those keywords were: Serious games, education, computer games, and students.

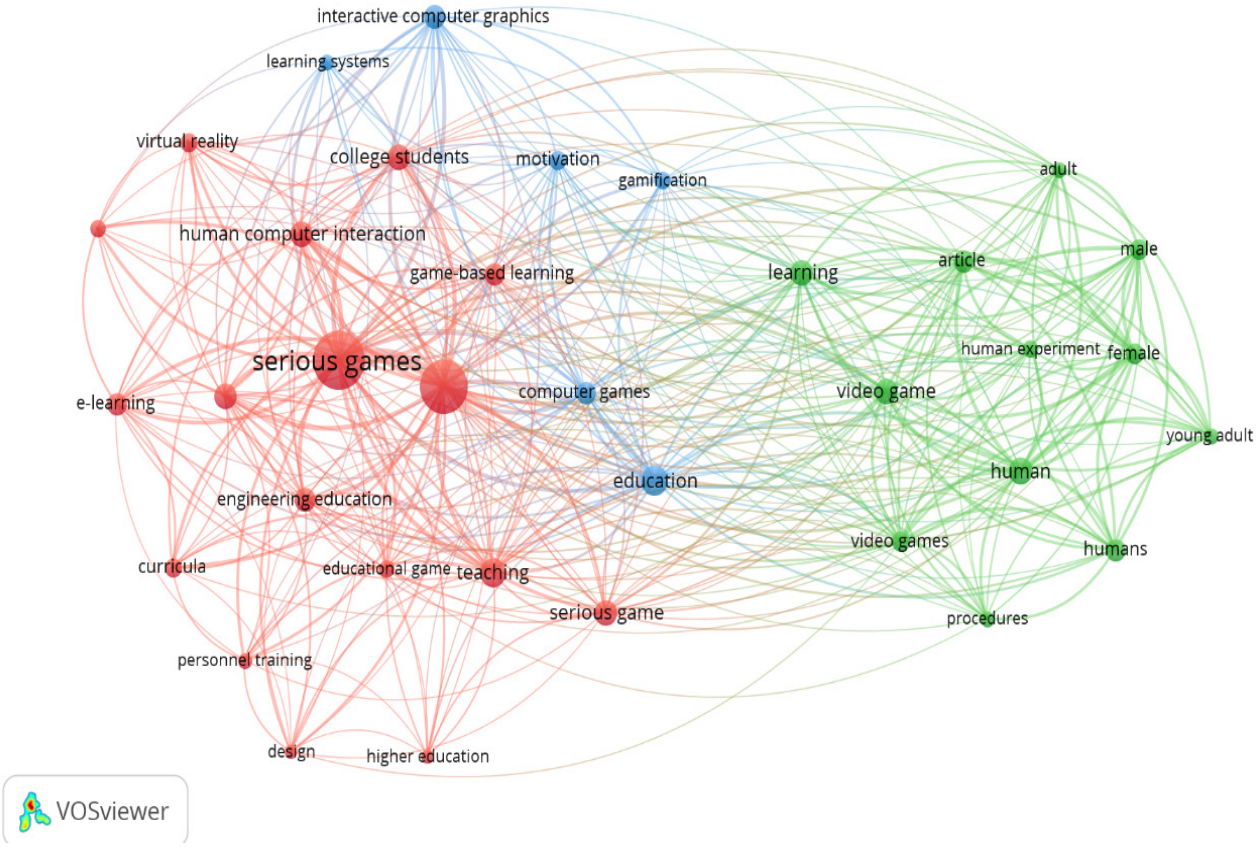

Figure 4. Authors keywords co-occurrence (own elaboration).

The red cluster in Figure 4 included words dealing with educational issues. The green cluster was related to methodological or procedural issues of the studies like samples (e.g., young adults, males, and females) and study conditions (e.g., video games, human experiments).

Finally, the blue cluster was related to computer themes like strategies (e.g., gamification), tools (interactive computer graphics), and their effects (e.g., motivation).

3.4. Current and Futures Trends in Serious Games Research

For the conceptual analysis, the author created a thematic map with RStudio and ggplot2. This map lets the reader know basic, motor, emerging or declining, and niche themes in the field (Figure 5). In the thematic map, those themes are distributed according to centrality (the extent to which a keyword network interacts with others) and density (internal strength of keywords networks; that is, how closely they relate to each other).

According to this distribution, motor themes represent well-developed topics that serve as structuring themes, niche themes are peripherical and specialized ones, emerging or declining themes are those with low density and centrality; finally, basic themes represent those being important, but with scarce development in the field.

The analysis showed that themes were distributed only in two quadrants (motor themes and emerging and declining themes). Motor themes were represented by four clusters mainly oriented to using serious games in formal educational contexts. Authors have focused on the study of the effectiveness of serious games in learning environments with undergraduate [39] and graduate students [8] for learning a variety of contents [7] and the development of different skills [6], [20]. Those studies have included virtual reality and medical education.

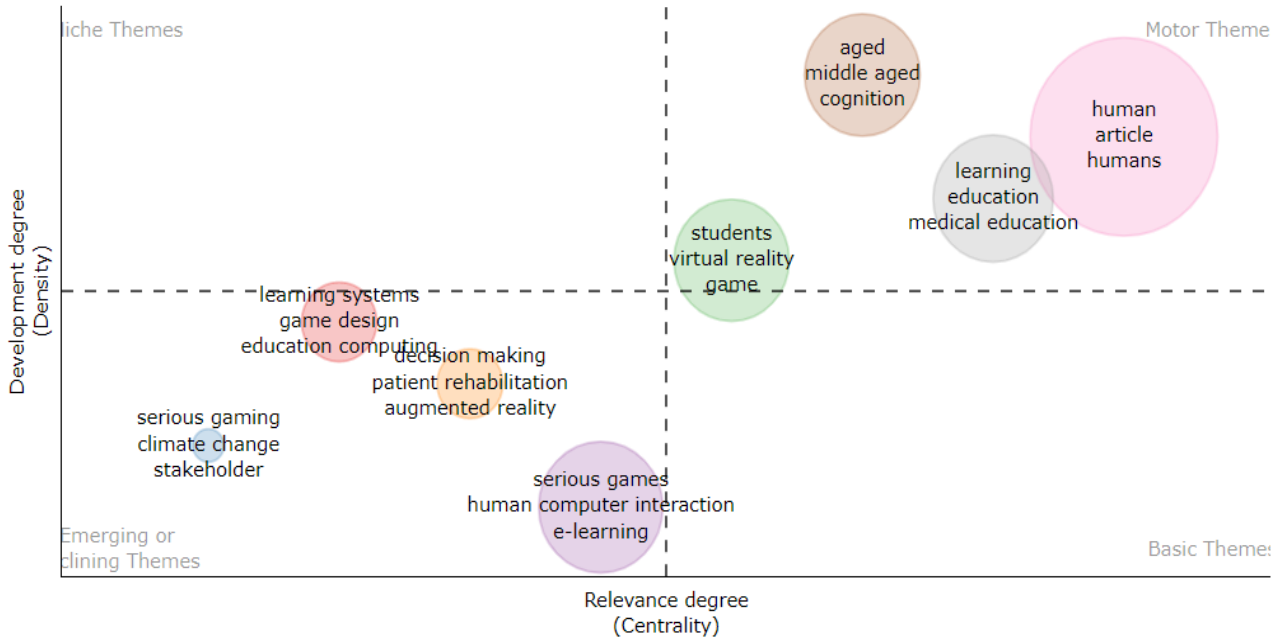

Figure 5. Thematic map for serious games research (own elaboration).

Emerging topics are summarized in four clusters. Those include the study of serious games outside educational and clinical contexts. The first cluster, 'serious games and climate change' represented the approach of serious games for educating people on environmental care issues [40]. The second one, 'decision making associated with serious games', included decision-making itself [41], the incorporation of emerging technologies for the design and application of serious games [15], [42], the study of game design to face new challenges according to users and environments [43], the study of design features and their effect on learning [44], proposals to assess serious games [23], and the effectiveness of serious games to train professionals, like policemen [2] and managers [45], to improve their practice through proper decision making. Finally, the cluster 'serious games for medical purposes', included the use of serious games for educating patients with special health conditions, under treatments or in rehabilitation processes [46], [47], [48].

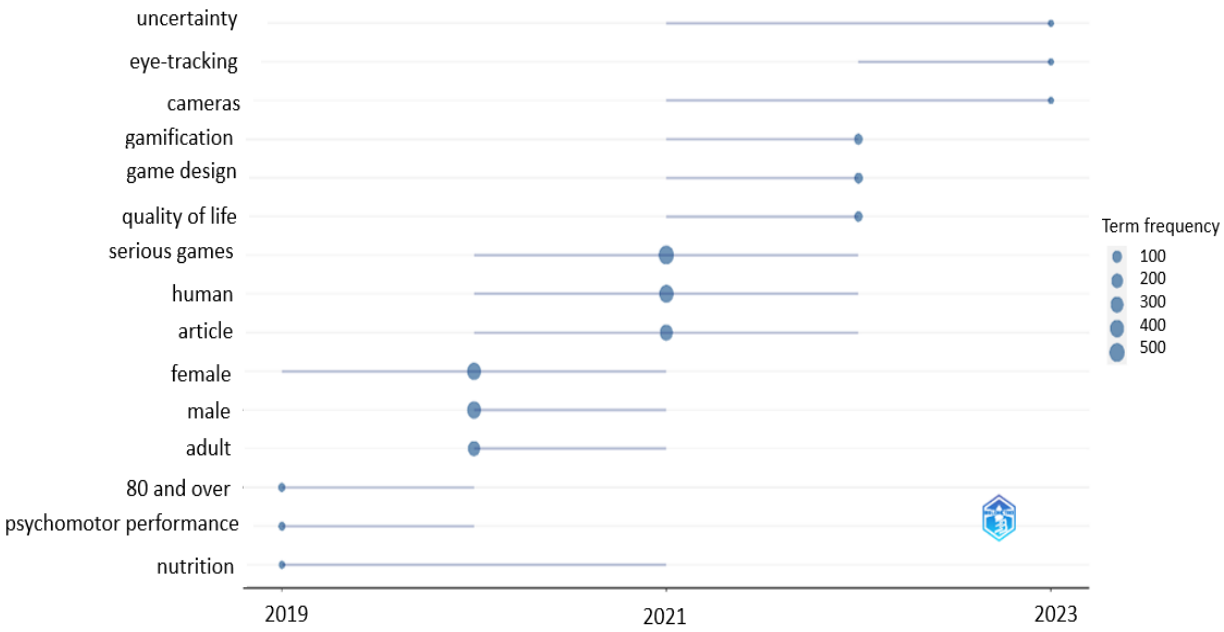

Figure 6. Main trend topics in the studied period (own elaboration).

For a more precise prospective view, the analysis of keywords over time was performed to track trend topics (Figure 6). It indicated that terms like 'eye tracking', 'uncertainty', and 'cameras' have recently been incorporated and have become new thematic trends in the last years of the studied period [49], [50], [51], [52]. This information suggests relevant technological and conceptual advances in the field of serious games and provides valuable clues for future research.

4. Discussion

The study of scientific production through research articles can show the trends of research interests within a homogeneous context. This bibliometric study analyzed scientific production on serious games in the Scopus database though performance analysis, collaboration networks, and science mapping. The results indicate a growing interest in the issue, highly consolidated themes and a variety of emerging ones.

Scientific production is mainly addressed to using serious games in formal educational contexts. This finding is consistent with previous studies with data obtained from the WOS database [17] and Scopus [18].

The areas of education with more publications in the present study were science, social sciences in general, and engineering, which is also consistent with [18]. This shows researchers and practitioners' interest in serious games to enhance students' abilities in different fields. This finding also suggests gaps on serious games research in other specific teaching contexts; for example, foreign languages.

Serious games have evolved and new technologies have opened new possibilities for formal instruction [53], [54]. In this sense, as technologies offer opportunities for enhancing serious games, more research on serious games in educational contexts is expected.

The ten most influential authors registered high citation scores. That means they are experienced in the study of serious games, and their work is influencing the field. Then, they are highly recommended for those interested on serious games research. The low percentage of international collaboration may be an indicator of the preference for the study of local contexts in which co-authors networks belong to the same institutions or different institutions from the same country.

The list of more influential countries and institutions did not include any from Latin America. This scarce research on serious games in Latin America could be associated to a technological innovation gap in the region. Serious games may be powered by emerging technologies such as virtual reality and artificial intelligence to create interactive and educational experiences [15], [54]. The low development of these games in Latin America could mean a lack of adoption and use of these technologies in the region. Hence, more research on the issue in Latin America is recommended.

Serious games and climate change designed for academic instruction [55], [56] and for other contexts outside educational institutions [40], [57], [58] were outstanding emerging themes. The use of serious games for medical/therapeutical purposes is also a promising research field.

The analysis indicated that serious games use and study goes beyond classrooms and labs. In that vein, the observed trends are related to the improvement of quality of life for patients with different health conditions [42], [48], [51] or under medical therapy and treatment [47], [52], [59]. This finding underscores the need for additional research to better understand the specific benefits and best practices in the clinical implementation of serious games.

Other emerging theme is the use of serious games to improve the employees' skills and decision-making. This finding has also been reported in previous studies for engineering [9]. However, the present bibliometric study showed scientific production in other scenarios like business, management and officers training [2], [41], [45]. The diversification in the application of serious games indicates the recognition of their effectiveness in professional and organizational development. It also shows a growing demand for innovative tools to improve work performance and promote efficiency in different arenas. These findings highlight the need for further research on serious games use in work settings and the importance of adjusting these tools to the specific needs for continuous training of professionals in service.

The results are consistent with [60] concerning the need for the study of serious games design. Certainly, this theme needs further research because technology offers more options to improve them and to propose new games for a wide variety of needs. Serious games need to be motivating, challenging and simple. For example, [59] claim that games for patients under therapy need to be challenging, but simple to avoid frustration. This emerging topic was also observed through the thematic and keyword analysis and is consistent with the qualitative analysis performed by [16].

5. Conclusion

The scientific production of serious games shows a constant increase in the last few years. The evidence found in the present study indicates that research on serious games is spreading in terms of quantity and fields; however, for some geographical contexts (e.g., Latin American countries) this production is scarce and must be enhanced.

Serious games were initially approached in the context of formal education for teaching and learning academic content. Nowadays, they are being used beyond those borders. They are being designed and studied to address social problems (e.g., genre violence and climate change), to promote self-care, to enhance therapies effectiveness, and for in-service training. All those fields are promising for further research.

Also, the evolution of the themes seems to justify the future bibliometric assessment of research on serious games in the short term to keep on track with the issue. Further bibliometric studies might also be more specific-field oriented; for instance, about the use of serious games to learn academic content of different subject areas, to enhance employees' competencies or about the effectiveness of serious games to train patients for self-care of chronic diseases, among other. In this sense, it would be possible to get a deeper and complete understanding of the subject for more specific purposes.

This paper reveals relevant information about the scientific production of serious games in Scopus. The study stated that there is enough evidence for researchers to perform systematic reviews and get a comprehensive qualitative appraisal for informed decision-making regarding specific topics related to serious games.

Even with Scopus, representing a prestigious and outstanding database, the analysis of only one might be seen as a limitation. Future studies addressing other important databases like the Web of Science would be helpful for a more complete view of scientific production on the issue. Also, comparative studies would be useful to know which database includes more information about serious games.

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