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Tecnología Innovación en la Educación STEM: Una Revisión y Análisis

Technology Innovation in STEM Education: A Review and Analysis

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RESUMEN.
Este estudio examina artículos de investigación sobre la educación STEM y la innovación tecnológica que han sido indexados por las bases de datos Scopus, Web of Science (WoS), Springer y Google, con el objetivo de proporcionar un análisis en profundidad de estudios empíricos de alto impacto en educación STEM. Las conclusiones de los autores son consistentes con estudios anteriores sobre el tema, destacando la creciente necesidad de ocupaciones basadas en tecnología a medida que los robots reemplazan a los humanos en la industria y la sociedad. El estudio destaca varios problemas en el campo de la educación STEM, incluyendo la brecha de género y los efectos de la educación STEM en personas de todas las etnias. Los autores ofrecen una detallada investigación de estudios empíricos de alto impacto en educación STEM para comprender el avance de los paradigmas de investigación en el tema. El estudio ofrece una vista actualizada de los artículos de investigación empírica altamente citados en educación y tecnología STEM, que sirve como una sólida base para futuros estudios. Se recomienda que la investigación futura continúe enfatizando la creatividad, particularmente en el campo de la ciencia, tanto en la investigación como en la educación. Los autores enfatizan la importancia de abordar los problemas de la brecha de género y los efectos de la educación STEM en personas de todas las etnias en futuras investigaciones.

PALABRAS CLAVE.
Educación STEM, Aprendizaje, Enseñanza, Innovación Tecnológica, SLR.

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ABSTRACT.
The study examines research articles on STEM education and its technology innovation that have been indexed by the Scopus, Web of Science (WoS) databases, Springer, and Google, and aims to provide an in-depth analysis of the high-impact empirical studies in STEM education. The authors' conclusions are consistent with past studies on the topic, highlighting the increasing need for technology-based occupations as robots replace humans in industry and society. The study highlights several issues in the field of STEM education, including the gender divide and the effects of STEM education on people of all ethnicities. The authors provide an in-depth investigation of high-impact empirical studies in STEM education to understand the progress of research paradigms in the subject. The study offers an up-to-date view of the highly cited empirical research articles in STEM education and technology, serving as a solid foundation for future studies. It is recommended that future research continues to emphasize creativity, particularly in the field of science, in both research and education. The authors stress the importance of addressing the issues of the gender divide and the effects of STEM education on people of all ethnicities in future research.

KEY WORDS.
STEM Education, Learning, Teaching, Technology Innovation, SLR.

1. Introduction.

Education is deemed critical in equipping young individuals with the skills required to address complex global challenges in a constructive manner. The emphasis on enhancing mathematical literacy, creative problem-solving abilities, and knowledge acquisition is crucial for students to succeed in the rapidly changing job market (Anito & Morales, 2019; Donnermann et al., 2022). However, the traditional academic system faces challenges in accommodating the multidisciplinary nature of learning (Hsieh et al., 2018). Education becomes meaningful when students apply newly acquired skills, knowledge, and insights to real-life situations (Zintgraff et al., 2020). To facilitate interdisciplinary learning, a holistic approach to curriculum development is recommended. This involves identifying various fields through a unified lens, either through the integration of course content or by fostering a multidisciplinary learning environment (Bridle et al., 2013; Goodwin et al., 2017). However, arbitrary divisions of subject matter as highlighted by Hirst (1974), result in a disconnect between students and real-world experiences, hindering the understanding process. The field of STEM (science, technology, engineering, and mathematics) education supports a blended approach, utilizing real-world scenarios to engage students in the application of science and technology (Kelley & Knowles, 2016). The integration of various subjects within a STEM curriculum is challenging and requires specialized knowledge and experience (Stohlmann et al., 2012). It is imperative to assess the relationship between the components and evaluate their level of integration within the STEM curriculum (Moore et al., 2014). According to Kelley and Knowles (2016), STEM education can be defined as the strategy of delivering a blend of two or more STEM subjects, connected through real-world STEM

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activities, aimed at integrating these subjects to enhance student outcomes (Kelley & Knowles, 2016).

Technology has a considerable impact on STEM education, serving as a tool to support teaching and learning in all four subjects, including science, technology, engineering, and mathematics. The use of technology in STEM education can enhance student engagement and provide opportunities to apply scientific and mathematical concepts in practical settings (Gonzalez & Kuenzi, 2012). For instance, technology can be utilized to create simulations, visualize abstract concepts, and gather and analyze data, leading to the development of problem-solving, critical thinking, and collaboration skills (Ng, 2019; Usman, 2017). Studies on integrated STEM education have shown that the approach can be divided into disciplinary and multidisciplinary methodologies (Anderson & Li, 2020; Barclay & Bentley, 2021; Honey et al., 2014). According to Sheppard et al. (2009), technology provides an opportunity for the integration of science and mathematics in addressing real-world problems, serving as an effective content integrator in the STEM curriculum (Kelley & Knowles, 2016). This integration of subjects is crucial in the current job market, which is seeing a growing demand for professionals in STEM fields, such as computer scientists, computer programmers, lab technicians, and design engineers, as machines are increasingly replacing human labor in many industries (Anito & Morales, 2019). In light of the critical role that technology plays in STEM education, it is deemed essential to consider the integration of technology and innovation in the STEM curriculum (Bryan et al., 2015). STEM innovation is crucial for the advancement of society and the economy, influencing new technologies and creating new industries (Marrero et al., 2014). However, despite its importance, research in this area is often neglected, and this lack of attention could have serious consequences, hindering progress and limiting our ability to solve some of society's most pressing problems. Thus, it is necessary to prioritize research in this field and to consider the integration of technology and innovation in the STEM curriculum (Anderson & Li, 2020). The field of STEM education has garnered considerable attention in recent years, with research examining a range of topics such as the impact of individual differences on STEM learning, the acquisition of STEM skills by students, and the training of educators in STEM-based pedagogical techniques. However, despite the growing interest in STEM education, there is limited research that has explored the field in a systematic and comprehensive manner. The research that has been conducted has mostly focused on the scientific aspect of STEM teaching and learning, with limited attention being paid to other aspects of technology (Gonzalez & Kuenzi, 2012). Given the importance of STEM education for the advancement of society and the economy, it is crucial to examine the field more closely and address some of the key questions related to STEM education. Below are three potential research questions considered in this research:

1. What is the role of innovation in STEM education and how does it impact student learning outcomes?
2. How can technology be effectively integrated into STEM curriculum to enhance student engagement and critical thinking skills?

3. What are the challenges faced by educators in adopting and implementing technology-based teaching methods in STEM classrooms?

The purpose of the research is to enhance the understanding of STEM education and technology in academia. The focus of the research lies primarily on the intersection of STEM education and technology, as it is widely recognized that technology is a key driver of innovation. In addressing the research questions posed, this study proceeds in several stages. Firstly, the study introduces the concept of STEM education and technology, with a particular emphasis on the role of innovation in the field. Secondly, the study presents the theoretical framework. Thirdly, an extensive review of the relevant literature is presented. Fourthly, the research methodology is outlined, followed by a discussion of the results obtained and then presents a detailed description of the findings. Finally, the study concludes with the implications of the findings for future research and practice, and highlights avenues for future inquiry in this field.

Theoretical Framework.

The theory of Technological Pedagogical Content Knowledge (TPACK) introduced by Mishra and Koehler (2006) provides a framework for understanding the relationship between technology, pedagogy, and content in the field of education. According to the authors, TPACK is a unique form of knowledge that teachers require in order to effectively integrate technology into their teaching practice. The framework defines TPACK as the intersection of three forms of knowledge: technological knowledge, pedagogical knowledge, and content knowledge. Technological knowledge refers to the understanding of technology tools and their uses in educational contexts. Pedagogical knowledge involves understanding how to design, implement, and assess teaching and learning activities. Content knowledge is an understanding of the subject matter that is being taught (Mishra & Koehler, 2006). The framework is grounded in the recognition that technology should not be seen as a standalone tool, but rather as an integral part of teaching and learning practices. The authors argue that the most effective teachers are those who possess not only a firm grasp of technology and pedagogy, but also a strong understanding of the content they are teaching. The integration of technology in STEM education is essential, as it provides opportunities for students to engage in practical applications of scientific and mathematical concepts. Innovation plays a critical role in STEM education, as it drives progress and leads to the creation of new technologies and industries. STEM innovation is crucial for the advancement of society and the economy, and it is necessary to prioritize research in this field to ensure that progress is not hindered. The theoretical framework for this study includes the integration of various disciplines, the use of real-world scenarios, and the incorporation of technology and innovation in STEM education. It is essential to adopt a holistic approach to curriculum development that identifies various fields through a unified lens, fosters a multidisciplinary learning environment, and integrates course content to facilitate interdisciplinary learning. Theoretical frameworks from various disciplines, such as education, psychology, and technology, are utilized to develop a comprehensive understanding of the role of innovation and technology in STEM education.

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Review of Literature.

Students Perspective.

The integration of STEM education and projects into the curriculum has gained significant attention in recent years and has been widely recognized as a way to broaden traditional education goals and foster creativity (Abichandani & Sivakumar, 2022; Conradty et al., 2018). Evidence suggests that STEM education has a positive impact on student motivation and self-efficacy, particularly in maker spaces where students engage in hands-on learning experiences such as pondering, investigating, innovating, testing, manipulating, and discussing (Menjívar Valencia et al., 2022; Pellas et al., 2020). STEM education provides students with the opportunity to think critically and creatively, solve problems, collaborate with others, engage in productive discussions, and understand their roles and responsibilities (Zollman, 2012). This has been shown to promote equality in the field of computer science and encourage more girls to pursue education in this field (Comin & Mestieri, 2018; Lehman et al., 2016). Furthermore, STEM education can equip students with the knowledge and skills needed to become informed and responsible citizens (Boy, 2013). In light of these findings, STEM education can be seen as an important component of the theory, which focuses on the integration of technology, pedagogy, and content knowledge to improve teaching and learning outcomes (Mishra & Koehler, 2006). By providing students with the opportunity to engage in hands-on STEM activities and learn through exploration and experimentation. This, in turn, leads to a new era of creativity and inspiration in learning and improved attention (Bevan, 2017).

Teaching Perspective.

The incorporation of STEM principles into educational curricula has gained traction in recent years as a means to provide students with a more thorough and engaging learning experience. The cognitive perspective of education emphasizes competency-based learning, which requires students to actively alter their knowledge (Stains et al., 2018). However, despite the potential of this approach to revolutionize the classroom, its effective implementation requires adequate support, time, and experience on the part of teachers (Henriksen, 2014). Unfortunately, the implementation of STEM techniques and teaching resources among teachers remains limited (Jho et al., 2016; Park et al., 2016), with few significant methodological changes observed in the classroom as a result (Nathan et al., 2011). Despite these challenges, it is imperative to recognize the potential of competency-based learning to transform the educational landscape. An integrated curriculum that effectively engages and motivates students in a relevant and practical manner must be a priority in the advancement of education at all levels (Ring et al., 2017). Given the significance of the educational process in shaping students' futures, it is crucial to encourage teachers to explore the potential of competency-based learning and integrate it into their teaching practices (Concepción et al., 2022; Tytler et al., 2011).

The integration of STEM education strategies into the classroom is crucial for fostering the development of students who are equipped with the necessary skills and mindset to meet the challenges of the future. According to Baran et al. (2016), STEM education underscores

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the importance of empowering students through meaningful engagement with the subjects they are learning. This can be achieved through the adoption of a student-centered approach, which emphasizes collaboration and teamwork (Baran et al., 2016). According to Thibaut et al. (2018), a collaborative approach that encourages students to work together to create an output is the most effective way to enhance learning and foster the development of a creative mindset. The integration of creativity STEM education has been demonstrated to be a powerful motivator for students (Thibaut et al., 2018). Marrero et al. (2014) argue that the integration of technology and the arts in the classroom is crucial for preparing students to become informed and responsible citizens in the future. An interdisciplinary curriculum that combines STEM education with the arts has the potential to provide students with a well-rounded learning experience and to foster the development of a creative and collaborative mindset (Marrero et al., 2014). STEM education strategies into the classroom is essential for preparing students for the future. A student-centered approach that emphasizes collaboration, creativity, and the arts is the most effective way to foster learning and to equip students with the skills and mindset necessary to meet the challenges of the future.

Technology Innovation Perspective.

The advancements of technology in the 21st century have resulted in a reconsideration of teaching and learning approaches in education. This shift is reflected in the integration of STEM and the arts in the educational system to facilitate active learning for students (Corlu et al., 2014). The utilization of multisensory technologies and maker spaces has been proven to enhance student engagement and learning outcomes, requiring educational reform towards a transdisciplinary, interdisciplinary, and multidisciplinary upgraded version of STEM education (Andino Sosa et al., 2021; Takeuchi et al., 2020). This necessitates the adoption of a comprehensive, engaging, and interesting teaching approach, with robotics and artificial intelligence (AI) emerging as novel sectors of STEM education (Kandlhofer et al., 2016). The increasing demand for technological occupations in the digital society and economy has created a need for qualified workers in STEM fields, such as programmers, systems engineers, biotechnologists, laboratory technicians, and project managers (Maass et al., 2019). To address this issue, a STEM movement has been initiated to increase interest and participation in mathematical, scientific, and artistic fields by promoting collaboration and creativity in learning environments (Baharin et al., 2018). The domains of robotics and AI have a significant impact on the preparation of future instructors of science, mathematics, and technology, and serve as educational bridges for acquiring human-assisted technology, AI, and robotics abilities in society (Pimthong & Williams, 2018). This highlights the need for the educational system, and classroom learning in particular, to meet the evolving demands and expectations of a technologically advanced society (Villanueva et al., 2012).

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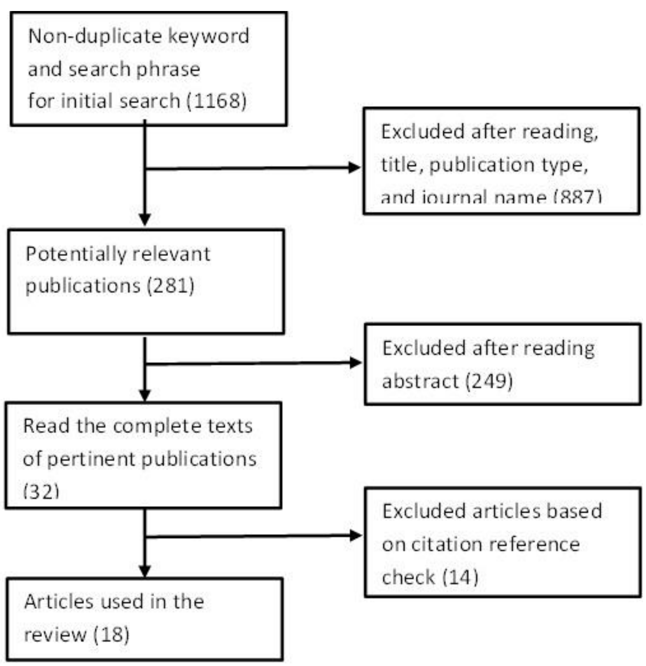
2. Metodology.

In this study, the authors utilized the Scopus, Web of Science (WoS), Springer and Google databases to obtain relevant studies on the state of the art being examined. The choice of these databases was based on their extensive coverage of a broad range of educational topics (Zhu and Liu, 2020), making them a valuable resource for contemporary research. The authors reported conducting a search for the term "STEM and Innovation" in multiple databases, resulting in a total of 1168 papers. It is evident that robust and consistent research facilities are critical in the STEM disciplines, which encompass a wide range of topics such as gender-related issues, impact on creativity and reasoning, influence on various racial groups and individuals, and teacher training for the implementation of STEM education in the classroom. In accordance with prior research on the advancements in STEM education, the present study chose to include publications that focused on Technology (i:e Innovation) and STEM Education, Similar to previous studies, the authors utilized the abbreviation STEM to distinguish disciplines and to search for relevant papers in the field of STEM education and technology (Baharin et al., 2018; Vincent-Lancrin, 2013). This study used Scopus, Web of Science, Springer and Google databases, with a focus on identifying high-impact journal papers. To limit the scope of the review, the authors chose to focus on the most cited studies from these databases. The search was limited to four categories within the STEM education field: "technology," "STEM and technology," "Innovation," and "Psychology educational." The authors ultimately identified and listed the 18 research journal publications in STEM education and Innovation.



Source: Adapted from Hunter el al. (2019)

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The scope of this study was limited to publications between the years 2012 to 2022. A search was conducted using the databases Scopus, Web of Science (WoS), Springer and Google and the terms "STEM," "Education," "Technology," “Innovation,” "Psychology educational," and "STEM and Innovation." To ensure accuracy, the researchers conducted further searches for whole publications when the publishing information was inadequate. Ultimately, 18 research articles were identified for this study. Despite the limited number of citations available for research in this area, strict procedures were followed to minimize bias and ensure the validity of the results. The study incorporated elements from previous research in this field to guarantee that all necessary steps were taken in the most effective manner (Scalise et al., 2011).

The present study adhered to a strict methodology in order to eliminate any potential biases and enhance its validity. Based on the considerations outlined in the prior study by Moral-Muoz et al. (2020), we implemented a systematic approach to ensure that all crucial steps were executed in an optimal manner. To this end, we selected the study databases, defined the concept of STEM to be evaluated, and established the inclusion criteria for the search, incorporating all related components, such as "STEM Education*," "Technology*," "Innovation*," "STEM*," "Technology education*," "STEM and Technology," "Innovation education*," and "STEM and Innovation." Moreover, we utilized the "Theme-focused" search option, which resulted in a total of 1168 relevant publication. The content analysis was performed utilizing various tools including analyze results. These tools facilitated the extraction of information such as the publication year, country of origin, document type, institutional affiliation, and language in the field of STEM education and technology. To maintain the validity of the data presented in the publication, specific inclusion criteria were established, including a time frame from 2012 to 2022, limiting the language to “English”, and defined parameters for the knowledge area.

Descriptive Analysis

The current study employs a systematic literature review and content analysis to examine the field of STEM education. The analysis of the publications focused on STEM education and technology in the context of innovation revealed two major groups. This categorization was a simplification compared to previous reviews and helped uncover patterns in discipline coverage and techniques used in high-impact STEM education research (Adams et al., 2011). The focus on the country of the corresponding author was also found to be a useful tactic. To further differentiate STEM education research from other subjects, two primary categories were established: "STEM Education" and "STEM + Technology". This approach has been effective in previous literature reviews and is highly recommended. Although co-authorship is common in STEM fields, little information is often provided about the multiple authors. The classification of the corresponding authors of the publications was thoroughly considered and established through prior research using the original department/institution affiliation. In response to the research questions, two categories were selected from previous literature reviews, middle and high schools, which were deemed appropriate and well-suited for the purpose of the study.

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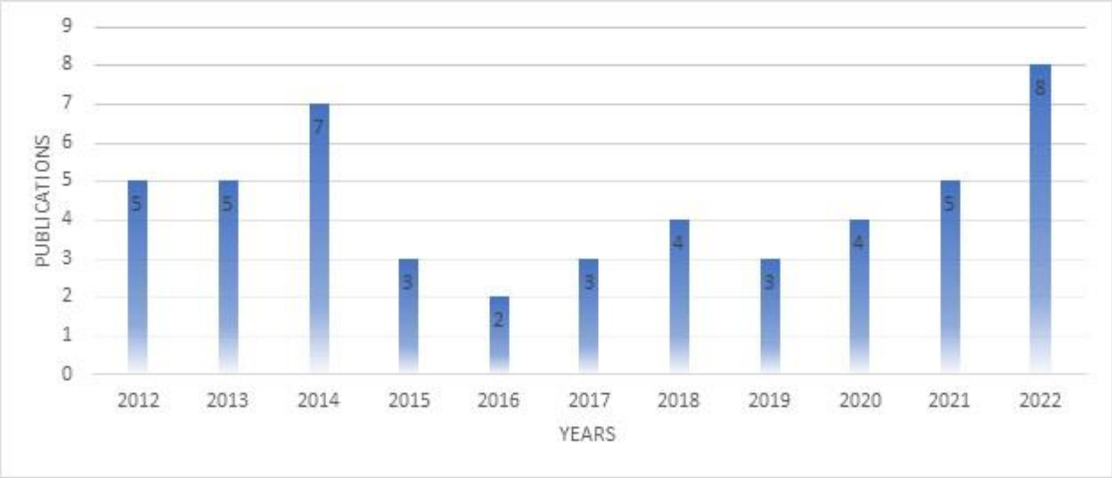
Figure 2

Year-wise Publications based on Review



The data presented in the table reflects the number of publications produced in a given year, ranging from 2012 to 2022. The highest number of publications was recorded in 2022, with 8 outputs produced. This represents a substantial increase compared to the previous years, and suggests a potential improvement in productivity or a change in circumstances that facilitated a higher output. In 2012 and 2013, the percentage of publications produced was equal, at 10.2%. The highest percentage of publications produced was in 2022, with 16.3%. The other years ranged from 4.1% to 14.3%.

3. Keywords Analysis.

The study conducted from 2012 to 2022 has demonstrated that the concept of "technology" holds the highest significance level compared to other areas. This finding is in line with the significance of technology in this time period. Furthermore, the concepts of "teachers" and "students" are also recognized as important elements of the era. Analysis of the cluster networks of these concepts reveals a strong association between "technology" and concepts such as "problem-solving," "technology knowledge," "understanding," "classroom," "innovation," "creativity," and "literature." The concept of "innovation" is also related to concepts such as "problem-solving," "advancement," "motivation," "performance," and "achievements." The study also indicates that Science and Computer Programming have been the most robust academic subjects between 2012 and 2022, with both subjects continually expanding during this period. The research has established a strong relationship among concepts such as "Computer Science," "STEM Education," "Coding," "Automation," "Technology," "Systems," "Machine Learning," and "Algorithms." Additionally, there is a clear association between Science and Technology, as well as concepts such as Calculus, Knowledge, Creativity, Numeracy Skills, Innovation, Women, and Education. These findings highlight the continued growth and development of Science and Computer Programming as the most successful and beneficial academic subjects during this period. The scientific

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community is currently focused on computer programming, imparting subject-matter expertise while incorporating STEM, student engagement in STEM-based learning strategies, and the effects of STEM on the science sector. The concepts of "innovation" and "creativity" should also be considered as potential future major subjects in this field of study, given their prominent position in the schematic as identified themes. It is noteworthy that the current research focus is on emphasizing the utilization of STEM in education beyond formal settings. This research is crucial in comprehending the accessibility of STEM to individuals of various educational backgrounds and in investigating the impact of STEM on individuals at different stages of their educational and professional journey, including middle schoolers, high schoolers, undergraduates, graduates, and those with job experience. Furthermore, STEM is being applied across a variety of fields of study, with technology and innovation being two of the most prominent.

Table 1

Author(s)	Finding(s)	Impact(s)	Country(s)
(Browwyn Bevan, 2017)	STEM-Rich Making is an innovative and highly beneficial approach to design and engineering that incorporates the use of digital tools and computational practices.	Students' conversation in technology education	USA
(Williams, 2016)	The comprehensive approach taken to STEM professional development, which included teaching strategies, technical literacy requirements, and interest creation.	Technology education	New Zealand
(Cook et al., 2019)	Academic libraries are embracing the potential of virtual reality (VR) technology to revolutionize research and teaching. By enhancing access to digital collections, presenting new research tools, and creating immersive learning environments, VR technology is opening up a world of possibilities for students and researchers alike.	Strategies for Educational Virtual Reality	USA
(Goodwin et al., 2017)	The findings of this study can be used as a model for other programs that wish to employ similar tactics, and should be taken into consideration as a viable approach to improving STEM education.	Strategies to address major obstacles to STEM-based Education	USA

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(Hsieh et al., 2018)	A recent study has revealed that corporate boards with a higher proportion of directors with degrees in science, technology, engineering, or mathematics are more likely to support greater innovation activities such as new technology invention, patent applications, and investments in research and development.	STEM-educated boards contribute to innovation activities	USA
(Klinbumrung & Surpare, 2022)	The evaluation of the innovative-based learning model's applicability by experts yielded highly satisfactory results. The learners expressed the highest degree of satisfaction with the novel learning methodology devised, illustrating the success of the model.	Development of Innovation-Based Learning and Teaching Model for Technology Education	Thailand
(Singkorn et al. 2022)	Research has consistently demonstrated that knowledge, initiative, and innovative thinking must be systematically integrated and linked in order to achieve success. The DLAAP innovative learning and teaching model was established and has proven to be particularly suitable for this purpose.	Development Innovation-based Learning Model to Study the Creation of Teaching Media	Thailand
(Roopaei & Klaas, 2021)	Through the use of immersive technology included in STEM subjects, children are inspired to use their problem-solving skills to discover solutions to insurmountable issues, which helps to better shape their future.	Immersive Virtual Reality in STEM Education	USA
(Abichandani & Sivakumar, 2022)	Results show that educational practices and techniques for teachers in order to establish successful IoT learning experiences for students. Such practices are essential for providing students with the opportunity to explore the full potential of the Internet of Things.	Internet-of-Things and STEM Education	USA
(Zhao, Muntean, et al., 2022)	It is evident that the implementation of games in the teaching and learning process has had a positive impact on all students, regardless of their geographical location, educational background, or the game they are playing.	Game-Based Learning	UK

(Dori, 2022)	Data analysis has revealed a significant and positive correlation between the FIRST program and participants' exposure to STEM fields and their preference for STEM-related careers.	STEM Exposure and Career Choices	Israel
(Iolanda et al., 2022)	The findings shows that students majoring in social sciences are more likely to possess communication, critical thinking, problem-solving, and technical digital abilities, while those majoring in humanities are more likely to possess other digital skills, such as creativity and information.	Digital Literacy Skills	Romania
(Appel & Mansouri, 2022)	The findings suggest that mentorship activities should be given more attention and resources, as they can have a positive, reinforcing effect when conducted by peers and close friends.	System Dynamics Modeling of the STEM	USA
(Maphosa et al., 2022)	The results of this study are highly encouraging, showing that the area is still expanding. An objective assessment criterion was used to identify and rank 32 elements, and a taxonomy of the components based on the social cognitive career theory was provided.	Students' Choice of and Success in STEM	South Africa
(Huang et al., 2021)	Research has revealed that students are engaging in a variety of real-world engineering projects and experiences, including carrying out design, manufacture, and lab testing; modeling and analyzing test samples; conducting tests on-site; and processing and analyzing data.	Using Cutting-Edge Technologies for STEM Education	USA
(Zhao, Playfoot, et al., 2022)	The outcomes demonstrate the impressive success of the suggested gasification strategy in significantly increasing student knowledge gain, while also improving their learning experiences and engagement.	Gamification Framework for Improved STEM Learning Experience	China
(Achilleos et al., 2019)	The statistical analysis and results of the platform and contest indicate a favorable impact on participants' STEM learning and motivation. Notably, the gender element was the only factor that had a discernible impact on the younger study group.	Contest-Based STEM Education and Motivation of Young Students	UK

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(Charlton & Avramides, 2016)	Research observations demonstrate the educational significance of cooperation and production in promoting opportunities for transdisciplinary learning.	Knowledge Construction in Computer Science and STEM Education	UK
(Halimatou & Yang, 2014)	To create an environment where instructors can work and kids can study, we need architects. It requires a vast area with a variety of uses, such as multimedia classrooms for students.	Adoption of Instructional Techniques and Educational Technologies	China
(Wu & Anderson, 2015)	According to the study, differences in science background knowledge may have an impact on significant outcomes like learners' modelling proficiency.	Technology-Enhanced STEM Education	China
(Hughes et al., 2022)	Instead of comparing results across participants, changes within subjects are presented. This article focuses more on changing technology in STEM contexts than it does on student learning.	Robotics & AI to improve STEM Education	Switzerland
(Baharin et al., 2018)	Problem-solving, critical thinking, creative thinking, and scientific thinking are all important components of the STEM education approach that can help students develop higher order thinking abilities.	Integrating STEM Education and Thinking Skills	Malaysia

Source: Literature Review

The table analyzed in this study provides a comprehensive overview of the various themes explored during the investigation, enabling a thorough comparison of the same themes across different time periods and their current relevance. There is no apparent conceptual gap within the field of study, as the term "creativity" is consistently present throughout the predetermined time frames. While its position within the different time diagrams does not indicate that it served as a central concept at any particular point in time, it highlights "creative thinking" as the overarching theme of the research on STEM, which is a noteworthy finding. Technology presents numerous avenues for research exploration, and among them, creativity has emerged as a prominent and persistent research theme. Furthermore, the STEM research field is well represented in the two other study streams of "learning laboratory-instruction" and "technology-science", which focus on the scientific domain and its corresponding instructional approaches. It is heartening to observe such a wide range of research opportunities within the technology field.

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4. Discussion.

In the context of STEM education, innovation plays a crucial role in shaping student learning outcomes. The study conducted by Kiira and Stéphan (2013) contributes to the existing body of knowledge on the topic and helps fill the gap between literature and reality. This allows for a better understanding of the significance of STEM education and technology in promoting innovation. The findings of the study demonstrate the importance of STEM education and technology in Scopus, WoS, Springer and Google research publications, and highlight their potential to positively impact the research landscape and further the progress of the scientific community. The topic of STEM education is widely covered in research publications, with a focus on "STEM learners," "learning," and "learning settings." However, there is limited research on disciplinary content integration in STEM teacher training and teaching and learning. Nevertheless, a growing trend of diversity in recent publications suggests that academics from other nations and regions may produce more high-impact research articles in the future (McClure et al., 2017). This is encouraging for the field of STEM education. Given the increasing reliance on digital technology and media in today's society, technology-related employment is on the rise. Bringing classroom technology into the classroom is crucial to prepare students for the future workforce. STEM programs have gained popularity since the late 2000s and have been the focus of continuous research since 2006 (Angel and Salgado 2018, Bush et al 2020, Chu et al 2018, Colucci-Gray et al 2019, Conradty and Bogner 2020, Dolgopolovas and Dagiene 2021, Greca et al 2021, Herro et al 2017, Lin and Tsai 2021, Webb and LoFaro 2020). The use of robots and virtual reality in academic research has also increased in recent years (López-Belmonte et al., 2021; Lopez-Belmonte et al., 2020a, 2020b).

The integration of technology into STEM curriculum presents a significant opportunity for the enhancement of student engagement and the development of critical thinking skills (DeJarnette, 2012). To effectively realize these benefits, it is crucial to adopt a strategic and well-thought-out approach towards the integration of technology in the classroom. This can be achieved by adopting a multidisciplinary approach, where technology is not viewed as a standalone subject but is integrated into various subjects to promote a more holistic understanding of its applications and implications. Additionally, incorporating interactive and hands-on technology-based activities and projects into the curriculum can foster student engagement and critical thinking skills, as they provide students with opportunities to apply their knowledge, analyze information, and solve real-world problems (Brownwyn Bevan et al., 2015). The use of technology-based tools such as virtual simulations, online assessments, and interactive learning platforms can also be an effective way to enhance student engagement and critical thinking skills (Micó-Amigo & Bernal Bravo, 2020). These tools can be designed to allow students to explore and experiment with concepts, engage in collaboration and teamwork, and reflect on their learning process, which can lead to a deeper understanding of the subject matter (Scalise et al., 2011). Furthermore, providing students with access to cutting-edge technology and tools can foster creativity, innovation, and problem-solving skills, which are crucial for success in STEM fields. To further enhance critical thinking skills, teachers can encourage students to critically evaluate and analyze

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information, to make informed decisions, and to use technology to support their reasoning and decision-making processes (Anderson & Li, 2020). Guzey et al. (2016) developed the STEM Integration Curriculum which consists of nine elements, including a stimulating and interesting situation, use of technology, combination of scientific and mathematical curriculum, teaching methodologies, collaboration, interaction, evaluation, and management. These elements serve as an assessment tool to evaluate the availability of essential components within a teaching module (Guzey et al., 2016). The implementation of technology-based teaching methods in STEM classrooms presents several challenges for educators. These challenges arise from various factors such as the lack of technical knowledge and skills, resistance to change, lack of funding and resources (Han et al., 2015), as well as concerns about the impact on student learning and engagement. These obstacles hinder the successful adoption and implementation of technology in STEM education, and it is important for educators to recognize and address these challenges in order to effectively integrate technology into their teaching practice (Al-Azawi et al., 2019). STEM education and innovation are critical areas of study that are rapidly evolving with the integration of new technologies. The findings of this study contribute significantly to the scientific community by highlighting the current state of research in this field and providing insights into the trends, gaps, and opportunities for future research. The authors' methodology and inclusion criteria ensured the validity and reliability of the results, which can serve as a valuable resource for educators, researchers, and policymakers in the field of STEM education and innovation. The study's focus on high-impact journal publications enhances the credibility of the findings and underscores the need for more research in this area. Overall, the study represents an important contribution to the scientific community by advancing our understanding of the intersection of STEM education and innovation and providing a roadmap for future research in this critical field.

Theoretical/Practical Contribution.

This research makes a theoretical contribution by applying the Technological Pedagogical Content Knowledge (TPACK) framework to the context of STEM education. By emphasizing the importance of integrating technology and innovation into STEM teaching practices, this study provides insights into how teachers can develop a deeper understanding of the intersection between technological, pedagogical, and content knowledge. The research also highlights the need for a multidisciplinary approach to curriculum development that fosters interdisciplinary learning and facilitates the practical application of scientific and mathematical concepts. Ultimately, this research aims to contribute to the advancement of society and the economy by fostering a generation of STEM professionals who are well-equipped to address real-world challenges and drive progress through innovation. Practical implications of this research include the need for educators to adopt a strategic and well-thought-out approach towards the integration of technology in STEM curriculum, considering the challenges that may arise from the implementation of technology-based teaching methods. Educators should also be aware of the importance of multidisciplinary approaches and the integration of technology into various subjects to promote a more holistic understanding of its applications and implications. Moreover, providing students with access to cutting-edge technology and tools can foster creativity, innovation, and problem-solving skills, which are crucial for success in STEM fields.

Limitations.

As the authors begun their investigation of STEM education and innovation, they followed a strict methodology to ensure the validity of their findings. However, despite their best efforts, several limitations emerged during the course of their study. One of the most limitations was the reliance on a limited number of databases to obtain their data. While Scopus, Web of Science, Springer, and Google are well-known and widely used in the academic world, they are by no means the only sources of information available. As a result, the authors may have missed out on potentially valuable insights and perspectives from other sources. Another limitation was the timeframe for the study. By choosing to focus only on publications from 2012 to 2022, the researchers may have overlooked earlier studies that could have provided important historical context and insights into the evolution of STEM education and innovation. Additionally, by limiting their study to this time frame, they may have missed out on more recent developments that have yet to be fully explored and understood. Finally, the study's strict inclusion criteria may have unintentionally excluded important research from certain countries or regions. By focusing only on English-language publications, for example, the research team may have missed out on valuable insights from non-English-speaking countries. Similarly, by only including research that specifically mentioned STEM education and innovation, they may have missed out on related research in other fields that could have been valuable to their investigation.

Future Research.

The authors of this study highlight the growth in fields associated with the STEM concept, as demonstrated by various bibliometric indicators. These findings present a current snapshot of STEM-related topics within the database, although it must be noted that the database is continuously evolving and future results may differ. Future studies should aim to provide more detailed insights into the factors that promote or hinder the adoption and implementation of technology in STEM education, as well as the impact of STEM education on student learning outcomes and the development of critical thinking skills. By building on the findings of this study, researchers, educators, and policymakers can work together to promote the development of effective STEM education programs that prepare students for success in the future workforce. These considerations are crucial for future research and should be given proper consideration.

5. Conclusiones.

In conclusion, this study has contributed to the research community by providing a comprehensive review of empirical studies in STEM education and technology innovation. The study utilized a systematic approach to identify and analyze the most cited research publications in STEM education and technology innovation from the years 2012 to 2022.

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The findings of the study are significant for future research in the field of STEM education and technology innovation. The study highlights the students', teachers' and technology perspective in the context of STEM education. These findings are in line with the study's objectives, as they provide a deeper understanding of the progress made in the field and areas that require further exploration. Overall, this study has contributed to the scientific community by providing a systematic and comprehensive review of the progress made in the field of STEM education and technology innovation. The study's findings provide valuable insights into the current state of research in the field and highlight areas that require further exploration. The study's results and recommendations can be used to inform future research in the field, guide policymakers and educators, and ultimately contribute to the development of a more inclusive and effective STEM education system.

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