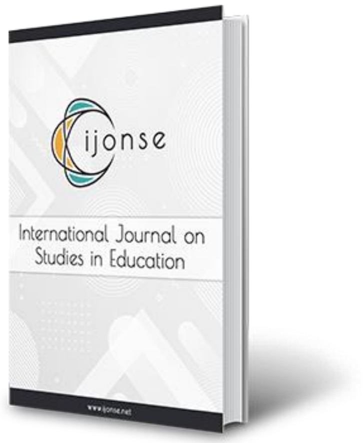

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A Review of Implementations of Math Competency Oriented Teaching-Learning Systems

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A Review of Implementations of Math Competency Oriented Teaching-Learning Systems

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Abstract

Mathematical skills are fundamental to students' cognitive and practical development and are essential to their academic and professional success. The implementation of effective teaching-learning systems is crucial to facilitate the acquisition of these competencies, providing students with tools and methodologies that promote a deep and lasting understanding of mathematical concepts, these systems must be interactive, adaptive and designed to address the individual needs of students, ensuring that each student can reach his or her maximum potential. This paper seeks to identify the methods used in the implementation of these systems, the technology and the relevant factors for their construction. The results show that gamification and game-based learning are popular and effective methods, while block-based programming is considered to be efficient. Factors include curriculum design, interactivity and content. Among the most used technologies, scratch and virtual reality (VR) are mentioned.

Introduction

Teaching-learning is a dynamic and interactive process in which teaching and learning are combined to facilitate the development of knowledge, skills, attitudes and competencies in students. The skills acquired at this stage form the basis for advanced learning and are essential for logical thinking and solving everyday problems (Koskinen & Pitkäniemi, 2022). However, many elementary school students have difficulties with fundamental mathematical concepts, resulting in poor academic performance and negative attitudes toward the subject (Nindiasari et al., 2024).

The implementation of teaching-learning systems in mathematics is vital to overcome these challenges, adapting to the individual needs of students and fostering deeper and more meaningful learning (Zainil et al., 2024). The teaching of mathematics at the primary level has evolved with technology. Traditionally, textbooks and paper exercises were used, but with the development of digital tools, educational software, online platforms and interactive applications are now used to improve mathematical comprehension (Tursynkulova & Madiyarov, 2023). These technologies allow for greater personalization and adaptation to the needs of students, and recent studies indicate that these innovations can facilitate more effective teaching, although ongoing evaluation is required to ensure their impact in diverse educational contexts. (Yang & Lin, 2024). In this context, building effective teaching-learning systems becomes essential to ensure that students understand and apply mathematical concepts correctly (Zainil et al., 2024). Deficiencies in this process can have a lasting impact on students' academic performance (Nindiasari et al., 2024).

The teaching-learning processes are supported by the incorporation of technologies, such as interactive software and online platforms, which have proven to be effective in making teaching more dynamic and accessible (Safitri et al., 2022). In addition, they are based on the development of innovative pedagogical methodologies, such as project-based learning, game-based learning, problem-based learning, among others (Koskinen & Pitkäniemi, 2022). The specialized literature shows a variety of pedagogical methods for the teaching-learning process, but details on the technologies used are scarce. This situation drives the search for innovative ways based on technologies to improve the educational process. A systematic literature review is proposed with the purpose of identifying the most effective methods and technologies for teaching mathematics in elementary school, including their implementation and possible limitations (Liberati et al., 2009), and uses the SCOPUS database because it is considered rigorous from the academic point of view.

24 pedagogical methods used in teaching-learning processes related to mathematics are identified, of which 8 proved to be efficient. With regard to educational technologies, 25 technologies were identified, of which 12 are shown to be very effective for the construction of teaching-learning systems. The article is organized as follows: the introduction in point one, followed by the theoretical framework in the second section and the review methodology in the third section, followed by the results and data analysis in the fourth section, culminating with the conclusions and bibliographical references.

Theoretical Framework

Mathematical Competencies in Primary School

Primary mathematical competencies refer to students' ability to understand, apply and communicate basic mathematical concepts. These competencies include skills such as numeracy, problem solving, understanding of mathematical structures, and the ability to reason logically and critically (Nadzri et al., 2023). In addition, mathematical competencies encompass the ability to interpret and analyze data, recognize patterns, and relate different mathematical concepts (Lavidas et al., 2022). Strengthening these skills is fundamental, not only to achieve academic success in mathematics, but also to enhance cognitive skills and solve problematic situations in daily life (Y.-H. Lin et al., 2023).

Teaching-Learning Process

The teaching-learning process is defined as a dynamic and interactive process in which teaching and learning are combined to facilitate the development of knowledge, skills, attitudes and competencies in students (Koskinen & Pitkäniemi, 2022), this process involves the integration of innovative pedagogical methodologies that foster critical thinking and problem solving from an early age (Dahshan & Galanti, 2024). In addition, this process is enriched with the implementation of active methodologies that promote the active participation of students in their own learning (Martín-García et al., 2024). Integrating these methodologies effectively into the teaching-learning process is essential to ensure meaningful and lasting learning for elementary school students.

Teaching-Learning Methods

Teaching-learning methods refer to pedagogical approaches and didactic strategies used by educators to facilitate student learning in the field of mathematics (Hoang et al., 2023). These methods may range from the use of educational technology, such as augmented reality and game-based learning platforms (Liu et al., 2024) , to the integration of computational thinking concepts in the teaching of fundamental mathematical concepts (Dahshan & Galanti, 2024). Research suggests that the effectiveness of these methods lies in their ability to personalize learning and foster a deeper and more meaningful understanding of mathematical concepts, which in turn can improve academic performance and attitudes toward the subject matter (Cheng et al., 2023).

Teaching-Learning System

The teaching-learning system can be conceptualized as a structured set of methods, tools and resources that facilitate the acquisition of knowledge, skills and competencies by students. This system not only focuses on the transmission of information, but also seeks to actively involve students in their learning process, encouraging participation, reflection and practical application of what they have learned (Alonso-Secades et al., 2022). The effectiveness of these systems lies in their ability to personalize learning and foster a deeper and more meaningful understanding of concepts, which in turn can improve academic performance and attitude towards the subject matter. It has also been observed that technology-based teaching-learning systems can be particularly effective in motivating students and making learning more interactive and engaging (Silva-Díaz et al., 2023).

In the context of modern education, the integration of advanced technologies has significantly transformed teaching and learning methods. The Madrasati platform is a leading example of educational technology used in several Arab countries, such as Saudi Arabia, to improve communication between teachers, students and parents by facilitating access to online educational resources and digital learning tools (Almulla & Al-Rahmi, 2023). On the other hand, "Robotics Education" has been noted for its hands-on, interactive approach to teaching STEM (Science, Technology, Engineering and Mathematics) concepts. The implementation of LEGO Education-based systems has been especially effective in creating dynamic and motivating learning environments, which has significantly improved student engagement and skills. LEGO Education has excelled at integrating robot construction with programming, allowing students to learn in a hands-on and creative way (Kyprianou et al., 2023).

Teaching and learning systems comprise several variants adapted to today's educational needs. Learning management systems (LMS) and learning content management systems (CMS) allow the administration and distribution of online courses and digital resources, respectively (Almulla & Al-Rahmi, 2023). Virtual learning environments (VLE) facilitate interaction between students and teachers in a collaborative online space (Hwang, Chen, et al., 2023). Adaptive learning systems customize the educational experience according to the needs of each student; synchronous and asynchronous online teaching tools offer real-time and delayed interaction, respectively (Zholaushievna et al., 2022). And m-learning based systems provide access to resources and activities from mobile devices, while simulators and virtual environments offer immersive experiences for practicing skills in a controlled environment (Christou et al., 2023). These variants reflect the diversity of different teaching-learning systems, enriching the teaching and learning process.

Regarding the technologies used for the development of teaching-learning systems, such as Scratch and Digital Interactive Notebooks (DINbs), they focus on creating interactive and collaborative environments that facilitate online communication and collaboration between students and educators (Kesler et al., 2022). On the other hand, tools such as Google Meet, WhatsApp Group and Zoom Cloud Meetings offer immersive experiences and gamification that motivate students and improve understanding of complex concepts (Rati et al., 2023). In addition, technologies such as Virtual Reality (VR) and Augmented Reality (AR) provide immersive experiences that allow students to explore concepts in a more practical and visual way, which has transformed education by improving its quality and accessibility (Sandoval Henríquez & Badilla Quintana, 2021).

Methodology

The systematic literature review was conducted under the PRISMA method, which defines a review as one that uses explicit and systematic methods to collect and synthesize the findings of studies that address a research question. This approach ensures the transparency and reproducibility of the review process, allowing an evaluation of the data collected (Liberati et al., 2009). This research aims to identify and analyze in detail the factors that influence the construction of teaching-learning systems for mathematics.

In addition, it seeks to understand the methods employed in the mathematics teaching-learning processes, as well as to explore the technologies used to implement these systems effectively. Subsequently, the following objectives are established in relation to the research questions:

- Q1: What are the methods used in mathematics-oriented teaching-learning processes?
  O1: Identify the methods used in mathematics-oriented teaching-learning processes.
- Q2: What are the factors that influence the construction of teaching-learning systems?
  O2: Identify the factors that influence the construction of teaching-learning systems.
- Q3: What technologies are used in the construction of mathematics-oriented teaching-learning systems?
- O3: Identify the technologies used in the construction of mathematics-oriented teaching-learning systems.
- Q4: Which methods are the most efficient in the mathematics-oriented teaching-learning process?
  O4: Identify the most efficient methods in the mathematics-oriented teaching-learning process.
- Q5: Which technologies are more efficient in the construction of mathematics-oriented teaching-learning systems?
  O5: Identify which technologies are more efficient in the construction of mathematics-oriented teaching-learning systems.

Search Strategy

For the search strategy, the Scopus database was used to search for bibliographic sources on the topic of study. To carry out the search, a strategy based on keywords derived from the research questions posed was used. The search string was formulated as follows: ("teaching-learning" AND (software OR system OR application OR platform OR "e-learning") AND (mathematics OR "arithmetic") AND ("elementary education" OR "elementary school")) AND (technology OR techniques OR tools OR methods OR "virtual education").

The choice of Scopus as the sole database for this search is due to its ability to cover a broad spectrum of academic disciplines and to offer a variety of sources relevant to educational research (Baas et al., 2020). In addition, it provides advanced tools to refine the search and access impact metrics that can be useful to assess the relevance of the studies found. It also highlights that in the search string the importance of keywords such as: teaching-learning, system, mathematics, technology, elementary education y methods.

Inclusion and Exclusion Criteria

To determine the inclusion and exclusion of articles in the literature review, specific criteria were established. Articles that address issues related to teaching-learning systems or education platforms, with a focus on learning in various subject areas, including mathematics, are included. In addition, articles that have students as subjects of study or addressees of the system are considered relevant. The search is limited to articles published between 2021 and 2024, ensuring that the review is based on recent research and the English language is prioritized for inclusion. On the other hand, we excluded articles that were not available, duplicated, not indexed or not research articles. These criteria in Table 1 ensure the selection of relevant and quality articles for the review.

Table 1. Search Criteria

Inclusion	Exclusion
Database articles such as (Scopus).	Non-research articles
Articles that talk about teaching-learning systems or Education Platform, including learning in various subject areas, such as mathematics.	Articles that are not accessible.
Articles involving students as subjects of study or recipients of the system.	Duplicate articles
Articles from 2021 to 2024.	Articles not indexed
Articles in English.	

Selection of Studies

In the first stage, 4155 articles were selected using the search string performed on May 4. Then, in the second stage, the inclusion and exclusion criteria indicated in Table 1 were applied, resulting in the selection of 360 articles. Subsequently, the titles of the articles were evaluated in the third stage, leaving 141. In the fourth stage, the abstracts were analyzed, reducing the number to 83. Then, the conclusions, results and introduction were evaluated in the fifth stage, leaving 68 articles. Finally, after reading the full text, 60 papers were selected. The details of the process are shown in Figure 1.

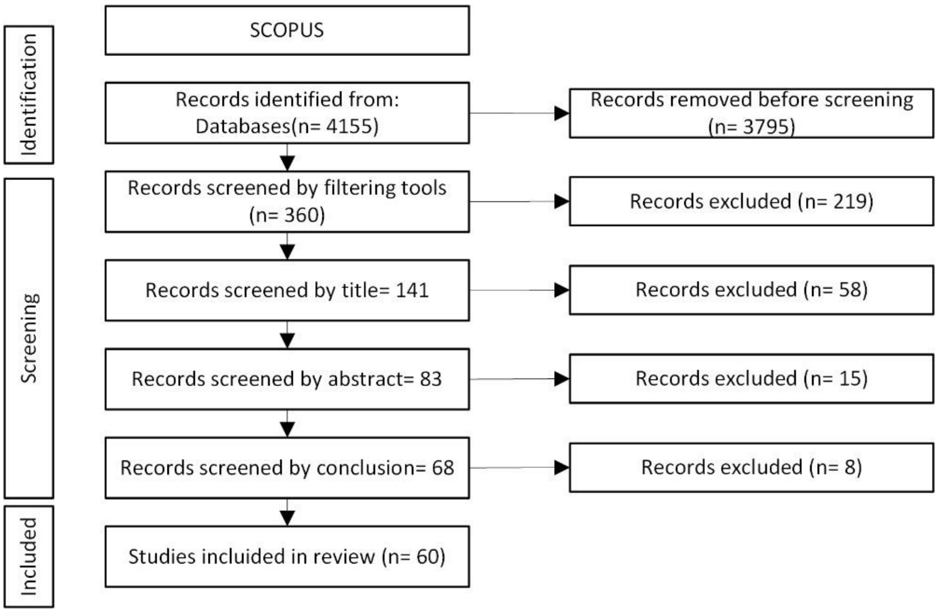

Figure 1. Flow Diagram

Data Analysis

After having selected the valid articles for the research, the relevant information is collected and organized. A quantitative analysis of the selected articles is performed, represented in statistical graphs and tables. These show the distribution of the articles according to different criteria, allowing trends to be identified. Figure 2 shows the distribution of the journals according to the quartile to which they belong.

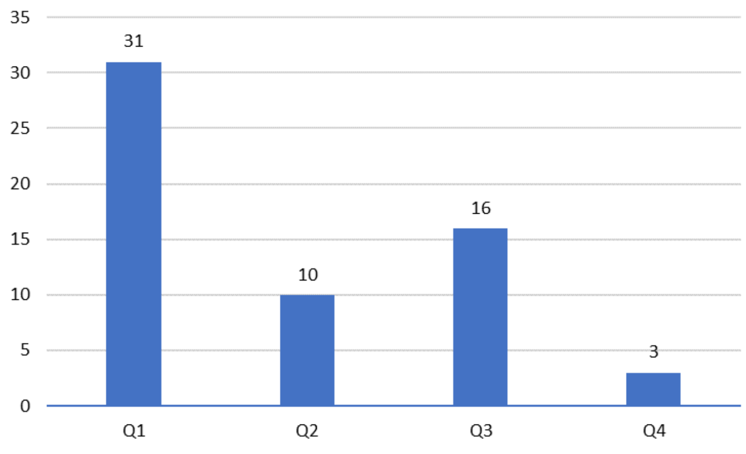

Figure 2. Journal by Quartile

Most of the publications are in the Q1 quartile, with a total of 31 articles, indicating that these papers were published in journals of higher impact and quality. In the Q2 quartile, 10 articles are counted, which are also in reputable journals, but with a slightly lower impact compared to Q1. The Q3 quartile includes 16 articles, placing them in a journal with moderate impact. Finally, the Q4 quartile contains 3 articles, which correspond to publications in journals with a lower impact within the quartile classification. The graph shows that most of the papers in the subject of study are outstanding for their relevance and scientific rigor.

Publications by year are shown in Figure 3. In 2021 there were 5 publications, indicating an initial interest in the topic. In 2022 and 2023 the number increased significantly to 20 and 26 respectively, reflecting increased interest and scientific production. Up to May 2023, 9 articles have been published showing a decrease in the number of papers in the field of study.

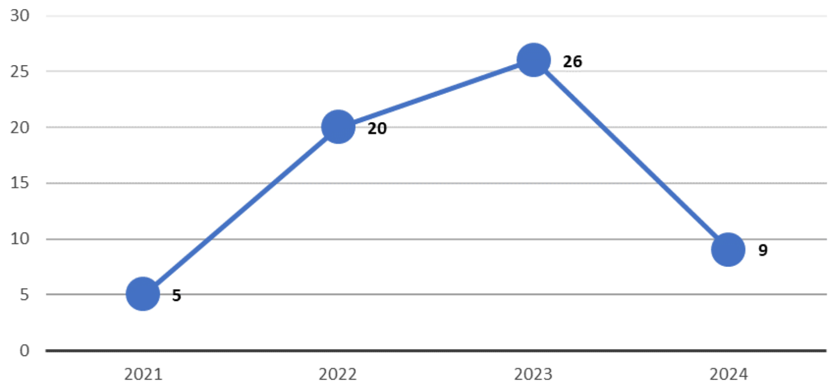

Figure 3. Articles Published by Year

Figure 4 shows the distribution of articles published by country. It can be seen that Indonesia and Taiwan have the highest number of publications with 10 articles each, followed by Spain with 8, Malaysia with 7 and Greece, China and the United States with 3 each. The rest of the countries contribute 1 or 2 articles each. The graph shows a significant concentration of articles in countries such as Indonesia, Taiwan, Spain and Malaysia, suggesting leadership in research and development of teaching-learning systems, and a greater commitment and allocation of resources to improve education compared to other countries.

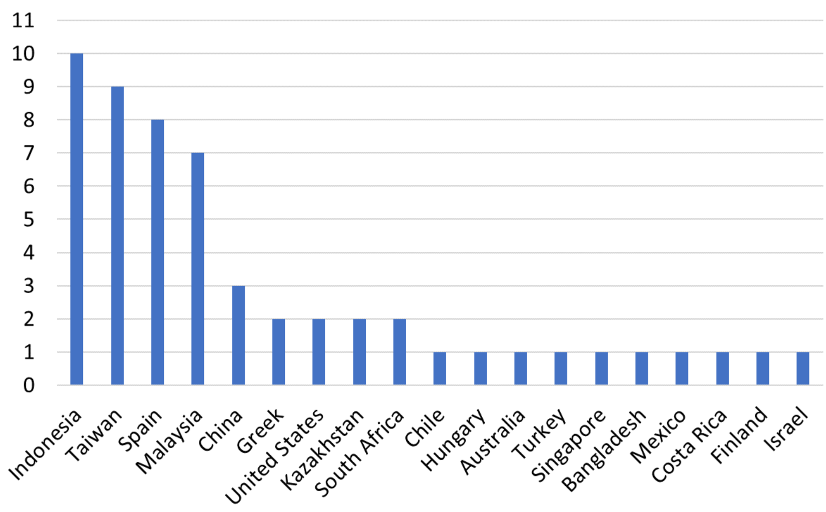

Figure 4. Articles Published by Country

Table 2 shows the number of publications by publisher. It can be seen that MDPI has the largest number with 15 articles, followed by Elsevier Ltd. with 10 articles. Modestum LTD contributes 5 articles, while Routledge and International Association of Online Engineering have 3 publications each. On the other hand, some publishers such as Asian Online Journal Publishing Group, STKIP Siliwangi Bandung, Institute of Electrical and Electronics Engineers Inc. and Academic Conferences and Publishing International Limited have 2 articles each on the topic of the study. This diversity in publication sources highlights the breadth and relevance of the topic related to teaching-learning systems in different academic media.

Table 2. Top 5 Publications by Publisher

Publisher	No. of Publications
MDPI	15
Elsevier Ltd	10
Modestum LTD	5
International Association of Online Engineering, Routledge	3
Academic Conferences and Publishing International Limited, Institute of Electrical and Electronics Engineers Inc, STKIP Siliwangi Bandung (IKIP Siliwangi), Asian Online Journal Publishing Group	2

Figure 5 shows the distribution of the articles according to the number of pages. It can be seen that most of the articles are in the range of 8 to 19 pages. The most frequent articles are those with 17 pages (8 articles), followed by those with 14 pages (6 articles) and 9, 8, and 18 pages (5 articles each). Other common sizes include 19- and 16-page articles (4 articles each). There are also 33- to 10-page publications, although in smaller numbers. This indicates that articles are concentrated between 9 and 19 pages, suggesting that research on the topic under study tends to be detailed but manageable in length.

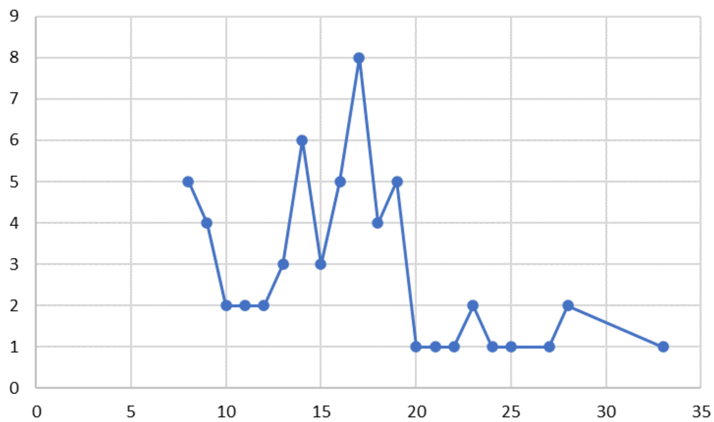

Figure 5. Number of Article Pages

Table 3 presents the 10 most cited articles taken into account by other authors when conducting research on teaching-learning systems. A most cited article is that of Hsu et al. (2022), with 22 citations, followed by the work of Pardamean et al. (2022) with 18 citations, and those of Almulla & Al-Rahmi (2023) and Chang & Yeh (2021), both with 17 citations. Then Chen et al. (2022). These articles are seminal in the academic literature on the subject and reflect their relevance and impact on the research community. Moreover, their high citation frequency suggests that they have contributed significantly to the advancement of knowledge in the field of teaching-learning systems.

Table 3. Top 10 Articles with the Highest Number of Citations

Author	Year of publication	Citation
(Hsu et al., 2022)	2022	22
(Pardamean et al., 2022)	2022	18
(Almulla & Al-Rahmi, 2023)	2023	17
(Chang & Yeh, 2021)	2021	17
(Chen et al., 2022)	2022	15
(Videla et al., 2022)	2022	13
(Cheng et al., 2023)	2023	12
(Zhussupbayev et al., 2023)	2023	11
(Kesler et al., 2022)	2022	10
(Sujarwo et al., 2022)	2022	10

Results

At this point, we consolidate the results obtained from the literature review and proceed to answer the research questions posed, addressing the 5 questions raised in the study.

Q1: What Are the Methods Used in the Teaching-Learning Process of Primary Mathematics?

Teaching-learning methods refer to the various pedagogical approaches employed by teachers to facilitate the learning process in students. Table 4 compiles and describes the methods employed by the authors in teaching mathematics to elementary school students.

Table 4. Methods Used in Teaching-Learning Processes

Reference	Methods	Observations
(Liu et al., 2024); (Andriyani, 2023); (Cheng et al., 2023); (Hwang, Chiu, et al., 2023); (Fernández-Oliveras et al., 2021); (Chang & Yeh, 2021)	Game-based learning	According to the authors, game-based learning is an educational methodology that employs game elements and dynamics to enhance teaching, integrating playful activities that facilitate the acquisition of knowledge and skills through practice.

Reference	Methods	Observations
(Dahshan & Galanti, 2024)	Block-based programming	Block-based programming uses graphical blocks to create programs visually, eliminating the need to write code. It consists of linking predefined blocks together to form programs.
(Rati et al., 2023)	Project Based Learning	This approach focuses on the completion of a practical, real-world project to acquire knowledge and skills. It consists of students working in teams to solve an assigned problem or challenge.
(Yang & Lin, 2024)	Method based on graphic organizers	This approach uses diagrams and visual tools to organize and understand information. It consists of using different types of diagrams, such as mind maps and flow charts, to facilitate the understanding of abstract concepts.
(Nadzri et al., 2023)	Augmented Reality Based Learning	This approach uses technology to superimpose digital information on the real world by interacting with physical objects or real environments enhanced with virtual elements.
(Hwang, Chen, et al., 2023)	Two-tier approach based on graphic organizers	This approach involves the use of first and second level questions. First-level questions are basic, while second-level questions are more complex and seek deeper understanding.
(Y.-H. Lin et al., 2023)	Model 6E	It is a sequential teaching approach that combines science education and engineering design processes. It consists of six stages: engage, explore, explain, design, enrich and evaluate.
(Sáez-López et al., 2023); (Binti Kamarudin et al., 2022); (Murillo-Zamorano et al., 2023); (Rincon-Flores et al., 2023)	Gamification	According to several authors, this approach uses game design elements and techniques in non-game contexts to engage people. It consists of applying and using game mechanics, such as points, levels, challenges and rewards, in non-game contexts.
(Zainil et al., 2024)	Blended learning	It is an approach that combines face-to-face teaching with online teaching. It consists of integrating classroom classes with digital materials. It is used by allowing students to access online content at their own pace.

Reference	Methods	Observations
(Nindiasari et al., 2024)	STEAM approach (Science, Technology, Engineering, Art and Mathematics)	It is an approach that begins with the exploration of STEAM concepts, followed by experimentation through testing and hands-on activities, and culminates in the creation of original projects.
(Nadarajan et al., 2023)	Flipped classroom	The teaching approach where students learn the material outside of the classroom and use class time for discussion, consisting of reversing traditional classroom activities.
(Herwinarso et al., 2023)	Research-based learning	This approach engages students in active problem investigation. It consists of students formulating questions, designing and conducting investigations, analyzing data, and reaching conclusions, all under the guidance of the teacher.
(Sook Ling & Krishnasamy, 2023)	Multimedia learning	This approach uses a variety of media and technologies, such as images, audio, video and interactive graphics. It consists of the integration of these elements to improve comprehension and retention of information.
(Wang et al., 2023)	Conceptual connections	This approach is based on relating different concepts in order to foster a deeper understanding; students are expected to relate what they learn to previous knowledge.
(Topali & Mikropoulos, 2023); (Bevan & Capraro, 2021); (Yu, 2022); (Kesler et al., 2022)	Constructivist approach	It consists of student-centered learning, where exploration, discovery and reflection are encouraged. It is used in education by promoting practical and collaborative activities.
(Almulla & Al-Rahmi, 2023)	E-learning	The approach uses information and communication technologies to facilitate access to educational content. It consists of delivering classes, courses or complete programs through digital platforms.
(Govender & Machingura, 2023)	Mathematical model	An educational approach that focuses on the use of mathematical models to understand and solve problems in various fields of knowledge. It consists of using mathematical tools, such as equations.
(Wicaksono & Rahmatya, 2023)	Interactive learning	Learning approach in which students interact with the content, such as 3D geometric objects with shapes and colors.

Reference	Methods	Observations
(Safitri et al., 2022)	Digital game-based learning	This approach uses video games and other digital media to motivate students to learn. It consists of integrating game elements, such as challenges, competitions, etc.
(Atin et al., 2022)	ARCS Learning Model	This approach addresses attention, content relevance, self-confidence and student satisfaction. It consists of the application of these four strategies to improve motivation.
(Ziden et al., 2022)	M-learning	An approach to learning through the use of mobile devices. It consists of offering educational content on mobile devices such as smartphones or tablets, and is characterized by mobility.
(Chen et al., 2022)	Inquiry approach	It is a pedagogical approach that promotes in students the ability to ask questions, seek answers, conduct research, analyze information and reach conclusions.
(Hsu et al., 2022)	Socratic Reflection Prompts (SRPs)	SRPs consist of a series of questions that are used to guide the student through the critical thinking process, including interpretation, analysis, evaluation, inference, explanation, and self-regulation.
(Setambah et al., 2021)	Fraction encryption method	This method is used to improve the teaching and learning of fractions. It consists of the use of a set of cipher symbols that replace conventional numbers and signs.

Q2: What are the factors that influence the construction of teaching-learning systems?

The factors are a wide range of elements that must be considered when designing, implementing and evaluating these systems. Table 5 compiles the factors that the authors indicate as influential in the construction of teaching-learning systems in their proposals. Only those elements that contribute significantly to the development and effectiveness of these systems are indicated.

Table 5. Influencing Factors in the Construction of Teaching-Learning Systems

References	Factors	Observation
(Kyprianou et al., 2023)	Confidence of educators	Educators' trust facilitates the adoption and regular use of the system, promoting continuous and constructive feedback. Lack of trust can generate resistance and suboptimal use, limiting the positive impact on learning.
(Kyprianou et al., 2023)	Previous experience	Previous experience allows a quick adaptation to the new system, optimizing its use and integration. Lack of experience requires greater investment in training,

References	Factors	Observation
		delaying adoption and reducing initial effectiveness.
(Liu et al., 2024)	Pedagogical technological knowledge (TPACK)	TPACK knowledge combines technology, pedagogy and content; lack of TPACK can result in a technically advanced, but pedagogically deficient system.
(Rati et al., 2023); (Zainil et al., 2024); (Zhussupbayev et al., 2023); (Koskinen & Pitkäniemi, 2022); (Sandoval Henríquez & Badilla Quintana, 2021)	Curriculum design	It is a factor that establishes the learning objectives, contents and methodologies that guide teaching. A solid design guarantees a positive impact on the effectiveness and relevance of the system.
(Andriyani, 2023); (Zhussupbayev et al., 2023); (Atin et al., 2022); (Zholaushievna et al., 2022).	Interactive designs	It is a factor that influences the effectiveness and usability of the system. An attractive design can increase learner motivation and engagement, positively impacting the experience.
(Hwang, Chen, et al., 2023); (Videla et al., 2022)	Customization	This is a fundamental factor since the lack of personalization can lead to a system that does not adjust to individual needs, limiting its effectiveness in learning.
(Hwang, Chen, et al., 2023); (Y.-R. Lin, 2023); (Sandí-Delgado et al., 2022)	Ease of use	An easy-to-use system requires little or no prior training, allowing users to use it effectively from the start, enhancing the user experience and increasing the likelihood that the system will be used effectively.
(Y.-H. Lin et al., 2023)	Available resources	This is an influencing factor as a larger budget may allow for more advanced features and more sophisticated design. Lack of resources may limit development capacity.
(Y.-H. Lin et al., 2023); (Saal & Graham, 2023)	Adaptability	A highly adaptable system can adjust its content, difficulty and methodology, improving the relevance and effectiveness of the software. In addition, lack of adaptability can limit its effectiveness.
(Nagy & Dringó-Horváth, 2024); (Saal & Graham, 2023)	Digital competence	It is a factor since it is crucial for developers to take advantage of available technologies and ensure the quality of the software, positively impacting its effectiveness.
(Nagy & Dringó-Horváth, 2024);	Institutional support	Strong support can facilitate integration and acceptance of the system, encouraging educational

References	Factors	Observation
		innovation, while lack of support can hinder implementation and generate resistance.
(Balanyà Rebollo & De Oliveira, 2023); (Yu, 2022)	Solid infrastructure	A solid infrastructure, including hardware, networks and content management systems, facilitates the implementation and operation of the system, positively impacting its effectiveness.
(Balanyà Rebollo & De Oliveira, 2023); (Hu & Hu, 2022)	Educational policies	Educational policies that encourage technological innovation, the integration of digital tools, and teacher training in educational technology can facilitate the adoption and use of the system.
(Balanyà Rebollo & De Oliveira, 2023); (Ding, 2022)	Pedagogical strategies	They determine the presentation of information, stimulate participation and facilitate student understanding, impacting the system's ability to maintain student interest and motivation.
(Hwang, Chiu, et al., 2023); (Topali & Mikropoulos, 2023); (Binti Kamarudin et al., 2022); (Pardamean et al., 2022)	Learning objectives	They guide the design and development of the teaching-learning system by establishing the educational goals that are expected to be achieved. These objectives ensure that the system focuses on the desired outcomes, impacting effectiveness.
(Hwang, Chiu, et al., 2023); (Sook Ling & Krishnasamy, 2023); (Almulla & Al-Rahmi, 2023); (Binti Kamarudin et al., 2022); (Murillo-Zamorano et al., 2023); (Zholaushievna et al., 2022); (Sujarwo et al., 2022); (Sandoval Henríquez & Badilla Quintana, 2021)	Content	It is a key factor as it determines the subject matter and depth of the educational materials. Relevant and appropriate content improves the quality of the system and its ability to meet learning objectives.
(Hu & Hu, 2022); (Safitri et al., 2022)	Feature integration	The integration of different resources, such as: texts, images, videos, simulations and interactive activities, in the teaching-learning system enriches the learning experience.
(Y.-R. Lin, 2023); (Almulla & Al-Rahmi, 2023)	Navigation	Clear and consistent navigation is essential to facilitate exploration and effective use of the system, which positively impacts the students' learning experience.
(Alonso-Secades et al., 2022)	Educational needs	A key factor since each educational community has specific needs that must be considered to ensure

References	Factors	Observation
		quality education.
(Hsu et al., 2022)	Animations	Important visual factor as they are used for an interactive and attractive presentation of problems or questions. By combining verbal and graphical aspects, they can improve information retention.

Q3: What Technologies Are Used in the Construction of Mathematics-Oriented Teaching-Learning Systems?

Technologies are the tools, platforms and digital resources used to develop and implement these systems. Table 6 presents the most common technologies used in the construction of mathematics-oriented teaching-learning systems. It includes those technologies that the authors consider fundamental for the effective development of these systems, highlighting their relevance in the creation of interactive and enriching educational environments.

Table 6. Technologies Used in the Construction of Teaching-Learning Systems

Reference	Technologies	Observations
(Liu et al., 2024)	CPSLens	CPSlens is an augmented reality platform used in teaching-learning systems. It allows teachers to observe students' critical thinking skills.
(Dahshan & Galanti, 2024); (Yang & Lin, 2024); (Cheng et al., 2023); (Topali & Mikropoulos, 2023); (Kesler et al., 2022)	Scratch	Visual programming language with an environment based on graphical blocks. It is a tool to teach students the basic concepts of programming and mathematics.
(Dahshan & Galanti, 2024)	Digital Interactive Notebooks (DINbs)	Digital interactive notebooks allow students to create and organize learning content. They are used in teaching-learning systems to facilitate organization, access and interaction with educational content.
(Hwang, Chen, et al., 2023); (Sandoval Henríquez & Badilla Quintana, 2021)	Spherical Video Based Learning Environments (SVLE)	Educational environments with 360-degree videos offer an immersive experience. They allow students to explore virtually, simulating real situations, improving understanding and retention of concepts.
(Rati et al., 2023)	Google Meet, WhatsApp Group, Zoom Cloud Meetings	Google Meet, WhatsApp Group and Zoom are digital communication technologies. Google Meet facilitates meetings, WhatsApp Group enables instant communication, and Zoom offers screen sharing and recording, popular in education.

Reference	Technologies	Observations
(Nadzri et al., 2023)	GeomAR3	Module with augmented reality to improve the learning of spatial concepts in mathematics. It uses AR to visualize characteristics of shape, length, size and dimensions of 3D figures that are controlled.
(Y.-H. Lin et al., 2023); (Silva-Díaz et al., 2023); (Tursynkulova & Madiyarov, 2023); (Nindiasari et al., 2024); (Zholaushievna et al., 2022); (Sandoval Henríquez & Badilla Quintana, 2021)	Virtual reality (VR)	It is a technology that creates an interactive digital environment that simulates the physical presence of users in a real or imaginary environment. It consists of the use of devices such as virtual reality glasses or helmets to immerse users in a three-dimensional environment.
(Sáez-López et al., 2023)	Kahoot	Platform used to create interactive educational quizzes, surveys and games. It consists of an online tool where teachers can create sets of multiple-choice questions.
(Sáez-López et al., 2023); (Chang & Yeh, 2021)	Socrative	Tool that allows the teacher to track the evolution of students through quizzes, assessments or other activities, focusing more on games and competitions in real time.
(Tursynkulova & Madiyarov, 2023); (Ziden et al., 2022); (Sandoval Henríquez & Badilla Quintana, 2021)	Augmented Reality (AR)	Technology that superimposes virtual elements, such as images, videos or information, on the real world. Through devices such as smartphones or special glasses, users can see and interact with these combined elements.
(Hwang, Chiu, et al., 2023)	RPG Maker	Role-playing game (RPG) creation tool that allows users to design and develop their own role-playing games.
(Naveed et al., 2023)	Cloud computing	Network of remote servers connected to the Internet to store, manage and process data, servers, databases, networks and software.
(Wicaksono & Rahmatya, 2023)	OpenCV (Open-Source Computer Vision Library)	Open-source computer vision and machine learning software library.
(Wicaksono & Rahmatya, 2023)	TensorFlow Lite	Cross-platform machine learning library optimized for running machine learning models on perimeter devices, including iOS and Android mobile devices.
(Wicaksono & Rahmatya, 2023)	Raspberry Pi	Single-board computers or low-cost single-board computers
(Rincon-Flores et al., 2023)	Gamit!	Interactive digital gamification platform designed for teachers and students, using a reward system based on

Reference	Technologies	Observations
		badges, avatars and rankings.
(Moral-Sánchez et al., 2022)	Classcraft	Tool to turn the classroom into an online educational role-playing game, in which both students and teachers play together.
(Sandí-Delgado et al., 2022)	AstroCódigo	Platform to help understand the basic concepts of programming, through problem solving by creating algorithms.
(Safitri et al., 2022)	Word-wall	Web platform that facilitates the creation of learning games based on mini-games. Allows teachers to design interactive games and printed materials for their students.
(Yu, 2022)	QuARKS	This tool allows students to generate multiple-choice questions and accompany them with self-generated explanations, either in text or multimedia format.
(Alonso-Secades et al., 2022)	Inteligencia artificial (AI)	The set of technologies that enable machines to learn, reason and perform tasks that, until now, could only be performed by humans.
(Alonso-Secades et al., 2022)	Big data	A set of technologies that allows the collection, storage and processing of large volumes of data. From this data, conclusions and patterns are drawn to improve process efficiency.
(Chen et al., 2022)	WILM-CDRASS	Inquiry-based learning platform specifically designed to help elementary school students develop online information evaluation skills.

Q4: Which Methods Are the Most Efficient in the Mathematics-Oriented Teaching-Learning Process?

Table 8 below presents a general analysis of the efficiency of the methods used, proposed by the authors in the teaching-learning processes. These methods have proven to have an impact on the improvement of students' understanding and performance in mathematics. Those that clearly present the results obtained or the levels of efficiency achieved have been included.

A classification system has been established in three levels of efficiency to evaluate the impact of various methods on students' academic performance in mathematics, the results indicated by the authors are analyzed and the percentage of improvement is determined according to the method used. An inefficient level (<30% improvement) is considered where the methods used have limited effectiveness in the understanding and application of concepts. The efficient level (30-50% improvement) includes methods with moderate improvement and considerable effectiveness. Finally, the very efficient level (>50% improvement) includes methods with significant improvements. Table 7 shows this rubric.

Table 7. Efficiency Evaluation Rubric

Efficiency Criterion (Performance Improvement)	Description
Inefficient (<30%)	The method shows minimal or no improvement in academic performance.
Efficient (30-50%)	The method shows a significant improvement in academic performance.
Very Efficient (>50%)	The method shows a significant improvement in academic performance.

Table 8. Efficiency Level of Methods Used

Reference	Method	Valuation	Observations
(Liu et al., 2024); (Andriyani, 2023); (Cheng et al., 2023); (Hwang, Chiu, et al., 2023); (Fernández-Oliveras et al., 2021); (Chang & Yeh, 2021)	Game-based learning	Efficient	The authors point out that the method increases student participation and collaboration; in the case of understanding geometric shapes, improvements of more than 50% were observed, but its impact on other similar topics was not notable with only 15% improvements.
(Dahshan & Galanti, 2024)	Block-based programming	Very efficient	The authors mention in the results that, by using this method through the Scratch tool, 75% were able to understand and correctly apply the representation of numbers and place value.
(Rati et al., 2023)	Project Based Learning	Inefficient	According to the authors, the results obtained when using the method in an experimental group of students with another group that used a traditional method, the improvement was only 18.8%.
(Yang & Lin, 2024)	Method based on graphic organizers	Inefficient	According to the authors, the results obtained using this method in the tests only showed an improvement of 10% in comparison with other students.
(Hwang, Chen, et al., 2023)	Two-level approach based on graphic organizers	Inefficient	The authors mention that the results showed that the group of students who received this new form of teaching obtained, on average, a 15% increase in their test results after applying it.
(Y.-H. Lin et al., 2023)	Model 6E	Efficient	According to the authors, the 6E approach led to superior performance, with an adjusted mean of 78.476, versus the group without such an

Reference	Method	Valuation	Observations
			approach (mean of 59.788), an improvement of 31.15%.
(Sáez-López et al., 2023); (Binti Kamarudin et al., 2022); (Murillo-Zamorano et al., 2023); (Rincon-Flores et al., 2023)	Gamification	Efficient	The authors point out that this method in the case of calculus, problem posing and problem solving, improvements of more than 30% were observed. In addition to highlighting other aspects such as reducing the level of depression, anxiety and stress.
(Safitri et al., 2022)	Digital game-based learning	Efficient	The authors note that the method produced significant improvements in students, with an average increase of 30% in academic performance.
(Atin et al., 2022)	ARCS Learning Model	Efficient	The authors concluded that the use of this method in the mathematics application showed results with a 42% increase in student comprehension.
(Topali & Mikropoulos, 2023); (Bevan & Capraro, 2021); (Yu, 2022); (Kesler et al., 2022)	Constructivist approach	Very efficient	The method demonstrated significant improvements in students' mathematical skills, outperforming conventional methods, with improvements of more than 50% in performance and flexibility in basic operations.
(Ziden et al., 2022)	M-learning	Inefficient	The authors observed significant improvements when using mobile learning with augmented reality, with a 16.4% increase in motivation and 16.7% increase in post-test scores.
(Chen et al., 2022)	Inquiry approach	Efficient	The authors found that the use of the WILM-CDRASS program improved students' academic performance by 44.53%, according to the results mentioned in the study.
(Hsu et al., 2022)	Socratic Reflection Prompts (SRPs)	Inefficient	The authors note that only a 15.5% improvement in academic performance was achieved in post-test scores compared to the pre-test.
(Setambah et al., 2021)	Method of teaching with fractional coding	Inefficient	The authors concluded that the use of the Fractions cipher showed minimal improvement in student learning, with only a 4.2% increase in mathematical achievement.

Q5: Which Technologies Are More Efficient In The Construction Of A Mathematics-Oriented Teaching-Learning System?

Table 9 specifies the technologies used in the development of educational teaching-learning systems according to the authors, based on the research carried out, the efficiency of these technologies is classified into three levels: Inefficient, Efficient and Very Efficient. To determine these levels, aspects such as ease of implementation, compatibility, adaptability, integration, scalability, among others, were considered.

Table 9. Efficiency of Technologies in Teaching-Learning Systems

Reference	Technologies	Efficiency	Observations
(Liu et al., 2024)	CPSLens	Very efficient	According to the authors, it was successfully implemented to evaluate the collaborative problem-solving process of students due to its ability to facilitate the evaluation of the process, allowing a real-time record, to assess the students' ability.
(Dahshan & Galanti, 2024); (Yang & Lin, 2024); (Cheng et al., 2023); (Topali & Mikropoulos, 2023); (Kesler et al., 2022)	Scratch	Efficient	According to the authors, this tool is efficient in the construction of the system because of its accessible interface, facilitating the development of mathematical thinking through interaction with customizable blocks and sprites, but prior knowledge or training is needed to use it.
(Dahshan & Galanti, 2024)	Digital Interactive Notebooks (DINbs)	Very efficient	The authors mention that the DINbs allowed for an organized documentation of teachers' interaction with Scratch programs and their reflections, which facilitated the collection of detailed qualitative data.
(Rati et al., 2023)	Google Meet, WhatsApp Group (WAG), y Zoom Cloud Meetings	Efficient	According to the authors, these 3 tools proved to be effective in the construction of the system, because it is easy to implement, allowed interaction and collaboration between students and teachers, enabled group chat activities, sharing of educational materials and collaborative activities.
(Nadzri et al., 2023)	GeomAR3	Very efficient	According to the authors, GeomAR3 was effective in building the system and improving students' understanding of geometric shapes. Classroom implementation was feasible and teachers needed little training to use the tool.
(Hwang, Chen, et al., 2023); (Sandoval Henríquez & Badilla Quintana, 2021)	Spherical Video Based Learning Environments	Efficient	According to the authors, SVLE was successfully implemented and was considered an efficient technology to build the system. Teachers found it easy to use and expressed a positive reception.

Reference	Technologies	Efficiency	Observations
	(SVLE)		Although there were suggestions for improvement, such as the need for patience when using it, it was generally well received.
(Y.-H. Lin et al., 2023); (Silva-Díaz et al., 2023); (Tursynkulova & Madiyarov, 2023); (Nindiasari et al., 2024);(Zholaushievna et al., 2022); (Sandoval Henríquez & Badilla Quintana, 2021)	Virtual Reality (VR)	Very efficient	The authors conclude that VR is very efficient in the construction of the system, as it lies in its ability to provide immersive and hands-on educational experiences, VR facilitated experimentation and problem solving in a safe environment.
(Sáez-López et al., 2023)	Kahoot	Efficient	According to the authors, it is efficient because of its widespread use and ease of access to implement it. However, its efficiency may vary depending on the educational context and the teacher's ability to integrate it.
(Sáez-López et al., 2023); (Chang & Yeh, 2021)	Socrative	Efficient	The authors mention that Socrative stands out for its ability to assess student learning quickly and easily, making it a valuable tool for teachers. However, its effectiveness may depend on the technological infrastructure available.
(Tursynkulova & Madiyarov, 2023); (Ziden et al., 2022); (Sandoval Henríquez & Badilla Quintana, 2021)	Augmented Reality (AR)	Very efficient	According to the authors, augmented reality (AR) stood out for transforming abstract geometric concepts into interactive experiences, enriching teaching by turning the theoretical into the tangible. The implementation was carried out using mobile devices with embedded sensors.
(Hwang, Chiu, et al., 2023)	RPG Maker	Very efficient	According to the studio, RPG Maker was efficient in building the TT-DGA system due to its user-friendly interface, which allowed designers to create the game environment and levels without the need for advanced programming skills.
(Naveed et al., 2023)	Cloud computing	Efficient	The combination of cloud computing and mobile technology proved efficient in building the system, allowing flexible access to educational resources and enhancing the user experience.

Reference	Technologies	Efficiency	Observations
(Wicaksono & Rahmatya, 2023)	Raspberry Pi, OpenCV, TensorFlow Lite	Very efficient	The technologies used were efficient: Raspberry Pi as the main brain, OpenCV to detect colors in images, and TensorFlow Lite to detect shapes in geometric objects.
(Rincon-Flores et al., 2023)	Gamit!	Efficient	The authors highlight the efficiency of Gamit! for its gamified reward system that modifies the learning environment. In addition, the platform maintains anonymity in class rankings, demonstrating attention to student privacy.
(Moral-Sánchez et al., 2022)	Classcraft	Very efficient	The authors mention that Classcraft is considered an efficient technological tool due to several factors. First, its implementation and use were perceived as relatively simple, which facilitated its adoption in the classroom. In addition, the platform offered a number of resources and features that complemented the flipped learning model.
(Safitri et al., 2022)	Word-wall	Efficient	The authors mention that Word-Wall is an efficient technology for the construction of the system. It is an attractive and flexible tool for creating educational games that integrate word walls, a form of visual teaching that associates key words with their definitions or reference images.
(Yu, 2022)	QuARKS	Efficient	According to the author, the tool was efficient for construction by facilitating the generation of questions and explanations. The multimedia elements enriched learning and motivated students to explain questions from their peers.
(Alonso-Secades et al., 2022)	AI, Big data	Very efficient	The authors conclude that artificial intelligence (AI) and Big Data were effective in building the system, enabling the implementation of predictive and machine learning algorithms, as well as the management and analysis of large volumes of data to provide personalized recommendations.
(Chen et al., 2022)	WILM-CDRASS	Efficient	According to the authors, it was efficient because it facilitated the effective application of the principles of information evaluation through the collaborative annotation tool, promoting a critical and detailed analysis of online information.

Discussion and Conclusion

The methods identified as efficient in teaching mathematics are: block-based programming, game-based learning, gamification, the constructivist approach, the ARCS learning model, the 6E model, digital game-based learning and the inquiry approach. These methods focus on active student participation, practical application of mathematical concepts, and the development of critical thinking and problem-solving skills. Block-based programming is considered very efficient, but it is only evidenced that it was used once and the constructivist approach that was used 4 times, unlike other methods that were only efficient, but were used more times such as game-based learning with 6 and gamification with 5, with the recurrent frequency of these 2 methods it could be said that they are considered effective and versatile methods to address multiple challenges in the teaching of mathematics.

With respect to the factors that influence the construction of teaching-learning systems, they are diverse and decisive. Those that stand out the most are: curricular design, interactive designs, personalization, ease of use, adaptability, digital competence, solid infrastructure, educational policies, pedagogical strategies, learning objectives, content, integration of features and navigation. These factors, when considered holistically, are essential to the development of these effective and successful systems. Among them, content was the most mentioned factor with 8 times, therefore, it could be said that the importance of a well-structured and adapted content is valued to facilitate understanding and learning, being fundamental for the success of teaching-learning systems.

Regarding the technologies used in the construction of educational systems for teaching-learning mathematics, a wide range is observed, including Scratch, Virtual Reality (VR), Augmented Reality, Socrative and Spherical Video-based Learning Environments (SVLE). Scratch stood out by being mentioned in 5 papers, indicating its effectiveness, particularly in the understanding of positional values, arithmetic operations, among others. On the other hand, technologies such as CPS Lens, Digital Interactive Notebooks, GeomAR3, RPG Maker, Raspberry Pi, OpenCV, TensorFlow Lite, Classcraft, and AI, Big Data were mentioned only once, suggesting that, although they could be efficient their use has not been as wide as Scratch. In this sense, it is important to consider the possibility that these technologies have not yet been further explored to determine their true potential in improving the teaching-learning process. With respect to Virtual Reality (VR) was the most used technology, mentioned in 6 papers, indicating its potential in education, especially in geometry. However, its application in other mathematical areas seems to be less developed, suggesting a need for further research.

Based on the literature review and data analysis collected, several key conclusions related to methods and technologies in mathematics-oriented teaching-learning processes have been drawn. The variety of methods identified, such as gamification, game-based learning, block-based programming, and the constructivist approach, underscores the diversity of strategies employed to enhance mathematics instruction. This diversity reflects an adaptive, learner-centered approach, seeking different ways to engage learners and facilitate understanding of complex mathematical concepts.

In addition, evidence suggests that gamification and game-based learning are highly effective, given their positive impact on learner motivation and engagement. Although block-based programming and the constructivist approach have also been shown to be efficient, the frequency of use of gamified methods suggests that they are preferred for their ability to make learning more interactive and engaging. On the other hand, the identification of factors such as curriculum design, interactivity, personalization and ease of use highlights the importance of careful planning and adaptation to the needs of learners. These essential factors ensure that teaching-learning systems are not only effective, but also accessible and relevant, promoting an inclusive and stimulating educational environment.

As for the featured technologies, including scratch, VR and SVLE, they show how innovative tools are being integrated to improve mathematics education. The prevalence of scratch and VR suggests their effectiveness and popularity in teaching, while the diversity of other technologies indicates a continued exploration of new solutions to enhance student learning and interaction with mathematical concepts. In particular, they indicate that technologies such as scratch and virtual reality are particularly efficient, given their ability to facilitate the understanding of mathematical concepts and their widespread use in education. The effectiveness of these technologies can be attributed to their ability to provide immersive and interactive learning experiences that enhance student engagement and knowledge retention.

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