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A scientometrics analysis and systematic review of STEAM education with gamification

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Abstract

This scientometric analysis and systematic review methodologies examine the integration of gamification into steam education from 2017 to 2023. We collected data from the Scopus database. The study employed content analysis to evaluate 34 articles published during the past 7 years. The aggregate magnitude and trajectory of publications. The study examined trends in terms of annual accounts, number of articles, distribution of articles by sources, most productive sources, keywords, top collaboration groups, theme evolutions, contributions, practical consequences, and conceptual framework. The findings revealed the publication of 34 papers across 30 sources between 2017 and 2023, offering significant insights into the data and document formats. The research on steam with gamification revealed fluctuations, alternating between deceleration and positive acceleration. The articles experienced their highest growth rate in 2022. "CEUR workshop proceedings" is the primary source for the most frequently published articles. We request the keyword Plus growth rate for phrases such as "computer-aided instruction," "e-learning," and "embedded systems." The analysis's findings on thematic evolution unveiled three significant advancements: (1) Studies in science and technology have shifted their focus towards steam education. (2) Research on learning environments has expanded to include further investigation into stem education and the integration of science and technology. (3) School students' research has evolved and merged with the study of the learning process. The outcomes, contributions, and real-world significance of incorporating gamification into steam education. The conceptual framework ultimately fosters the development of creativity, problem-solving skills, and innovative abilities.

Keywords: STEAM, STEAM education, Gamification, STEAM and gamification, Scientometrics analysis, Systematic review, Scopus.

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Contents

Contribution of this paper to the literature
The Scientometrics Analysis and Systematic Review of STEAM Education with Gamification shows the trends of STEAM Education with Gamification, directions for applying STEAM Education with Gamification, number of articles, distribution of articles by sources, most productive sources, keywords, top collaboration groups, theme evolutions, contributions and practical consequences, and conceptual framework.

1. Introduction

Lately, there has been a notable increase in the implementation of gamification in the realm of education, particularly in the subject of STEAM education. Researchers have conducted several systematic reviews and meta-analyses to investigate the effects of gamification on student engagement, academic achievement, and motivation. Previous studies have confirmed that gamification is a valid educational method that can improve student performance (Camacho-Sánchez, Manzano-León, Rodríguez-Ferrer, Serna, & Lavega-Burgués, 2023; Manzano-León et al., 2021). Recent research has revealed that integrating game components and design strategies into educational settings enhances student enthusiasm, commitment, and academic performance(Nadi-Ravandi & Batooli, 2022; Ruipérez Valiente, 2022). Nevertheless, further investigation is necessary to fully grasp the obstacles and prerequisites faced by students while employing gamified learning methods (Zeybek & Saygı, 2024). Moreover, the field of applying game elements in science education lacks a sufficient amount of academic literature and presents conflicting findings. This emphasizes the importance of conducting more empirical research and exploring new areas of interest in the future. A thorough analysis of the incorporation of gamification into STEAM education, using scientometric and systematic methods, would provide valuable insights on the effectiveness and impact of gamification on students' academic performance.

The application of bibliometric analysis and other scientometric techniques (Supriyadi, Turmudi, Dahlan, & Juandi, 2023; Wang & He, 2022) has provided valuable insights into research trends and productivity in the field of STEAM education. Santi et al. (2021) provide strategies that entail analyzing the publication trends, influential authors, affiliations, and countries that make contributions to the topic. An analysis of the literature on STEAM education using bibliometric methods found that the number of publications has been increasing at an annual rate of 24.19% (Singh, Solkhe, & Gautam, 2022). Additionally, the study acknowledged notable contributors like Piperopoulos and Perignat, and identified Jeju National University and the Korea National University of Education as among the most significant institutions (Jetsadanuruk & Chansanam, 2023). Examinations of bibliometric data reveal that the most commonly studied subjects in the field of digital literacy in higher education are the incorporation of digital technology and the consequences of the COVID-19 pandemic. Bibliometric analysis provides academics with useful insights into the STEAM education research environment. It helps them understand patterns, identify important contributions, and guide future research efforts. Conducting systematic reviews involves several important steps, including defining the clinical question and methodology, identifying and analyzing relevant studies, collecting data, assessing the risk of bias in the included studies, conducting qualitative and quantitative analysis, assigning a level of certainty to the evidence, and drawing conclusions. These approaches are considered optimal for conducting systematic reviews (McKeown & Mir, 2021). Farhat et al. (2022) identified Ovid, Covidence, and Rayyan as the most accurate electronic tools for identifying and removing duplicate references.Moreover, researchers can gain advantages from the integration of a Visual Analytics system that combines interactive visualizations and artificial intelligence. This integration facilitates the implementation of complex protocols and analysis during the review process (Sina & Nazemi, 2022; Sobieraj & Baker, 2021). Practitioners must use critical appraisal methods and carefully consider the quality of the systematic review before applying the evidence (Boaye & Zhao, 2022).

Systematic reviews and scientometric methodologies improve understanding of STEAM education by providing valuable information on its prevalence, implementation, and trends. These methods aid in identifying the practical uses of developing technology in STEAM education, such as integrating art and utilizing innovative tools and components. Furthermore, they prioritize the cultivation of skills in data management, problem-solving, creativity, critical thinking, and communication. The examination of scientometric data reveals the efficiency of different nations and the subjects within the realm of STEAM education that have yielded the highest amount of research. Systematic reviews highlight the need to perform carefully designed intervention studies that involve collaboration among experts from different fields and utilize advanced measures to assess educational outcomes. The aforementioned methodologies aid in identifying gaps in the existing knowledge and provide opportunities for further exploration in the field of STEAM education (Juca-Aulestia et al., 2021; Marcelo, Deyanira, Margoth, & Jacinto, 2021; Nurhasnah, Festiyed, & Yerimadesi, 2023; Santi et al., 2021). Scientometrics and rigorous evaluations of STEAM education are vital for several reasons. Scientometrics is a field that focuses on quantitatively studying scientific literature. It helps us map and analyze STEAM education research pattern. The analysis provides data regarding the productivity of authors, nations, and the most extensively researched issues (Aguilera & Ortiz-Revilla, 2021; Juca-Aulestia et al., 2021; Santi et al., 2021). Furthermore, thorough literature reviews facilitate the identification and synthesis of current research pertaining to educational interventions rooted in STEM and STEAM disciplines. The evaluations by Marcelo et al. (2021) and Kwan and Wong (2021) provide a thorough analysis of the different approaches and methods used in STEM and STEAM education, as well as their effects on students' creativity and resourcefulness. Systematic evaluations enable researchers to offer evidence-based recommendations for improving and implementing STEAM education. These recommendations might cover various aspects such as curriculum development, learning settings, and teaching methods. Overall, the application of scientometrics and systematic reviews improves the quality and advancement of STEAM education by providing insights into research trends and integrating evidence-based methods.

This study aims to conduct a comprehensive scientometric analysis and systematic review of the intersection between science, technology, engineering, arts, and mathematics (STEAM) education and gamification. This research will span the years 2017 to 2023, exploring the growth, impact, and trends within the field. By analyzing data obtained from Scopus dataset, this research aims to address eight research questions (RQs):

RQ1. What is the overall volume and growth pattern of publications in the steam education with gamification literature?

RQ2. What are the leading publications in the field of steam education with gamification?

RQ3. Which are the top sources (journals, book series, conferences) in steam education with gamification literature in terms of volume of publications and citations?

RQ4. What are the keywords plus in the steam education with gamification?

RQ5. In terms of publication, who are the top collaboration groups in the steam education with gamification literature?

RQ6. What are thematic evolutions of steam education with gamification?

RQ7. What are the contributions and practical implications of steam education with gamification?

RQ8. What is the conceptual framework of steam education with gamification that aims to cultivate innovators?

2. Research Methodology

2.1. The Approach

This investigation aims to develop a novel approach to integrating scientometrics and systematic review using PRISMA 2020. This approach is both essential and suitable for investigating underexplored subjects and the evolution of educational technologies (Chen, Zou, Kohnke, Xie, & Cheng, 2021). Therefore, we apply scientometrics to demonstrate the descriptive analysis and thematic evolution prior to disclosing the systematic reviews (Santana & Cobo, 2020). Scientometrics are followed by the presentation of the systematic review conducted in accordance with the PRISMA 2020 recommendations (Brennan & Munn, 2021). Figure 1 depicts the PRISMA flowchart that guides the article selection process.

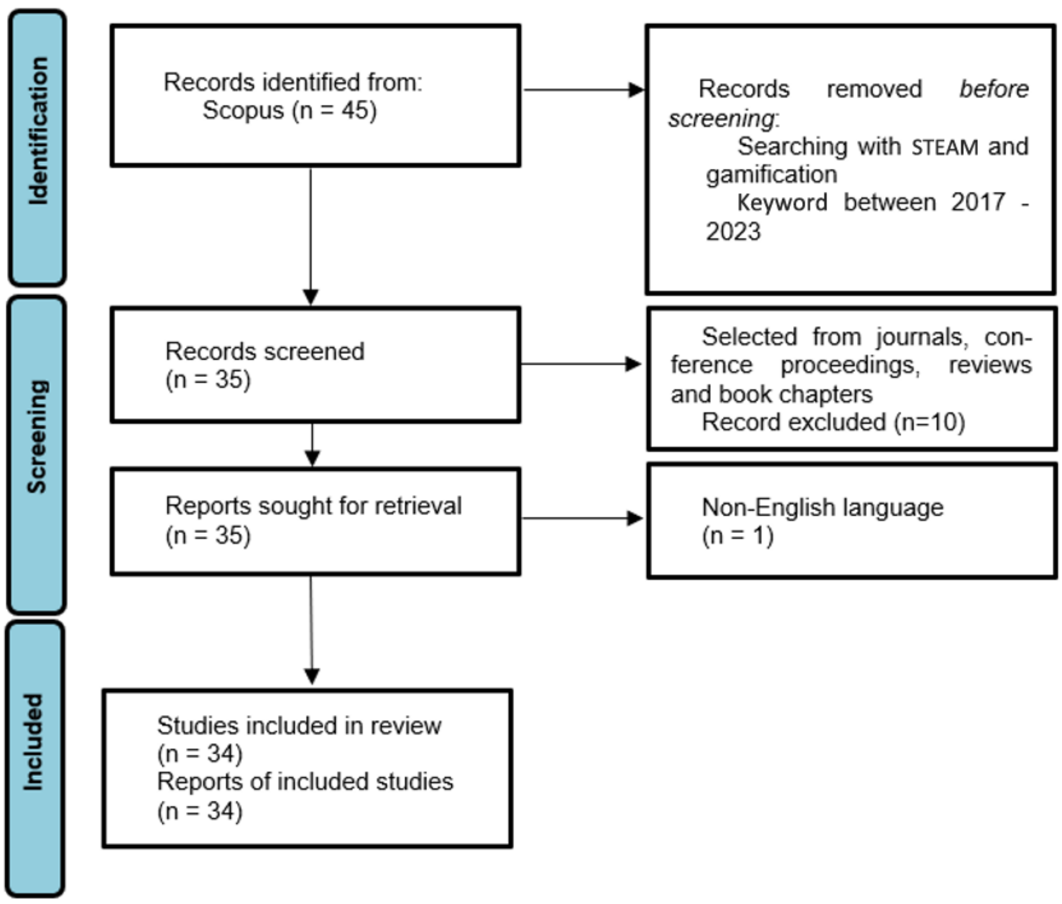

Figure 1. PRISMA 2020 of article selection.

2.2. Database, Keyword Selection and Date of Search

The terms "STEAM" and "STEAM education" are commonly employed to refer to the fundamental development of an "integrated approach to learning" within the context of the integrated knowledge process. We evaluated their applicability to gamification in tandem with the development of STEAM education. Therefore, to align with the study's objective, we used three keywords ("gamification") and "STEAM" or "STEAM education") to narrow down the search to relevant literature sources in the SCOPUS database. The preliminary search outcomes as of November 7, 2023, indicated that the SCOPUS database contains 45 indexed documents.

2.3. Inclusion and Exclusion Criteria

The research excluded supplementary materials such as conference proceedings, book chapters, and review articles, because of their non-English language publication status. Therefore, for the study, a total of 34 articles were included, all of which were published in peer-reviewed journals that were indexed in SCOPUS.

2.4. Tools and Techniques

For the scientometric analysis of the 34 articles chosen for the study (Khokhlov, 2020) the Bibliometrix package (Aria & Cuccurullo, 2017) implemented in the R programming language (Chan, 2018) was utilized (Chan, 2018). The following section provides the results of the analysis.

3. Descriptive Analysis

The articles utilized in this investigation are summarized in Figure 2 and Table1. An analysis of the data reveals that 30 sources published a total of 34 articles between 2017 and 2023. The research on this topic exhibits limited collaboration, with an average of 2.62 authors per paper and a total of 81 authors. There were only four documents that had a single author. The descriptive analysis yielded another crucial aspect: the mean number of citations per document. In this corpus, the mean number of citations per document is 4.588, indicating that articles published in this domain receive very few references. The subsequent part presents the document's content, including the author's keywords (n = 139) and Keyword Plus (n = 237).

Figure 2. The descriptive summary of article selection.

Table1. Main information.

Description	Results
"Main information about data"	
"Timespan"	2017:2023
"Sources (Journals, books, etc)"	30
"Documents"	34
"Annual growth rate %"	4.91
"Document average age"	2.62
"Average citations per doc"	4.588
"References"	841
"Document contents"	
"Keywords plus"	237
"Author's keywords"	139
"Authors"	
"Authors"	81
"Authors of single-authored docs"	4
"Authors collaboration"	
"Single-authored docs"	4
"Co-authors per doc"	2.79
"International co-authorships %"	5.882
"Document types"	
"Article"	13
"Conference paper"	21

3.1. Annual Scientific Production

Only three studies specifically addressed the integration of STEAM with gamification in 2017. Nevertheless, the number of articles has risen to 6 in 2019, 7 in 2020, 4 in 2021, and 8 in 2022. By November 2023, a total of four articles had been published. Hence, the findings from the yearly scientific output (Table 2 and Figure 3) substantiate the increase in research enthusiasm within this field throughout 2022.

Table2. Annual scientific production.

Year	Articles
2017	3
2018	2
2019	6
2020	7
2021	4
2022	8
2023	4
Total	34

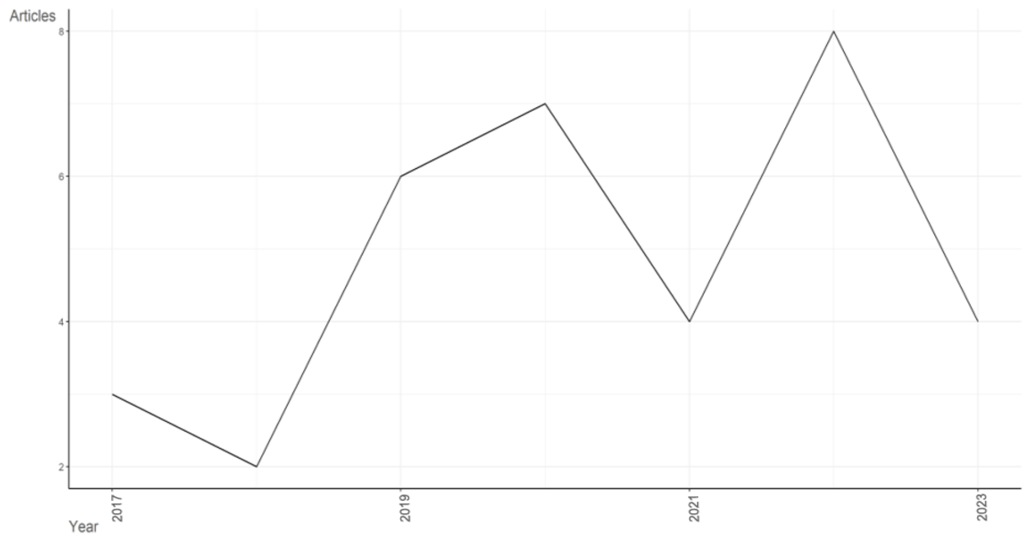

Figure3. Annual scientific production.

3.2. Top 5 Sources of STEAM and Gamification Research in Zone 1 (Bradford's Law)

The Bradford law, formulated by Bradford (1934), employs the Pareto distribution to classify goods into three specific zones: Zone 1, Zone 2, and Zone 3. According to Bradford's law (Table 3), the sources with the highest article frequency are "CEUR workshop proceedings," "Advances in intelligent systems and computing," "TEM journal," "2021 44thinternational convention on information, communication, and electronic technology, MIPRO 2021-proceedings," and "2022 IEEE 2nd international conference on educational technology, ICET 2022." During the chosen time period, these sources have published a total of 3, 2, 2, 1, and 1 article, respectively.

Table3. Top 5 sources in zone 1 (Bradford's law).

Sources	Rank	Frequency
CEUR workshop proceedings	1	3
Advances in intelligent systems and computing	2	2
TEM journal	3	2
2021 44th international convention on information, communication and electronic technology, MIPRO 2021 – proceedings	4	1
2022 IEEE 2nd international conference on educational technology, ICET 2022	5	1

3.3. Word Dynamics (Keyword Plus Growth Rate)

Figure 4 illustrates the cumulative count of occurrences of Keyword Plus occurrences and its growth rate from 2017 to 2023. The phrases "COMPUTER AIDED INSTRUCTION", "E-LEARNING", "Embedded systems", "EDUCATION COMPUTING", "ENGINEERING EDUCATION", "GAMIFICATION", "Life Cycle", "HIGH SCHOOL STUDENTS", "HUMAN COMPUTER INTERACTION", "LEARNING SYSTEMS", "STEAM", and "STUDENTS" emerged and grew over the specified timeframe. The keyword's existence, coupled with the rate of expansion, indicates the emergence of new study topics in this field. Hence, the following section will examine and elucidate the conceptual advancement of Keyword Plus.

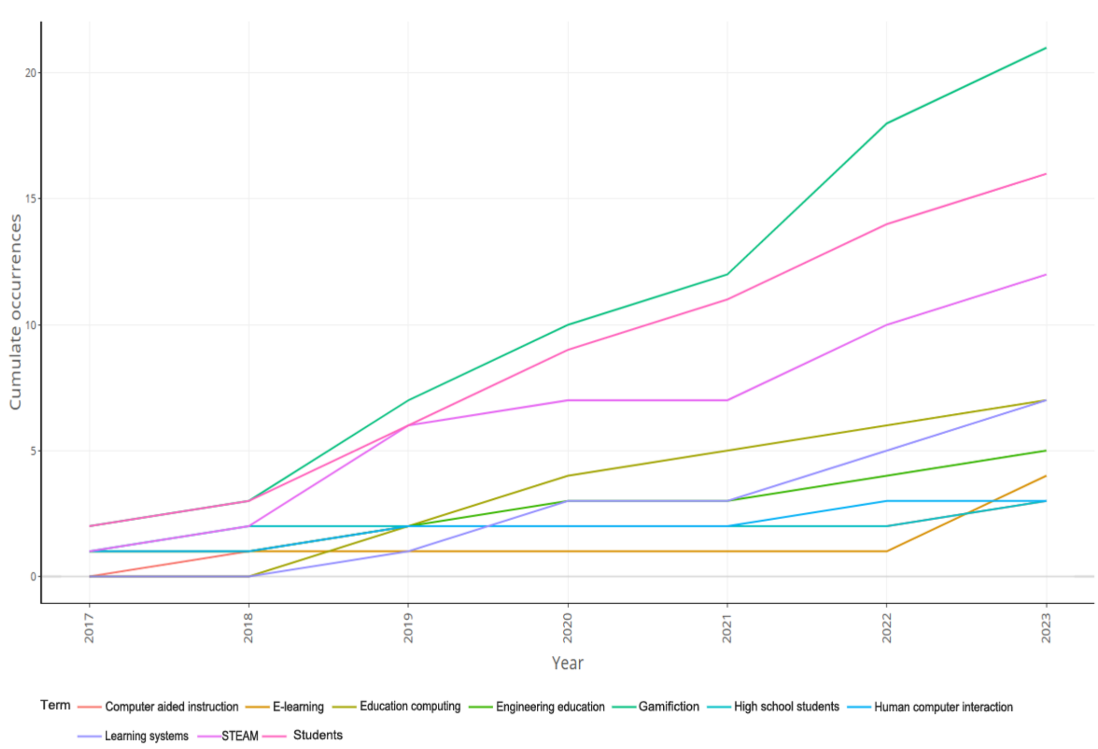

Figure 4. Words' frequency over time (Keyword plus).

3.4. Social Structure (Collaboration World Map)

The social structure, shown by the cooperation global map (Figure 5), illustrates the extent of collaboration among authors from various nations on the study topic. The findings indicated that German authors had the most foreign collaborations (n = 3) in this specific study field, with one collaboration each from France, Latvia, and Norway. Norway and France had the second and third greatest number of foreign cooperations, with a count of 2 each. Authors from Norway cooperated with one author from France and one author from Latvia. Authors from France collaborated with one Latvian author and one German author. Therefore, the results of the social structure analysis (collaboration world map) indicate that research in this field is both restricted and characterized by collaboration.

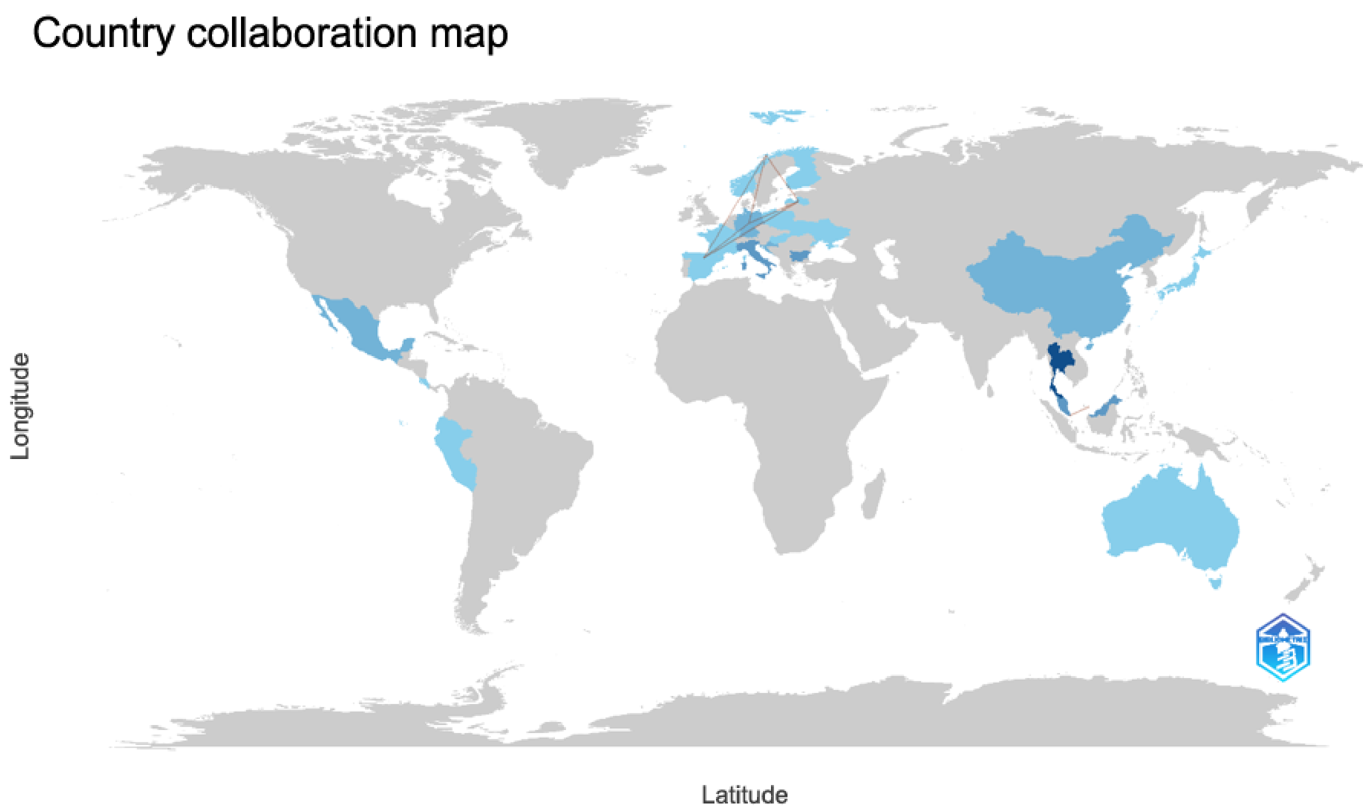

Figure 5. Social structure of the research.

4. Thematic Evolution of STEAM Education with Gamification

When represented in two dimensions, co-word analysis (Chen, Chen, Wu, Xie, & Li, 2016) can offer valuable insights about the expansion of words (Rahmani, 2018) by considering their centrality and density. Therefore, in line with the concept of word dynamics, this study employed 2020 as a definitive boundary. The findings unveiled three significant advancements: (1) Studies in science and technology have shifted towards steam education. (2) Research on learning environments has expanded to include stem education and science and technology integration. (3) Research on school students has evolved and merged with the learning process (Figure 6).

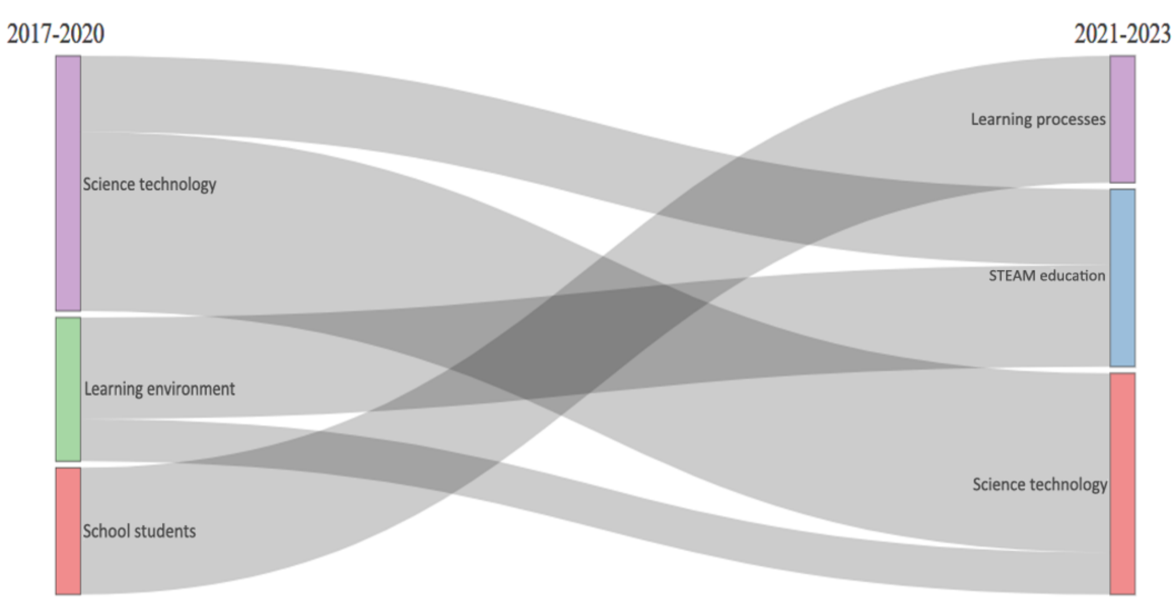

Figure 6. Thematic evolution.

4.1. Thematic Evolution (2017–2020)

Only in 2017, the SCOPUS database publishes the first article on STEAM education with gamification. Hence, the first thematic evolution map was plotted for the time period of 2017 to 2020. The results revealed that "science technology", "technology engineering", "steam education", "creative innovation", "developed model", and "steam gamification" were basic themes, and studies on the "school student", "steam subjects", "computational thinking", "learning environment", "learning management", and "management system" were niche themes (Figure 7).

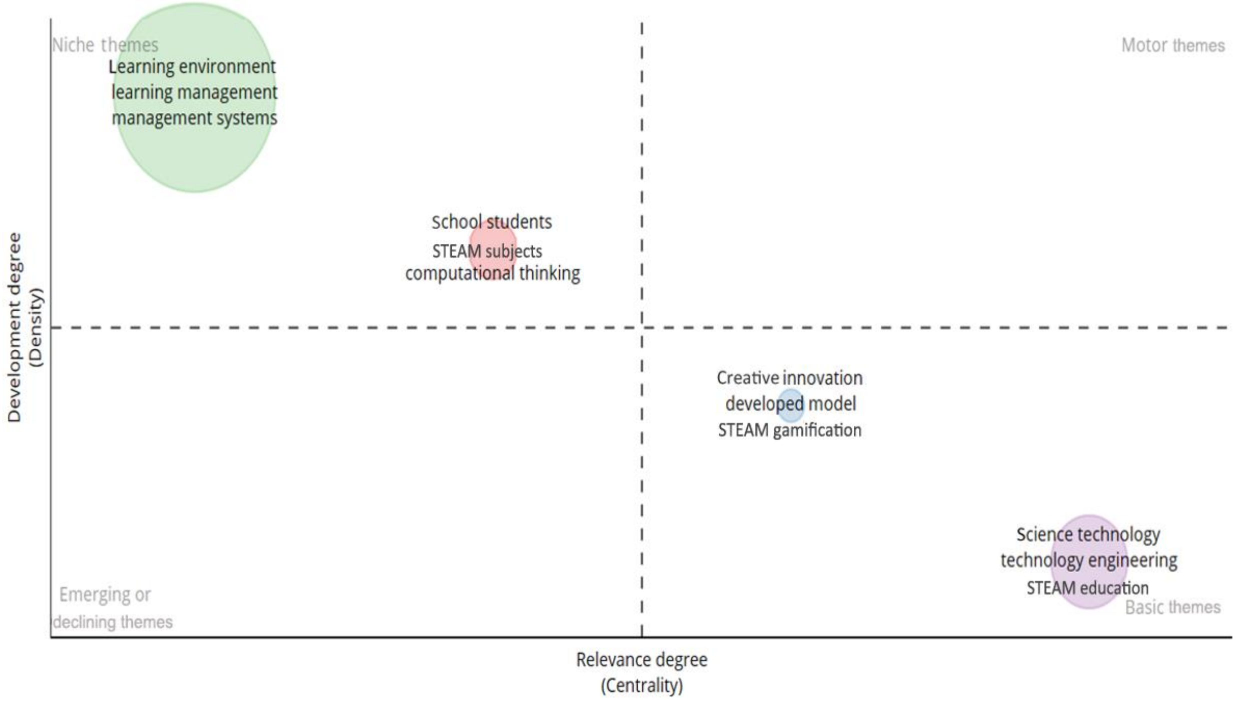

Figure 7. Thematic evolution 2017–2020.

4.2. Thematic Evolution (2021–2023)

"Steam education," "educational resources," "engineering art," "science technology," "technology engineering," and "learning environment" of STEAM education with gamification have emerged as motor themes. The results revealed that "learning process," "motivate students," "school student," and "student learning" were emerging themes. "Learning experience," and "game-based learning" evolved during this period (Figure 8).

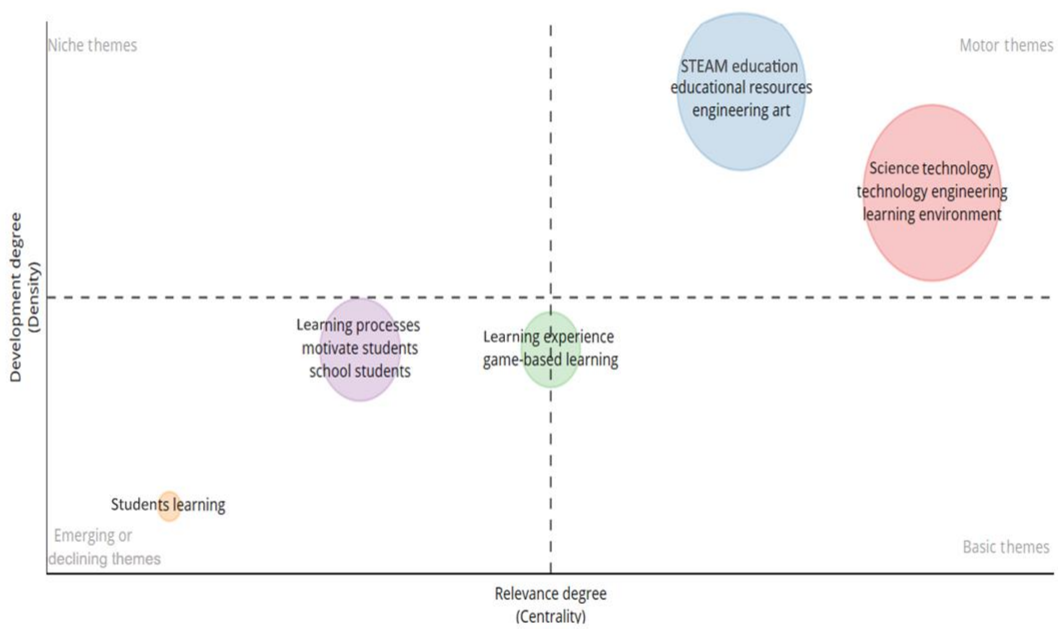

Figure 8. Thematic evolution 2021–2023.

4.3. Review of the Contributions and Practical Implications of STEAM Education with Gamification

We individually assessed each of the 34 papers that met the inclusion requirements. Table 4 presents the results and practical consequences. Moreover, the table has the reference number, title, researchers' technique, findings, contributions, and practical implications of merging STEAM education with gamification.

Table 4. Contributions and practical implications of STEAM education with gamification.

Items	Title	Method	Conclusions	Contributions	Practical implications
P1	"Dynamic educational philosophy for learning technology management" (Centeno-Leyva & Barreto, 2023)	- Gamification and information and communication technology(ICT)in Latin American education - Industry 4.0 technologies for production and services	- Latin American education faces challenges in ICT implementation - Industry 4.0 influences the development of education 4.0	- Rapid advance of genetic engineering and neuroscience - Hyperconnectivity of communicative media and digital interconnection	- Implementation of education 4.0 in Latin America - Challenges in introducing industry 4.0 in education
P2	"Ohm VR: Solving electronics escape room challenges on	- Scenario-based usability tests with N=5 users	- Prototype validated as proof of concept - Further development	- Explore potential of gamified virtual reality (VR)for	Experienceandjudgement moderatelyfavor oneactivityoveranother

Items	Title	Method	Conclusions	Contributions	Practical implications
	the roadmap towards gamified STEAM education"(Zamojski et al., 2023)	- Triangulation of qualitative and quantitative methods	and larger scale study needed	teaching - Validate VR tools for knowledge acquisition and soft skills	
P3	"A physics learning system using gamification for high-school students" (Katanosaka, Khan, & Sakamura, 2023)	- Next.js and react framework for front-end - Matter.js for simulation environment	- PhyGame improved motivation and engagement in online education - Students found PhyGame fun, engaging, and motivating	- Section V: Preliminary evaluation results - Section VI: Limitations and future outlook	- Improves motivation and engagement in online education - Students desire to use gamified learning for other subjects
P4	"Digital learning ecosystem based on the steam gamification concept to develop innovator characteristics of vocational learners" (Kummanee, Nilsook, & Wannapiroon, 2020)	- Selection of qualified tools for learning management - Use of gamification mechanics in learning activities	- Positive correlation between innovation portfolio, innovative skills, and vocational characteristics. - Experimental group had significantly higher learning achievement than control group.	- Compare academic achievement scores before and after learning - Assess creative innovation performance, skills, and attributes	- Development of digital learning ecosystems for vocational learners - Promotion of innovator characteristics and lifelong learning skills
P5	"Improving serious games by crowdsourcing feedback from the STEAM online gaming community" (Moro, Phelps, & Birt, 2022)	- Analysis of steam community player and in-class student written comments	- Crowdsourced feedback from steam community valuable for educators - Insights extend beyond what is available from literature	- Engaging international gaming community for feedback - Game freely available on steam for reviews	- Steam community feedback can enhance game development. - Crowdsourcing reviews from steam community is valuable.
P6	"From atoms to stars: An interactive theatre play based on 'the little prince' novella to describe spatial thinking"(Acuña-Umaña, Gómez-Quirós, & Herrera-Sancho, 2022)	- Conceptual issues about spatial thinking: This refers to difficulties students face in understanding spatial concepts, such as the visualization of objects and their development over time.	The study highlights the importance of didactic strategies in designing a unique theatre play that links the history of atomic models with literature to enhance students' understanding of spatial thinking. The successful qualitative assessment results have led to plans for further exploration of these strategies to have a greater impact on students' learning processes.	-Interdisciplinary approaches: This refers to the integration of different academic disciplines, in this case, science and theatre, to create a more comprehensive and meaningful learning experience. It emphasizes the importance of combining knowledge from various fields to enhance understanding.	-STEAM careers: STEAM stands for science, technology, engineering, arts, and mathematics. It emphasizes the integration of arts and humanities with the traditional STEM fields. - Gamification and collaborative work: Gamification involves using game design elements in non-game contexts, such as education, to make learning more engaging.
P7	"Thai undergraduate science, technology, engineering, arts, and math (STEAM) creative thinking and innovation skill development: A conceptual model using a digital virtual classroom learning environment" (Wannapiroon & Pimdee, 2022)	- Mix-method research approach (Quantitative and qualitative methods) - Systematic review of factors affecting STEAM-ification process	- Virtual classroom learning environment (VCLE)enhances creative thinking and innovation skills. - Gamification contributes to higher levels of creativity and innovation.	- Pre-service teachers and institutions need to be technologically savvy. - Digital storytelling and use of digital media.	- VCLE enhances creative thinking and innovation skills - Gamification contributes to motivation and innovation in learning
P8	"Preliminary construction of gamification teaching evaluation system in primary and secondary schools based on steam theory" (Tian & Yang, 2022)	- Mathematical calculation and measurement methods - Interdisciplinary thinking to solve practical problems	- Gamification teaching evaluation system needs improvement - Evaluation elements should be comprehensive and diversified	- Initial construction of gamification teaching evaluation system - Application of STEAM teaching concept to gamification teaching evaluation	- Gamification teaching can improve students' technical operation and innovation ability. - STEAM theory helps in understanding students' psychological changes.
P9	"Gamification of strategic thinking: Using a digital board game on steam" (Kodalle,	- Observe, orient, decide, act (OODA-Loop) and decision support techniques	- Scythe is an engaging strategy game for training strategic thinking skills. - Digital scythe offers new opportunities for	- Application of a framework for distributed wargaming - Reconstruction of the development and	- Scythe is an engaging strategy game for training strategic thinking skills. - Digital Scythe opens new opportunities for training 21st-century skills.

Items	Title	Method	Conclusions	Contributions	Practical implications
	2022)	- Strengths, weaknesses, opportunities, and threats (SWOT-Analysis), Kanban-board, Scrum, and other agile management methods	training 21st-century skills.	facilitation of the seminar	
P10	"The graded multidisciplinary model: fostering instructional design for activity development in STEM/STEAM education"(Flores-Nicolás & Reyes, 2022)	- Process engineering - Educational systems engineering	- Graded multidisciplinary model(GMM) allows for multidisciplinary activities in STEM/STEAM education. - Minecraft Education Edition (Minecraft EE)can be used for basic level students.	- Proposal for instructional design in STEM/STEAM education - Use of pedagogical methodologies and technology in activities	- GMM allows for multidisciplinary integration in STEM/STEAM education. - Minecraft EE can be used for teaching basic level students.
P11	"Features of introduction of components of gamification in the course of development of constructive strategies of overcoming youth's life crises" (Varina, Osadchyi, Goncharova, & Sankov, 2022)	- Playing games with simple tasks - Managed acupressure using vibration tactile motors	- Introduction of gamification in education is important. - Gamification and augmented reality and virtual reality (ARVR) technologies can enhance stress resistance.	- Implementing gamification elements in higher education system - Formation of GameHub infrastructure in higher educational establishments in Ukraine	- Introduction of gamification in education for stress resistance development - Use of augmented and virtual reality in constructive coping strategies
P12	"Fostering business education using playful and STEAM Pedagogy" (Sigcho & Jadán-Guerrero, 2022)	-Data collection from 9 teachers and 130 eighth-year high school students -Questionnaire	-The study involved data collection from teachers and students, resulting in the development of instruments for domestic laboratories that received high levels of motivation and interaction.	-STEAM education promotes interdisciplinary learning in science, technology, engineering, art, and mathematics, helping children adapt to a changing world.	-This research suggests using recyclable materials at home to create domestic laboratories, fostering scientific thinking and problem-solving skills.
P13	"The applicability of gamification in architectural design education" (Palócz & Katona, 2021)	- Systematic analysis (meta-analysis, lexical analysis, keyword analysis, literature analysis) - Inductive methods (grounded theory, field research, content analysis)	- Gamification can be applied in different areas of life. - The study explored the application of gamification in architectural design education.	- Outlining trends and patterns in game research - Exploring how digital interventions influence architectural design	- Consideration of age, knowledge, skills, and abilities of students - Formation of heterogeneous groups for problem-solving activities
P14	"Ideia space's steam program, an innovative educational project in Brazil" (Ideia Space's Steam Program An Innovative Educational Project in Brazil, 2021)	- Project base learning (PBL) and gamification, Ideia Space aims to motivate students on learning and getting involved in STEAM.	- Ideia space is an innovative program in Brazil that uses space as a tool to engage middle school students in scientific learning. - The program consists of a 20-hour course where students simulate a space mission using an educational PocketQube satellite model.	-The program incorporates active methodologies like PBL and gamification to motivate students and involve them in STEAM subjects.	-Through ideia space, students gain hands-on experience, work interdisciplinary, and develop data-based solutions to real problems.
P15	"Creating multisensory learning experiences that go beyond the limitations of traditional media"(Bekeš, 2021)	- Cross-curricular approach combined with cultural heritage - Augmented reality paired with gamification	- Collaborative augmented reality enhances mathematics and geometry education. - AR app allows for interactive and engaging learning experiences.	- Collaborative augmented reality in mathematics and geometry education - Use of AR technology for creating interactive learning experiences	- Allows for instant feedback from students - Experiences can be easily shared via unique links or QR codes
P16	"The e-facilitator as a key player for interactive dissemination of STEAM resources for e-learning via	- Webinars as a means of disseminating educational resources - Interactive forums for sharing	- Webinar is suitable for sharing educational resources. - The goal of the webinars was successfully achieved.	- e-Facilitator facilitates access to electronic services and information space. - Webinars provide interactive	- Webinars provide interactive dissemination of educational resources. - Webinars are suitable for sharing educational resources. - The role of the e-

Items	Title	Method	Conclusions	Contributions	Practical implications
	webinar" (Yoshinov, Chehlarova, & Kotseva, 2021)	results and emotions		dissemination of educational resources.	Facilitator is crucial for webinar success.
P17	"Effects of steamification model in flipped classroom learning environment on creative thinking and creative innovation" (Wannapiroon & Petsangsri, 2020)	- Evaluation form for creative skills, creative innovation, and satisfaction - Data analysis using content analysis, mean, and standard deviation	- STEAMification model enhances creative thinking and creative innovation. - Flipped classroom learning environment increases learning satisfaction.	- Development of the STEAMification model in flipped classroom learning environment - Comparison of creative scores and quality scores of creative innovation between students studying through the STEAMification model and control group students studying through traditional approach.	- STEAMification model enhances creative thinking and creative innovation. - Use of technology can enhance immersive learning experience.
P18	"Digital learning ecosystem involving steam gamification for a vocational innovator" (Kummanee, Nilsook, & Wannapiroon, 2020)	- Analysis of digital learning ecosystem involving STEAM gamification - Development and evaluation of digital learning ecosystem involving STEAM gamification	- STEAM education approach consists of five steps - Gamification elements motivate students and improve skills	- Quality education meeting international standards - Improvement in country's competitiveness	- STEAM education approach consists of five steps - Gamification elements motivate students and improve skills
P19	"Gamified evaluation in STEAM for higher education: A case study" (Boytchev & Boytcheva, 2020)	- Gamified evaluation software for university students - Extending Meiro to support evaluation via 3D models	- Gamified evaluation software based on competence profiles - Positive results in student performance and motivation	- Introduction of project-based learning (PBL) in university education - Development of gamified evaluation software for STEAM courses	- Gamified evaluation software for university students - Positive expectation of students' performance and motivation
P20	"A bike-sharing optimization framework combining dynamic rebalancing and user incentives" (Chiariotti, Pielli, Zanella, & Zorzi, 2020)	- Combination of rebalancing and incentives improves service quality. - Incentives and dynamic rebalancing reduce system downtime and failed trips.	- Joint optimization of rebalancing and user incentives - Simulation-based analysis of bike-sharing system optimization	- Analytical model for bike-sharing network rebalancing - Combined approach of user incentives and dynamic rebalancing strategy	- Combination of rebalancing and incentives improves service quality. - Incentive scheme encourages users to change their habits.
P21	"Stem competency-based learning for engineering and design students of the educational model tec21" (Almaguer et al., 2020)	- Gamification - Meccano workshop and models	- Gamification improves knowledge retention and application in students. - Meccano and STEAM workshops enhance learning experiences.	- Meccano models used to visualize real working environment - Gamification to engage students and improve learning	- Gamification helps students apply knowledge in games. - Meccano develops professional skills and resilience in students.
P22	"Gamification after almost a decade: Is it still relevant? A case of non-STEM hybrid e-learning university course" (Bernik, Radošević, & Dvorski, 2020)	- General scientific methods (observation, description, comparison, synthesis) - Statistical methods (t-test) for data analysis	- Gamification enhances the use of teaching materials. - There is a statistically significant difference in results between the experimental and control groups.	- Lack of time, authority, and knowledge among teaching staff - Negligence of lifelong learning and positive effects of ecourse motivation	- Gamification enhances the use of teaching materials. - Management should implement gamification in online systems.
P23	"STEAM gamification learning model to enhance vocational students' creativity and innovation skills" (Kummanee, Nilsook, Piriyasurawong, & Wannapiroon, 2020)	- Defining problems, designing solutions using mathematics and technology - Testing, evaluating, and improving problem-solving	- The STEAM Gamification learning model is appropriate for enhancing vocational students' creativity and innovation skills. - The learning processes in the model were approved by experts.	- Informing people about scientific skills and technology - Increasing capacity in the global competitive market	- The STEAM gamification learning model is appropriate for enhancing vocational students' creativity and innovation skills. - The learning processes in the model are effective and approved by experts.

Items	Title	Method	Conclusions	Contributions	Practical implications
		methods			
P24	"Research on application of steam teaching in primary school based on gamification task orientation-taking the fifth grade campus sandbox as an example" (Ding, Qian, & Feng, 2019)	Questionnaire and interview method -After the steam lesson, the researchers plan to use a questionnaire and interview method to gather feedback and understand the teaching effect of the steam class. -This method involves collecting data through structured questionnaires and conducting interviews with students and teachers to gain insights into their experiences and perceptions of the lesson.	The results of the study show that the steam teaching mode is effective in primary school classroom teaching. It enhances students' enthusiasm for learning and provides them with a better learning experience. This suggests that the integration of multiple disciplines, gamification elements, and project-driven tasks in steam education can have positive impacts on student engagement and learning outcomes.	-This model provides a framework for designing and implementing steam lessons that incorporate game elements and focus on practical tasks. -By following this model, educators can create engaging and effective steam lessons that promote active learning and student participation.	The researchers hope that the case study presented in this paper will serve as a reference for other researchers and educators interested in implementing steam education in practical settings.
P25	"Steam for stem-include 'art' in STEM (Science, technology, engineering and mathematics)" (Halvorsen, Tretjakova, Timmerberg, Thiriet, & Mylvaganam, 2019)	- Adding "art" to STEM to create STEAM - Incorporating elements of "art" in existing courses	- STEAM can strengthen female students in STEM education. - Gender balance in STEAM education is important.	- Adding "art" to STEM to create STEAM - Incorporating elements of "art" in existing courses	- Strengthen female students in STEM education - Incorporate art in STEM curricula for gender balance
P26	"The effect of the STEAM-GAAR field learning model to enhance grit" (Chujitarom & Piriyasurawong, 2019)	- Implementing the learning model with the samples - Study the correlation between a formative evaluation of the grit score and a formative evaluation of the learning achievement score	- Learning system has 9 segments - Post-test grit score higher than pre-test	- Integration of real world and virtual world space - Promoting creativity, critical thinking, and problem solving	- Implementing the learning model enhances grit scores. - Grit is positively correlated with learning achievement.
P27	"Gamified evaluation in steam" (Boytchev & Boytcheva, 2019)	-The characteristics of gamification in the context of students' evaluation pose specific requirements for the learning tools used. -These requirements cannot be met by general learning management systems, which are typically designed for traditional assessment methods.	-The process of gamification in education, specifically in evaluating students in STEAM subjects, requires unique learning tools and a new method of grading based on continuous scores generated during gameplay.	-It takes into account the temporal tendencies of competence development, providing a more accurate representation of students' progress over time.	-The system tracks and analyzes the students' performance over time to capture their competence development
P28	"A statistical analysis of steam user profiles towards personalized	- Exploratory factor analysis (EFA) - Parallel Analysis	- Analysis of user preferences in game design elements - Potential for	- Majority of gamification systems use one-size-for-all design approach.	- Analysis of user preferences for personalized gamification - Potential for data-driven

Items	Title	Method	Conclusions	Contributions	Practical implications
	gamification" (Li, Lu, Peltonen, & Zhang, 2019)	(PA)	personalized gamification design and recommender systems	- Study focuses on factors that distinguish Steam users and determine their preferences.	recommender systems for gamification
P29	"Towards a trading zone. A semiotic method for cross-disciplinary case study analysis of gamified systems" (Cassone, 2019)	- Analytical framework for cross disciplinary case study analysis - Semiotic perspective on artefacts and design choices	- The paper proposes an analytical framework for gamified systems. - The framework aims to facilitate description, evaluation, and understanding of gamification design choices and effects.	- Semiotic framework for crossdisciplinary analysis of gamified systems - Analytical aims: description, evaluation, and highlighting effects.	- Proposes an analytical framework for gamification design - Facilitates communication between different disciplines and practices
P30	"Effectiveness of debugging-design in 2D simulations to facilitate STEAM learning" (Tembo & Lee, 2017)	The findings indicate that the system is effective in helping students increase their interest in STEAM and move up Bloom's Taxonomy. However, the researchers note that the system needs some improvement in its scaffolding features.	-The researchers conducted a preliminary experiment with middle school students to test the effectiveness of the system. -They collected student assessments and analyzed questionnaire responses.	A small pilot case study found that using a debugging-design approach with 2D simulation applications and incorporating scaffolds and gamification in the learning environment effectively increased students' interest in STEAM and promoted higher-order thinking skills.	They used a debugging-design approach with 2D simulation applications and developed scaffolds and gamification for the learning environment.
P31	"Deriving a gamified learning-design framework towards sustainable community engagement and mashable innovations in smart cities: Preliminary findings" (Lee & Wong, 2018)	- Meta-analysis of two capstone project reports - Qualitative research method using rich data	- Crowdsourcing has potential for sustainable career options. - Gamification shows promise for community engagement.	- Derived design factors for community engagement - Explored possibilities for personalized inclusive design	- Implications for incentivizing crowdsourcing and gamification - Complementing entrepreneurship with learning for sustainability
P32	"Mimicking gamers: Understanding gamification through Roger Caillois" (Idone, 2017)	This analysis will likely involve examining how Caillois' ideas align or diverge from contemporary perspectives on gamification.	This suggests that the author believes Caillois' theories are relevant and can contribute to the understanding of gamification.	This comparison will likely involve examining different perspectives and ideas put forth by scholars and researchers in the field of game studies.	This implies that Caillois' ideas can provide insights into the relationship between gamification and society by considering how games and societies have interacted historically and the role of imitation or mimicry in this interaction.
P33	"Using 2D simulation applications to motivate students to learn STEAM" (Tembo & Lee, 2017)	- Learning by design pedagogy - PhET and Algodoosimulation applications	- Interdisciplinary activity to teach STEAM subjects - Fun and engaging approach to motivate students to pursue STEM	- Developing a learning activity to motivate students to learn STEAM - Using a combination of learning by design pedagogy along with PhET and Algodoosimulation applications to teach Physics topics	- Make STEM less intimidating for students - Motivate students to pursue STEM in the future
P34	"Make world, a collaborative platform to develop computational thinking and STEAM" (Guenaga et al., 2017)	- Internal piloting with 524 students in partner countries - Pre-piloting process with informed consent and training	- Make world is an effective tool for STEAM education. - Students have a positive feeling towards make world.	- Make world platform for creating programming challenges - Analysis of student difficulties in STEAM education	- Make world is an attractive and effective tool for STEAM education. - Make world fosters the creation and assessment of new user-generated learning activities.

4.4. The Conceptual Framework of STEAM with Gamification Used to Create Innovators

The integration of STEAM education and gamification features, as depicted in Figure 9, combines the conceptual framework of STEAM with gamification to foster the development of innovators. STEAM education integrates the disciplines of science, technology, engineering, arts, and mathematics to cultivate a variety of talents and foster problem-solving abilities and creativity (Lee & Wong, 2018). Gamification entails the utilization of game principles and mechanisms to stimulate learners and enhance the level of engagement in the learning process (Kummanee, Nilsook, & Wannapiroon, 2020). The process of STEAMification has five sequential stages: research, discovery, connection, invention, and reflection (Wannapiroon & Petsangsri, 2020). During this procedure, students actively participate in practical learning encounters, cooperate with peers, and employ their understanding to resolve practical issues (Tian & Yang, 2022). The gamification components encompass objectives, scores, insignias, rankings, tiers, incentives, accomplishments, trials, rivalry, and feedback (Wannapiroon & Pimdee, 2022). The framework seeks to improve students' creative thinking, problem-solving, and innovation abilities by integrating STEAM education and gamification.

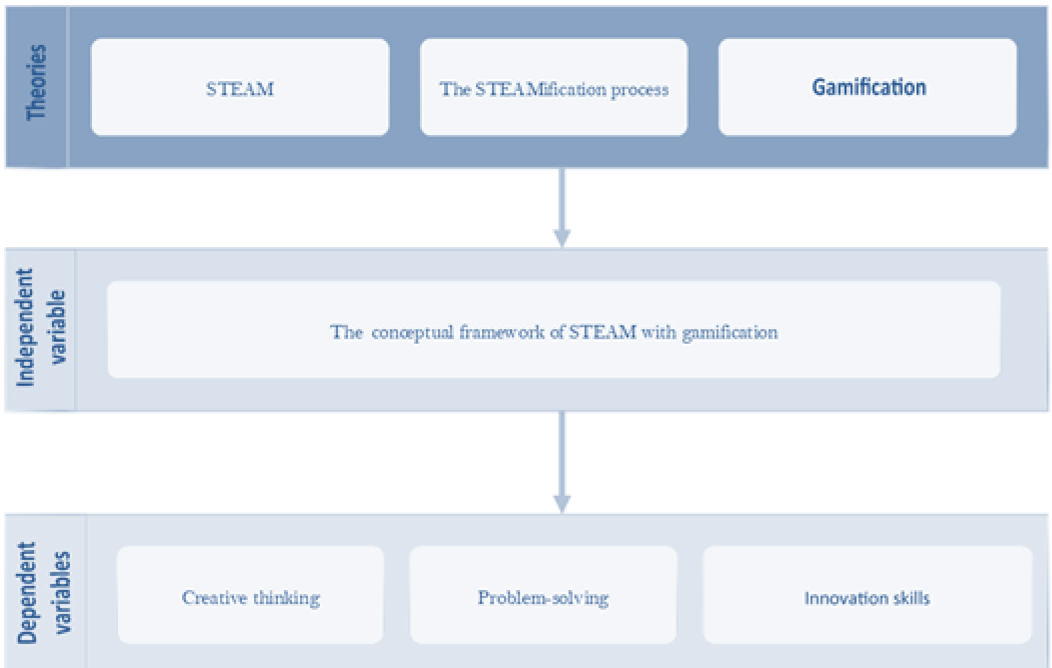

Figure 9. The cyclical process of needs analysis.

5. Conclusion

This study presents the scientometrics and systematic review results of publications on steam education with gamification that were published in journals indexed in the Scopus database. According to the Scopus database, the study on steam education and gamification underwent consistent changes between 2017 and 2023. Possible explanations for this could be that the topic was abstract, multifaceted, and seen as encompassing a wider scope. The findings indicate a substantial growth in the adoption of steam education with gamification in recent years. The majority of papers published from 2020 to 2023 suggest that the subject is gaining traction. The data and document categories reveal that 30 sources published a total of 34 articles between 2017 and 2023. The top five sources with the highest frequency of articles are "CEUR workshop proceedings," "Advances in intelligent systems and computing," "TEM journal," "2021 44th international convention on information, communication, and electronic technology, MIPRO 2021-proceedings," and "2022 IEEE 2nd international conference on educational technology, ICET 2022." These sources have an average of 2.62 authors per article, for a total of 81 authors. The growth rate of Keyword Plus from 2017 to 2023. The terms "COMPUTER AIDED INSTRUCTION", "E-LEARNING", "Embedded systems", "EDUCATION COMPUTING", "ENGINEERING EDUCATION", "GAMIFICATION", "Life Cycle", "HIGH SCHOOL STUDENTS", "HUMAN COMPUTER INTERACTION", "LEARNING SYSTEMS", "STEAM", and "STUDENTS" developed and gained prominence over the given period. Figure 3's collaboration globe map illustrates the social structure of authors from various nations participating in collaborative research within the given subject. The findings indicated that German authors had the most foreign collaborations (n = 3) in this specific study field, with one collaboration each from France, Latvia, and Norway. Thematic evaluation revealed three major developments: (1) science technology-related studies moved towards steam education; (2) learning environment-related studies expanded further into stem education-related research and science technology integration-related research; and (3) school student-related research evolved and merged with the learning process. We examined each of the 34 publications that fulfilled the inclusion criteria separately to assess their respective contributions and practical consequences. The STEAM framework, enhanced with gamification, combines science, technology, engineering, the arts, and mathematics to promote problem-solving and creativity. Gamification, which integrates gaming principles, stimulates learners through interactive learning experiences. The process of STEAMification comprises five distinct steps: research, discovery, connection, creation, and reflection. This technique fosters the development of pupils' creative thinking, problem-solving, and innovation abilities.

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