DAARUS TSAQOFAH
Jurnal Pendidikan Pascasarjana Universitas Qomaruddin

E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

Trends in STEM Learning Research in Primary Schools: A Bibliometric Analysis from 2016 to 2025

Thufail Mujaddid Al-Qoyyim[1], Siti Maulidiya Nabila[2]
[1]Master of Natural Science Education Program, University of Mataram, Indonesia
[2]Master of Primary Education Program, University of Mataram, Indonesia

Email: Thufail.mujaddid19@gmail.com

Informasi Artikel

Submitted: 28-04-2025
Revised:06-05-2025
Published:03-07-2025

Keywords:
STEM Education; Primary School; Bibliometric Analysis; VOSviewer; Learning Trends

Abstract

This study aims to map research trends in STEM (Science, Technology, Engineering, and Mathematics) education at the primary school level from 2016 to 2025. The analysis adopts a bibliometric approach utilizing data sourced from Dimensions.ai, processed using VOSviewer software. Over 180,000 publications were evaluated based on annual trends, document types, fields of study, and keyword co-occurrence visualizations. The findings reveal a significant increase in the number of publications, peaking in 2023. Scientific articles emerged as the most dominant document type, followed by book chapters and monographs. Education, social sciences, and psychology were the most frequently represented thematic areas, indicating a strong interdisciplinary orientation. Network visualization identified three major clusters: pedagogical, demographic, and psychosocial. Meanwhile, overlay visualization highlights a shift in research focus from student characteristics to implementation-oriented and contextual issues in the post-pandemic era. These findings underscore the importance of developing adaptive, contextual, and evidence-based STEM learning policies and practices in primary education. This study offers strategic insights for researchers, educators, and policymakers in shaping the future direction of more relevant and sustainable STEM education.

INTRODUCTION

The 21st century has been marked by rapid technological advancements and increasingly complex global challenges (Widiyawati et al., 2021). These changes have not only transformed the socio-economic landscape but also fundamentally influenced educational paradigms (Wise et al., 2022). Amid the wave of the Fourth Industrial Revolution and the digitalization era, the demand for 21st-century competencies—such as critical thinking, creativity, collaboration, and communication (the 4Cs)—has become more prominent (Ivert et al., 2024). Education is no longer solely aimed at transferring knowledge; it is also expected to prepare learners to live, adapt, and contribute in a technology- and information-driven society. In this context, the STEM (Science, Technology, Engineering, and Mathematics) learning approach emerges as a key strategy for fostering a generation that is not only technically skilled but also adaptive, innovative, and capable of solving real-world problems (English, 2023).

Conceptually, STEM education emphasizes the integration of scientific, technological, engineering, and mathematical disciplines in real-world contexts (Archila et al., 2023). STEM learning encourages students to integrate multiple domains of knowledge to solve problems, think systematically, and develop essential 21st-century skills (Hebebci & Usta, 2022; Parno et al., 2020; Susanti et al., 2021). Therefore, introducing STEM at the primary school level is crucial as a foundational step in shaping students' thinking patterns and learning habits. However, while STEM education has seen significant development in many advanced countries, its adoption in developing nations—particularly within primary education—still faces numerous conceptual, practical, and policy-related challenges.

In practice, the integration of STEM into primary school curricula encounters various obstacles, including limited teacher understanding, inadequate professional training, insufficient educational resources, and resistance to changes from traditional learning models (Kartini et al., 2022) Furthermore, socio-cultural contexts play a significant role in influencing the success of STEM implementation at the elementary level (Carpio et al., 2025; Farrugia, 2023; Lokollo et al., 2024; Wise et al., 2022). Consequently, mapping the trends of STEM education research in primary schools is essential to gain a better understanding of the scientific development trajectory, key recurring issues, and interdisciplinary collaboration potentials that may enhance the effectiveness and sustainability of STEM implementation.

Over the past decade, research on STEM in primary education has shown dynamic and exciting developments. Many studies have explored various STEM-based learning models, their impact on students' critical thinking and problem-solving skills, as well as the role of digital technology in enriching learning experiences (English, 2023; Mafugu et al., 2022; Sulisworo et al., 2021; Susanti et al., 2021). However, the extent of these studies, their research foci, and their distribution across subject areas have not been systematically examined. In other words, despite the increasing volume of STEM-related publications, there remains a gap in achieving a holistic understanding of the knowledge landscape shaped by these scholarly outputs.

One effective method for addressing this issue is bibliometric analysis—a quantitative approach used to evaluate and visualize the characteristics of scientific publications comprehensively. This method not only reveals publication trends over time but also maps topic relationships, identifies thematic clusters, and analyzes collaborations among researchers and institutions. In the context of STEM education in primary schools, bibliometric analysis can uncover deeper scientific dimensions, including primary research themes, thematic evolution over time, and the strengths and limitations of global academic production.

The urgency of such research is amplified by the growing need for evidence-based educational policy. Policymakers, curriculum developers, and decision-makers require structured scientific information on research trends to formulate relevant and adaptive policies. At the same time, educators and researchers need a comprehensive overview of the field's development to avoid topic redundancy and promote more innovative and collaborative research. Thus, mapping STEM education research trends through bibliometric approaches is critical not only in academic contexts but also in supporting a stronger and more sustainable educational ecosystem.

This study specifically aims to analyze research trends in STEM learning at the primary school level between 2016 and 2025. Drawing from publication data in the Dimensions.ai database and using bibliometric tools such as VOSviewer, this study will evaluate the number and types of publications, their disciplinary distribution, keyword co-occurrence patterns, and thematic transformations over time. The findings from this analysis are expected to make a significant contribution to the literature on STEM education, serving as a basis for the development of more contextual and evidence-based policies, practices, and future research.

Accordingly, this article seeks to address the need for a comprehensive understanding of the research landscape in STEM education at the primary level and to identify the directions, challenges, and opportunities that can be leveraged to build a resilient, relevant, and globally competitive primary education system.

METHOD

This study employed a quantitative bibliometric approach to analyze scientific publication trends related to the topic of "STEM and Primary School" within the period of 2016 to 2025. Bibliometric analysis was selected as it offers a comprehensive and systematic overview of the development of scientific literature in terms of volume, distribution, and inter-topic connections. This approach is also relevant for evaluating the dynamics of scholarly work and for mapping the knowledge structure within a particular field.

E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

The primary data source for this study was the Dimensions.ai platform—one of the largest scientific databases, encompassing millions of publications across various disciplines. Data were collected using the keywords "STEM" AND "Primary School," with filters set to English-language publications and document types limited to journal articles, book chapters, proceedings, monographs, edited volumes, and preprints. Data extraction was conducted between April 22 and 24, 2025, resulting in over 180,000 publication entries.

The exported data included publication metadata such as year, document type, author names, institutions, keywords, and abstracts. The data were then analyzed using Microsoft Excel to visualize publication trends and distribution across categories, while VOSviewer was used for keyword co-occurrence analysis, thematic cluster mapping, overlay visualization (temporal evolution of topics), and density visualization (topic intensity). The interpretation of results was carried out descriptively and exploratively through a thematic approach. The validity of the analysis was ensured through cross-checking between datasets and visual confirmation of the mapping results. The outcomes of this analysis are expected to provide significant contributions to the understanding of the direction, focus, and dynamics of STEM research in the context of primary education.

.

RESULTS AND DISCUSSION

Scientific studies on STEM learning at the primary school level have experienced significant development in parallel with the growing urgency of science and technology literacy within global curricula (Hu et al., 2024; Liu et al., 2023). The increasing complexity of 21st-century life has prompted the academic community to re-evaluate how science and technology are introduced from an early age, as well as how research in this field has evolved both methodologically and thematically. Although the STEM approach has been widely discussed across various publications, systematic mapping of its developmental trajectory, research frequency, and thematic focus over a specific time span has rarely been conducted comprehensively. Therefore, bibliometric analysis serves as a strategic approach to reveal the knowledge landscape and research trends that have unfolded over the past decade.

By utilizing data from Dimensions.ai and bibliometric visualization techniques, this study presents a scientific map that reflects the evolution of STEM research in primary education from multiple perspectives: publication trends, interdisciplinary contributions, document type distribution, keyword co-occurrence patterns, and thematic transformations. The information presented is not merely descriptive but also interpretative, aiming to provide meaningful insights for the development of educational policies, teaching innovations, and future research directions. The following sections will present the key findings derived from the bibliometric analysis, beginning with the annual publication dynamics that serve as an initial indicator of scientific intensity and attention to this topic.

Based on Figure 1, over the past decade, research on the integration of STEM (Science, Technology, Engineering, and Mathematics) in primary education has shown a significant upward trajectory. According to data extracted from Dimensions.ai on April 22, 2025, the number of scientific publications explicitly addressing the topic "STEM AND PRIMARY SCHOOL" has steadily increased from 2016, peaking in 2023. In 2016, the total number of publications was around 7,000, but this figure surged dramatically over the next five years, surpassing 16,000 in 2020 and continuing to rise beyond 20,000 in 2023.

This growth reflects the rising global attention toward establishing STEM literacy foundations from an early age. The paradigm shift in 21st-century education—emphasizing critical thinking, creativity, collaboration, and communication (the 4Cs)—has encouraged researchers and educators to explore diverse approaches, strategies, and innovations in STEM

E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

learning at the primary level (Indarta et al., 2021; Widiyawati et al., 2021). Notably, the sharp increase during the 2019–2020 period may be attributed to educational responses to the disruption caused by the COVID-19 pandemic, which compelled institutions to accelerate digital adoption and develop more interdisciplinary and contextual learning models. This, in turn, led to a surge in publications discussing curriculum design, technology integration, and the development of interactive media for STEM education in primary schools (Asrizal et al., 2023; Fauziyati, 2023; Lestari & Muhajir, 2024; Rafiq et al., 2022).

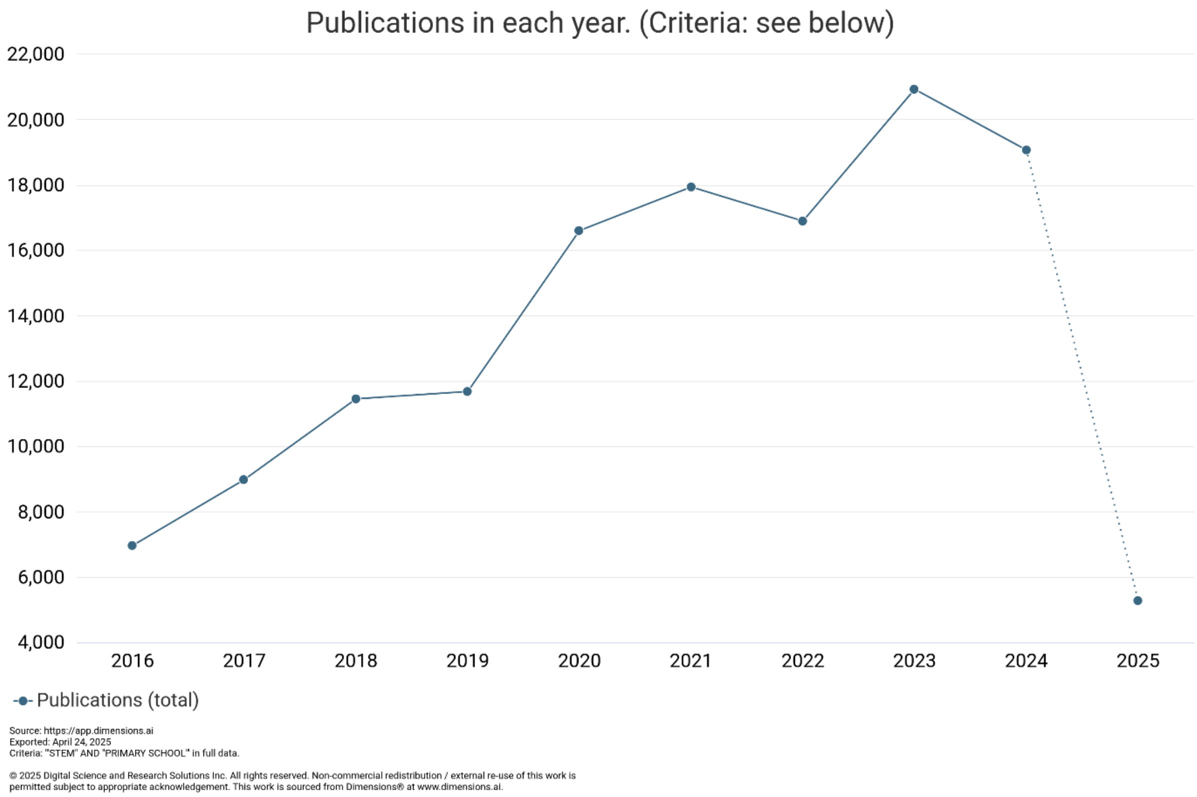

Figure 1. Research Trends in STEM Learning at the Primary School Level

Following its peak in 2023, the trend saw a slight decline in 2024. This decrease is likely due to temporary factors such as shifts in educational policies across different countries or post-pandemic research redirections toward other locally prioritized fields. The noticeable drop in 2025 should be interpreted with caution, as the year is still ongoing and the publication and indexing processes for scientific articles typically require time. Thus, the lower publication count for 2025 more accurately reflects incomplete data at this stage rather than a genuine decline in interest in STEM topics at the primary level.

Accordingly, the data presented in this figure reinforces the hypothesis that STEM has become a central focus in global primary education reform over the past decade. The significant growth in publications demonstrates that researchers, educators, and policymakers are actively promoting pedagogical transformation toward more contextualized, integrated, and 21st-century skills-based learning (Abas et al., 2024; Berg et al., 2021). These findings highlight not only the urgency of fostering early science and technology literacy but also provide a roadmap for developing evidence-based curricula and educational policies.

In addition to the temporal trend in publication volume, Figure 2 presents the distribution of publications by research field, offering a more comprehensive view of the multidisciplinary focus and approaches in STEM-related studies at the primary level. Based on Dimensions.ai data as of April 24, 2025, the field of Education dominates, with a total of 49,565 publications, reaffirming that STEM at the primary level is predominantly studied through pedagogical and curriculum development perspectives.

The Human Society category ranks second with 31,246 publications, underscoring the close connection between STEM education and social issues such as equitable access, character development, and technology-driven social transformation. Additionally, the field of Language, Communication, and Culture also shows a notable volume of 16,646 publications, highlighting the importance of literacy, scientific communication, and cultural context in promoting inclusive and contextual STEM learning in primary schools (Ayuso et al., 2020; Bakirci & Karisan, 2018; Larkin & Lowrie, 2023; Mafugu et al., 2022; Rogosic et al., 2020).

Interestingly, the field of Psychology (14,317 publications) also plays a substantial role, indicating that many studies examine the cognitive, motivational, and socio-emotional development of children in the context of STEM learning. This suggests a need for educational approaches that account for students' mental readiness and developmental characteristics (Ismatullina et al., 2022; Mulas et al., 2023).

Meanwhile, the Biomedical and Clinical Sciences and Health Sciences collectively contribute more than 24,000 publications, likely reflecting the integration of health-related topics and applied sciences into STEM learning—such as through simple biology experiments, health-themed projects, or technology-enhanced health literacy (Borger et al., 2025; Darmawansah et al., 2023; Liang et al., 2022; Sapounidis & Alimisis, n.d.).

On the other hand, the relatively low number of publications in Mathematical Sciences (1,833), Physical Sciences (575), and Chemical Sciences (278) may indicate that STEM approaches at the primary level do not emphasize these disciplines in isolation. This aligns with the integrative and thematic nature of STEM education, especially in early education settings, which prioritize interdisciplinary experiences over single-subject instruction (Hawani et al., 2023; Mafugu et al., 2022).

Thus, this distribution further reinforces the finding that STEM research in primary education does not solely focus on pure science or technology, but rather promotes a holistic interdisciplinary approach that combines educational, social, psychological, and cultural dimensions (Dere, 2024; Heni et al., n.d.). This provides a strong signal to curriculum developers and educational researchers that STEM innovation at the primary level must be designed comprehensively and contextually, considering child development, social values, and cultural and linguistic diversity.

DAARUS TSAQOFAH
Jurnal Pendidikan Pascasarjana Universitas Qomaruddin
E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

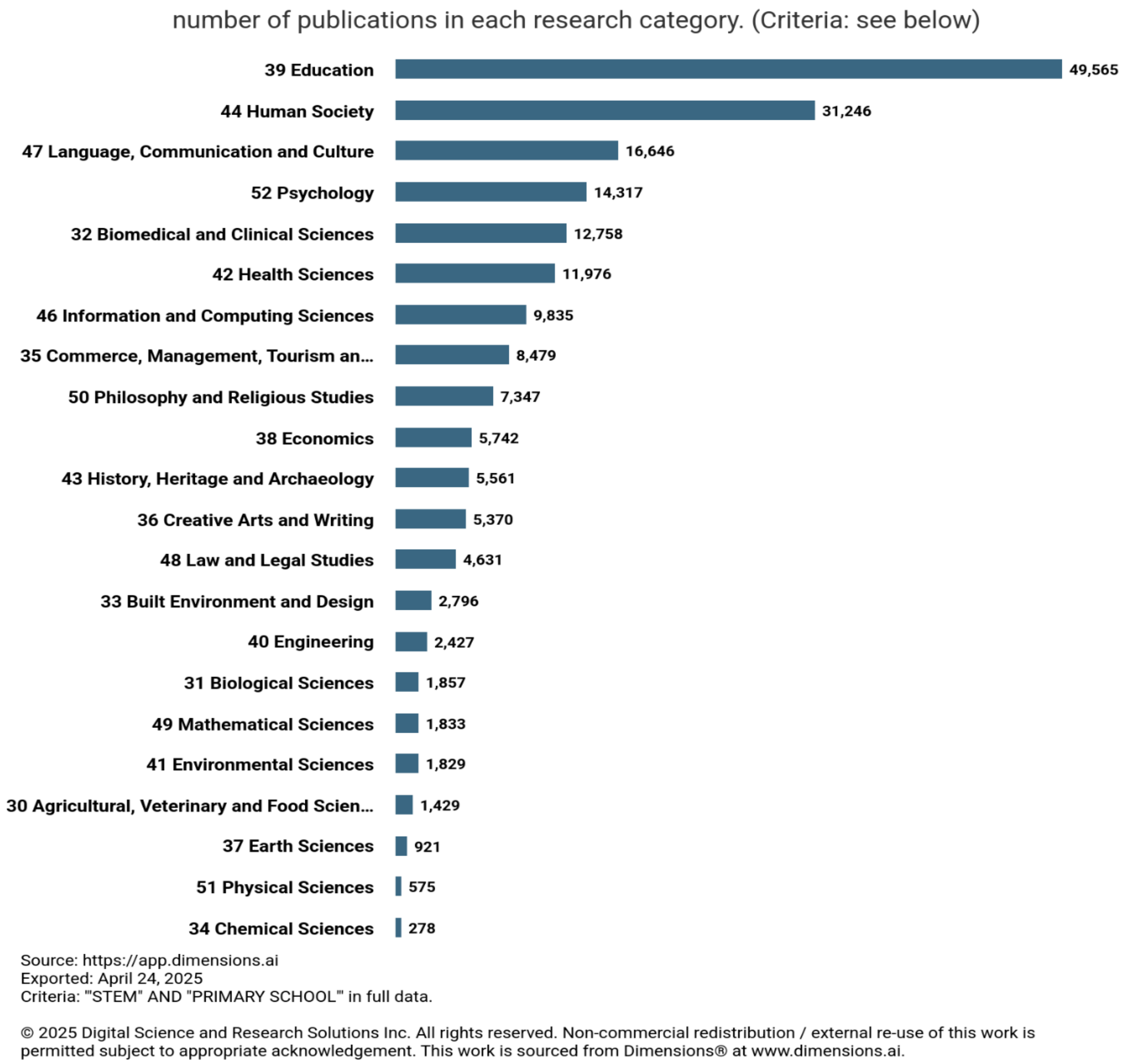

Figure 2. Distribution of publications by research field category with STEM topics

Table 1. Types of STEM Publications in Elementary Schools

Publication Type	Number of Publications
Article	84813
Chapter	57443
Edited Book	32731
Monograph	28053
Proceedings	4159
Preprint	3660

Based on Table 1, the distribution of publication types on the topic of "STEM and Primary School" shows that the majority of research contributions come from journal articles, totaling 84,813 publications. This indicates that articles remain the primary medium for disseminating research findings and developments in STEM learning at the primary school level. Journal articles offer a more flexible and faster publication process, making them more responsive to the evolving dynamics of education.

E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

In addition, there are 57,443 published book chapters, suggesting that a significant portion of STEM research in primary education has also been compiled in comprehensive volumes containing contributions from multiple authors, often in collaborative or thematic contexts. This demonstrates that STEM teaching approaches are being explored in-depth through academic discourse presented in book format.

The categories of edited books and monographs contributed 32,731 and 28,053 publications, respectively. Edited books typically compile diverse perspectives or case studies from educators and researchers in various educational settings, while monographs tend to be more singular and in-depth, offering extended reflection by the author(s) on a specific topic in STEM education.

Meanwhile, the number of publications in the form of conference proceedings (4,159) and preprints (3,660) is relatively smaller. This may be due to the fact that STEM research in primary education is not always presented in conference forums or disseminated widely through preprint platforms, which are more commonly used in pure science or technology fields. Nevertheless, the presence of proceedings and preprints remains significant as they reflect the development of real-time scholarly discussions and often serve as stepping stones toward indexed journal publications.

Overall, the variation in publication types demonstrates that STEM research at the primary level has been disseminated through various formats—ranging from fast and targeted articles to more comprehensive book-based works. This diversity in formats is essential for reaching a broader audience, including academics, teachers, policymakers, and teacher educators.

Table 2. Top 5 Citations on Trend of STEM in Primary Education Research in 2016-2025

Cites/year	Author (Year)	Title
16.00	Larkin & Lowrie (2023)	Teaching Approaches for STEM Integration in Pre- and Primary School: a Systematic Qualitative Literature Review
14.29	Bakirci & Karisan (2018)	Investigating the Preservice Primary School, Mathematics and Science Teachers' STEM Awareness
13.80	Ayuso et al. (2020)	Gender Gap in STEM: A Cross-Sectional Study of Primary School Students’ Self-Perception and Test Anxiety in Mathematics
13.00	Hu et al. (2024)	Integrating educational robot and low-cost self-made toys to enhance STEM learning performance for primary school students
13.00	Küçükaydın et al. (2024)	Modelling the relationships between STEM learning attitude, computational thinking, and 21st century skills in primary school

E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

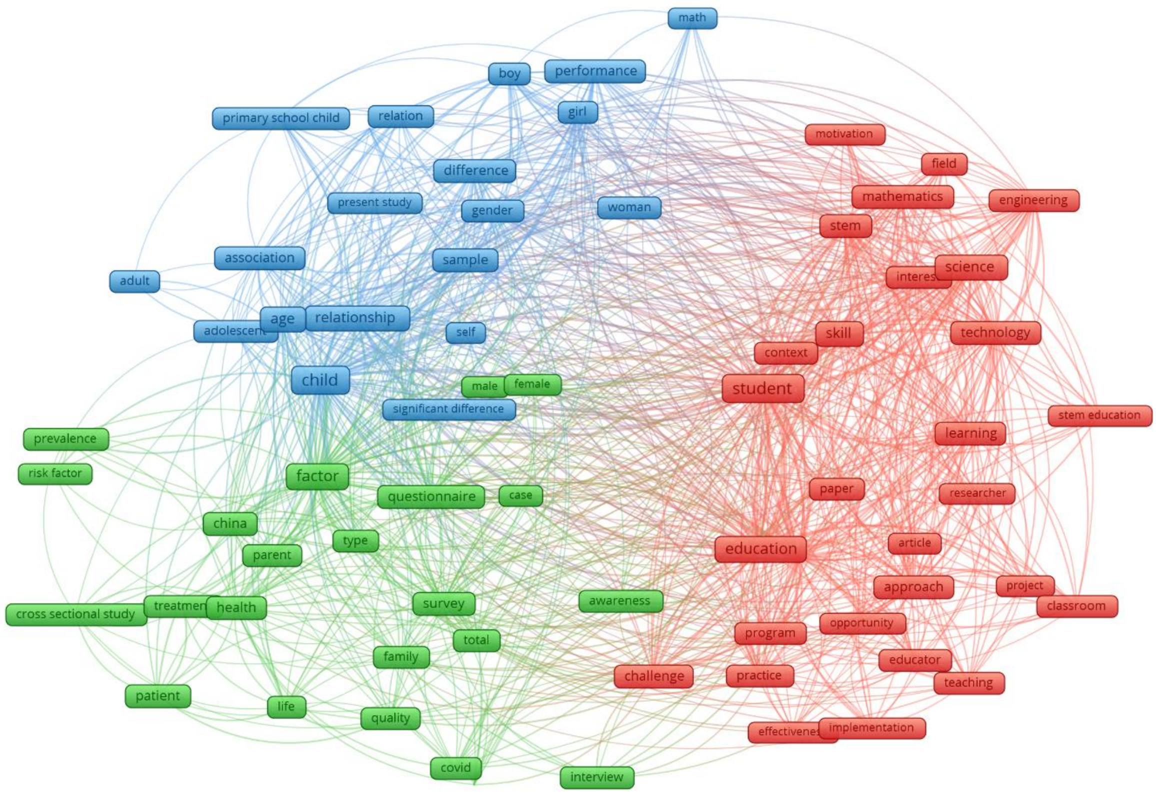

Figure 3. Visualization of keyword network

The keyword co-occurrence network visualized using VOSviewer software in Figure 3 illustrates the complexity and breadth of the research spectrum on STEM at the primary education level. Each node in the graph represents a frequently used keyword in the publications, while the lines connecting them indicate conceptual associations based on co-occurrence within scientific articles. The different colors reflect clusters of closely related topics or themes, revealing three dominant clusters in the visual map.

The first cluster, marked in red, represents the pedagogical core of STEM education research. Keywords such as student, education, learning, skill, technology, science, engineering, and mathematics dominate this cluster, indicating that learning approaches, teaching strategies, and STEM content integration in classroom contexts are central themes. Additionally, the presence of terms such as program, approach, implementation, and teaching suggest widespread exploration of the effectiveness of innovative learning models such as problem-based learning (PBL), project-based learning (PjBL), and technology-integrated instruction (Anwar et al., 2024; Fiteriani et al., 2021; Prajoko et al., 2023; Solihin et al., 2021).

The second cluster, represented in blue, reflects research focusing on student characteristics. Keywords such as child, age, gender, relationship, performance, boy, and girl emerge as central terms, indicating that researchers have also paid serious attention to demographic and cognitive factors that may influence children's responses to STEM learning approaches. Studies within this cluster often discuss how age, gender, and learning preferences affect academic achievement, interest in STEM, and gender disparities in mathematics and technology skills (Ertl et al., 2017; Merayo & Ayuso, 2022; Miller et al., 2024; Yamani & Almazroa, 2024).

The third cluster, visualized in green, represents a broader and more interdisciplinary dimension, where keywords such as factor, health, survey, COVID, parent, and life act as

E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

connectors to psychosocial and health-related topics. The appearance of terms like quality, treatment, and prevalence suggests that STEM education is not limited to cognitive or academic contexts, but is increasingly linked to children's well-being, the impacts of the COVID-19 pandemic, and parental involvement in home-based science education. This reflects a paradigm shift in primary education that views STEM learning as part of holistic child development, including the promotion of health awareness and social well-being (Borger et al., 2025; Çelik et al., 2022; Darmawansah et al., 2023).

The density of connections among clusters—especially between keywords such as student, education, and learning—indicates that the main research themes are not isolated but interconnected and mutually reinforcing. This visualization reveals that STEM approaches in primary education have evolved into a multidisciplinary research field that integrates pedagogical, psychological, social, and cultural dimensions simultaneously. Therefore, effective curriculum design and teaching strategies for STEM must consider the diverse factors influencing students' learning experiences—not only in terms of content but also regarding personal, social, and emotional backgrounds.

The overlay visualization of keyword analysis in STEM and Primary School publications, as shown in Figure 4, provides a temporal dimension that enriches the understanding of topic evolution from 2021 to 2023. In this visualization, the color of each node (keyword) represents the average publication year associated with that keyword: dark purple indicates earlier emergence (around 2021), while bright yellow signifies more recent and currently trending topics (around 2023).

From this overlay map, it is evident that several keywords—such as primary school child, relationship, difference, and sample—appear in purple and blue tones, indicating their earlier prominence within the analysis period. This suggests that in the initial phase of increased research attention, the focus was predominantly on student characteristics, particularly demographic and cognitive aspects such as gender, age, and individual differences in the context of STEM learning (Al Tamime & Weber, 2022; Morales et al., 2021). It also reflects that the foundational phase of research emphasized descriptive and correlational studies (Idrizi et al., 2023).

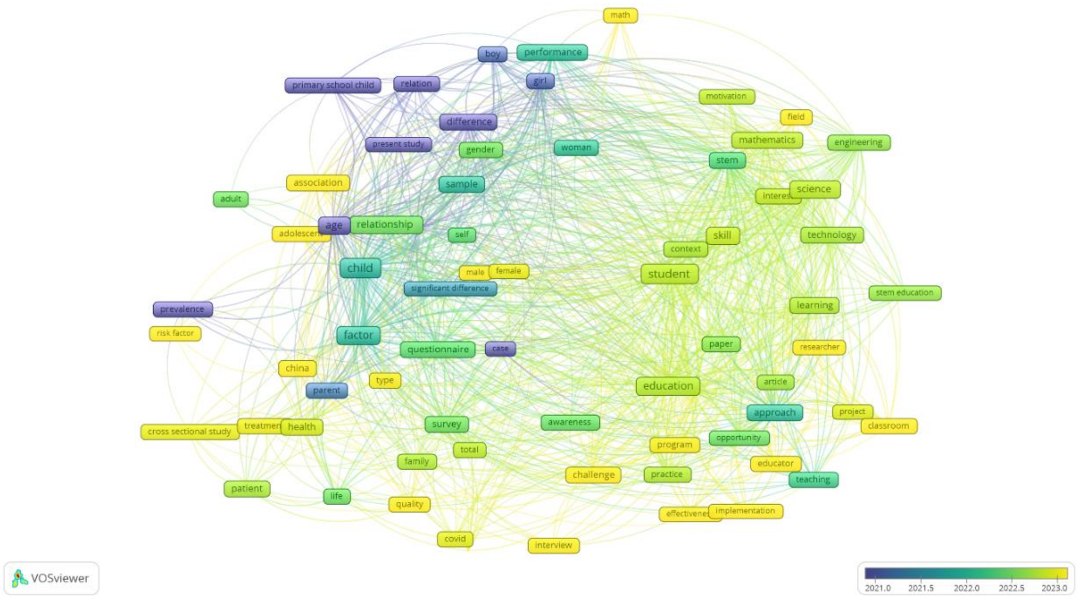

Figure 4. Overlay Visualization

E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

Over time, scholarly attention has gradually shifted toward more pedagogical and applied aspects of STEM education. Keywords such as education, learning, skill, technology, and approach appear in greenish-yellow hues, indicating a transition in research focus toward the development of instructional strategies, learning design, and the integration of STEM into primary school curricula. This trend suggests that in the past two years, research has increasingly emphasized the practical implementation and effectiveness of STEM approaches in real classroom settings.

Notably, keywords such as challenge, interview, implementation, and COVID appear in bright yellow, signaling their recent prominence in scientific discourse. The emergence of terms like COVID and awareness in brighter colors indicates a research response to the educational disruption caused by the COVID-19 pandemic, which prompted exploration of new topics related to remote learning challenges, technological access disparities, and increased awareness among teachers and students regarding 21st-century skills (Mäkelä et al., 2022; Priemer et al., 2020; Yulianti et al., 2022). Moreover, the growing presence of interview highlights a methodological shift toward more in-depth qualitative approaches aimed at understanding the subjective experiences of students and teachers in implementing STEM learning.

Overall, this overlay visualization reflects the dynamic progression of STEM literature in primary education—from early studies focusing on learner characteristics and correlational patterns to more pedagogically applied approaches that account for complex social contexts. The temporal mapping is essential not only for understanding how research topics have evolved but also for identifying research gaps and future priority areas. This data can serve as a valuable reference for researchers, curriculum developers, and policymakers in designing STEM programs that are relevant and sustainable.

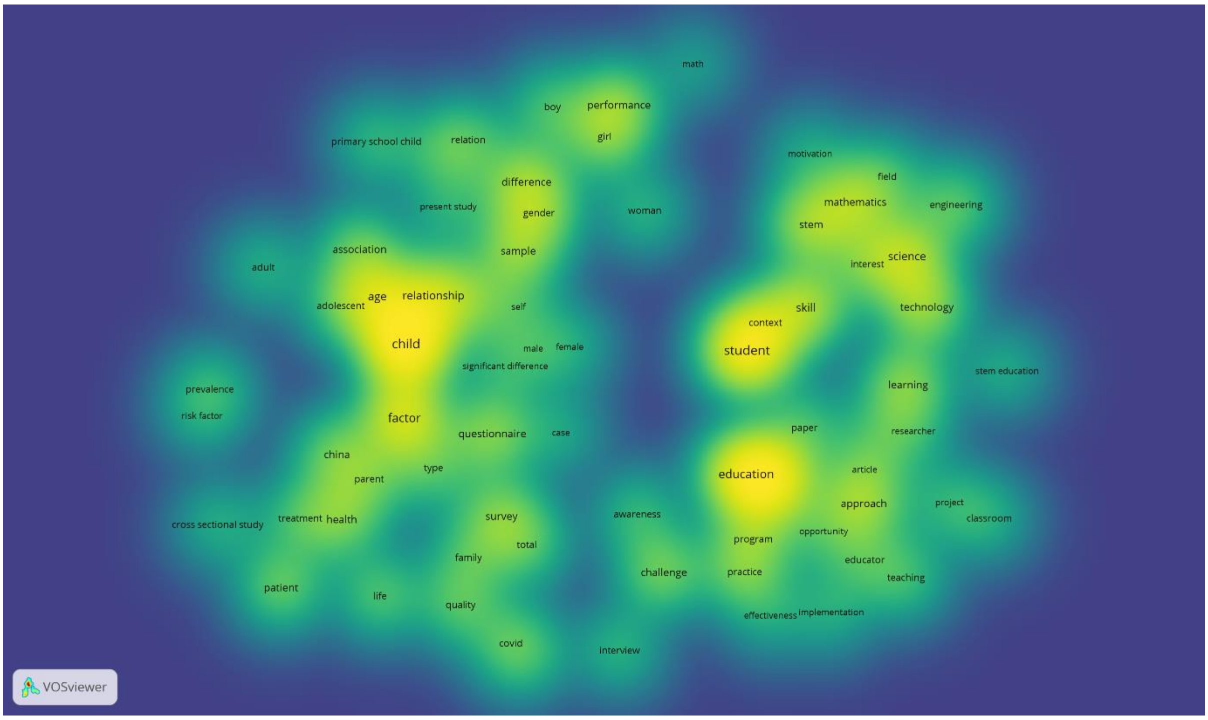

Figure 5. Density Visualization

E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

The density visualization of keyword analysis in "STEM and Primary School" publications offers deeper insight into areas of concentrated scholarly focus. In this visualization, regions with bright yellow colors indicate keywords with high frequency and connectivity within the research network, while blue areas represent lower density or less engagement in the academic discourse.

The two highest-density hubs are centered on the keyword's student and education, highlighting their centrality in STEM research at the primary level. The high density around these terms confirms that issues related to learners and educational contexts are key nodes in the academic knowledge production, encompassing pedagogical approaches, curriculum development, and early competency building in STEM disciplines. Other terms such as skill, learning, approach, and technology also appear in medium-to-high density zones, suggesting sustained research interest in innovative and technology-based instructional design for primary education.

Additional high-density areas are found around keywords such as child, age, relationship, and factor, indicating that individual student variables—such as age, social interactions, and cognitive or environmental factors—are foundational in shaping how STEM education should be designed for young learners (Cohen et al., 2023; da Silva Soares et al., 2024). Keywords such as gender, difference, and performance, also located within these dense zones, suggest that differences in student characteristics are frequently studied to develop more inclusive and effective STEM instructional strategies (Al Tamime & Weber, 2022; Megreya et al., 2025; Musso et al., 2022).

Interestingly, keywords like COVID, challenge, and interview appear in zones with low to medium density, indicating that although these are relatively new topics, they are gaining traction in the scientific discourse. This reflects an adaptive response among researchers to educational challenges during the pandemic and a growing interest in exploring qualitative methods for evaluating student and teacher experiences in STEM implementation.

In sum, this visualization shows that the landscape of STEM research in primary education is largely centered on pedagogical issues, student characteristics, and instructional effectiveness, while gradually expanding to incorporate social, emotional, and external challenges that impact implementation. These findings underscore the importance of designing STEM education that is contextual, sensitive to children's developmental characteristics, and adaptable to broader social, technological, and global shifts.

CONCLUSION

Based on the bibliometric analysis of publications on the topic of "STEM and Primary School" from 2016 to 2025, it is evident that research on STEM learning at the primary level has shown a significant upward trend, both in terms of publication volume and thematic complexity. The highest surge occurred in 2023, indicating that STEM literacy has become a central priority in curriculum reform and 21st-century instructional innovation. The education category emerged as the most dominant research domain, followed by studies in the social sciences, psychology, and health, suggesting that the STEM approach extends beyond content mastery to encompass the development of critical thinking skills, social awareness, and student well-being. The distribution of publication types is dominated by scholarly articles, indicating that evidence-based discourse continues to be the primary channel for disseminating ideas. The keyword co-occurrence network identified three major clusters—pedagogical, demographic, and psychosocial—which highlight the strong interconnection between teaching strategies, children's characteristics, and broader family and community contexts. Topic evolution depicted in the overlay visualization illustrates a shift in research focus from descriptive studies to more contextual and responsive approaches aligned with global changes. These findings reinforce the urgency of developing adaptive, inclusive, and evidence-based STEM education at the primary level, aiming to equip younger generations with the skills and mindsets necessary to navigate an increasingly complex and dynamic future.

BIBLIOGRAPHY

Abas, S., Alirahman, A. D., & Mabrur, H. (2024). Humanizing STEM-Based Learning (Science, Technology, Engineering, and Mathematics) for the Transformation of Islamic Education in the 21st Century. *EDUCAN : JURNAL PENDIDIKAN ISLAM*, *8*(1), 98–120. https://doi.org/10.21111/educan.v8i1.11429

Al Tamime, R., & Weber, I. (2022). Using social media advertisement data to monitor the gender gap in STEM: opportunities and challenges. *PeerJ Computer Science*, *8*, e994. https://doi.org/10.7717/peerj-cs.994

Anwar, R., Elbashir, A. M., Magdy, R., Ahmad, Z., & Al-Thani, N. J. (2024). Effectiveness of STEM based workshop for deaf education: Exploratory study. *Heliyon*, *10*(16), e36012. https://doi.org/10.1016/j.heliyon.2024.e36012

Archila, P. A., Restrepo, S., Truscott de Mejía, A., & Molina, J. (2023). STEM and Non-STEM Misconceptions About Evolution: Findings from 5 Years of Data. *Science & Education*, *33*(5), 1211–1229. https://doi.org/10.1007/s11191-023-00428-5

Asrizal, A., Annisa, N., Festiyed, F., Ashel, H., & Amnah, R. (2023). STEM-integrated physics digital teaching material to develop conceptual understanding and new literacy of students. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(7). https://doi.org/10.29333/ejmste/13275

Ayuso, N., Fillola, E., Masiá, B., Murillo, A. C., & ... (2020). Gender gap in STEM: A cross-sectional study of primary school students' self-perception and test anxiety in mathematics. *IEEE Transactions ….* https://ieeexplore.ieee.org/abstract/document/9142452/

Bakirci, H., & Karisan, D. (2018). Investigating the Preservice Primary School, Mathematics and Science Teachers' STEM Awareness. *Journal of Education and Training Studies*. https://eric.ed.gov/?id=EJ1163274

Berg, T. B., Achiam, M., Poulsen, K. M., Sanderhoff, L. B., & Tøttrup, A. P. (2021). The Role and Value of Out-of-School Environments in Science Education for 21st Century Skills. In *Frontiers in Education* (Vol. 6). Frontiers Media S.A. https://doi.org/10.3389/feduc.2021.674541

Borger, J. G., Longley, R. J., Taylor, M. F., Motrich, R., Payne, J. A. E., & Kemp, R. A. (2025). Global perspectives to enhance strategies for advancing women in healthcare and STEMM leadership. *Immunology and Cell Biology*, *103*(3), 234–250. https://doi.org/10.1111/imcb.12854

Carpio, M. A., Gomez, L., & Lavado, P. (2025). The Impact of Social Health Insurance on Student Performance: Evidence From an RDD in Peru. *Health Economics*. https://doi.org/10.1002/hec.4961

Çelik, S., Güven, Z. T., İpekten, F., Keklik, M., Ünal, A., & Kaynar, L. (2022). Evaluation of COVID-19 fear and quality of life in patients with haematopoietic stem cell transplantation during the COVID-19 pandemic. *European Journal of Cancer Care*, *31*(5), 10.1111/ecc.13604. https://doi.org/10.1111/ecc.13604

Cohen, L. D., Gross, J. J., & Rubinsten, O. (2023). Using Reappraisal to Improve Outcomes for STEM Teachers and Students. *Journal of Cognition*, *6*(1), 45. https://doi.org/10.5334/joc.313

da Silva Soares, R., Oku, A. Y. A., Barreto, C. S. F., & Sato, J. R. (2024). Exploring neural efficiency in spatial cognition: A comparative study of 3D visual stimuli in virtual reality across STEM and non-STEM fields. *Behavioural Brain Research*, *477*, 115288. https://doi.org/10.1016/j.bbr.2024.115288

Darmawansah, D., Hwang, G. J., Chen, M. R. A., & Liang, J. C. (2023). Trends and research foci of robotics-based STEM education: a systematic review from diverse angles based on the technology-based learning model. In *International Journal of STEM Education* (Vol. 10, Issue 1). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1186/s40594-023-00400-3

Dere, Z. (2024). Do scientific attitude and intelligence affect motivation towards STEM? Structural equation modelling. *Frontiers in Psychology*, *15*, 1481229. https://doi.org/10.3389/fpsyg.2024.1481229

English, L. D. (2023). Ways of thinking in STEM-based problem solving. *ZDM - Mathematics Education*, *55*(7), 1219–1230. https://doi.org/10.1007/s11858-023-01474-7

Ertl, B., Luttenberger, S., & Paechter, M. (2017). The Impact of Gender Stereotypes on the Self-Concept of Female Students in STEM Subjects with an Under-Representation of Females. *Frontiers in Psychology*, *8*, 703. https://doi.org/10.3389/fpsyg.2017.00703

Farrugia, A. (2023). Under pressure: The paradox of autonomy and social norms in drug education. *International Journal of Drug Policy*, *122*, 104194. https://doi.org/10.1016/j.drugpo.2023.104194

Fauziyati, K. A. (2023). Gamification of Wordwall Maze Chase as a STEM-Based Learning Media to Improve Students' Creative Thinking Skills. *Research and Innovation in Social Science Education Journal (RISSEJ)*, *1*(1), 1–9. https://doi.org/10.30595/rissej.v1i1.13

Fiteriani, I., Diani, R., Hamidah, A., & Anwar, C. (2021). Project-based learning through STEM approach: Is it effective to improve students' creative problem-solving ability and metacognitive skills in physics learning? *IOP Conference Series: Earth and Environmental Science*, *1796*(1). https://doi.org/10.1088/1742-6596/1796/1/012058

Hawani, A., Masmoudi, L., Trabelsi, O., Souissi, M. A., Chikha, A. ben, Mrayah, M., Souissi, N., Marsigliante, S., Rozmiarek, M., & Muscella, A. (2023). Enhancing Time Reading and Recording Skills in First-Grade Children with Learning Difficulties Using the "Clock Motor Game." *Children*, *10*(11), 1748. https://doi.org/10.3390/children10111748

Hebebci, M. T., & Usta, E. (2022). The Effects of Integrated STEM Education Practices on Problem Solving Skills, Scientific Creativity, and Critical Thinking Dispositions. *Participatory Educational Research*, *9*(6), 358–379. https://doi.org/10.17275/per.22.143.9.6

Heni, N., 1∗, A., Rusilowati, A., & Subali, B. (n.d.). STEM-Based Learning Analysis to Improve Students' Problem Solving Abilities in Science Subject: a Literature Review. *Bambang Subali / Journal of Innovative Science Education*, *10*(1), 79–86. http://journal.unnes.ac.id/sju/index.php/jise

Hu, C. C., Yang, Y. F., Cheng, Y. W., & ... (2024). Integrating educational robot and low-cost self-made toys to enhance STEM learning performance for primary school students. *Behaviour &Information …*. https://doi.org/10.1080/0144929X.2023.2222308

Indarta, Y., Jalinus, N., Abdullah, R., & Samala, A. D. (2021). 21st Century Skills : TVET dan Tantangan Abad 21. *EDUKATIF : JURNAL ILMU PENDIDIKAN*, *3*(6), 4340–4348. https://doi.org/10.31004/edukatif.v3i6.1458

Ismatullina, V., Adamovich, T., Zakharov, I., Vasin, G., & Voronin, I. (2022). The Place of Gender Stereotypes in the Network of Cognitive Abilities, Self-Perceived Ability and Intrinsic Value of School in School Children Depending on Sex and Preferences in STEM. *Behavioral Sciences*, *12*(3), 75. https://doi.org/10.3390/bs12030075

Ivert, L. U., Winther, A. H., Jonsson, P., & Brauner, H. (2024). Exploring the educational needs of patients with cutaneous lymphoma using an educational needs assessment tool. *Frontiers in Oncology*, *14*, 1433821. https://doi.org/10.3389/fonc.2024.1433821

Kartini, C. D., Chastanti, I., & Harahap, D. A. (2022). Analysis on Obstacles to the Science Education Process. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 309–315. https://doi.org/10.29303/jppipa.v8i1.1282

Larkin, K., & Lowrie, T. (2023). Teaching Approaches for STEM Integration in Pre- and Primary School: a Systematic Qualitative Literature Review. *International Journal of Science and Mathematics Education*, *21*(Suppl 1), 11–39. https://doi.org/10.1007/s10763-023-10362-1

Lestari, I. F., & Muhajir, S. N. (2024). The Development of Hydraulic Robotic Arm as a STEM-Based Physics Learning Media. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, *9*(1), 88–94. https://doi.org/10.26737/jipf.v9i1.4743

Liang, H., Pan, L., Xie, Y., Fan, J., Zhai, L., Liang, S., Zhang, Z., & Lai, Y. (2022). Health-related quality of life in pediatric patients with β-thalassemia major after hematopoietic stem cell transplantation. *Bone Marrow Transplantation*, *57*(7), 1108–1115. https://doi.org/10.1038/s41409-022-01663-0

Liu, X., Wang, X., Xu, K., & Hu, X. (2023). Effect of Reverse Engineering Pedagogy on Primary School Students' Computational Thinking Skills in STEM Learning Activities. *Journal of Intelligence*, *11*(2), 36. https://doi.org/10.3390/jintelligence11020036

Lokollo, L. J., Lasaiba, M., Arfa, A. M., & Lasaiba, D. (2024). Mengembangkan Kemampuan Berpikir Spasial Melalui Pendidikan STEM di Sekolah Dasar: Developing Spatial Thinking Abilities Through Stem Education In Elementary Schools. *Scholaria: Jurnal Pendidikan Dan Kebudayaan*, *14*(3), 293–308. https://doi.org/10.24246/j.js.2024.v14.i3.p293-308

E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

Mafugu, T., Tsakeni, M., & Jita, L. C. (2022). Preservice Primary Teachers' Perceptions of STEM-Based Teaching in Natural Sciences and Technology Classrooms. *Canadian Journal of Science, Mathematics and Technology Education*, *22*(4), 898–914. https://doi.org/10.1007/s42330-022-00252-z

Mäkelä, T., Fenyvesi, K., Kankaanranta, M., Pnevmatikos, D., & Christodoulou, P. (2022). Co-designing a pedagogical framework and principles for a hybrid STEM learning environment design. *Educational Technology Research and Development*, *70*(4), 1329–1357. https://doi.org/10.1007/s11423-022-10114-y

Megreya, A. M., Hassanein, E. E. A., Al-Emadi, A. A., & Szűcs, D. (2025). Math anxiety mediates the association between gender and STEM-related attitudes: Evidence from a large-scale study. *Acta Psychologica*, *253*, 104689. https://doi.org/10.1016/j.actpsy.2025.104689

Merayo, N., & Ayuso, A. (2022). Analysis of barriers, supports and gender gap in the choice of STEM studies in secondary education. *International Journal of Technology and Design Education*, *33*(4), 1471–1498. https://doi.org/10.1007/s10798-022-09776-9

Miller, D. I., Lauer, J. E., Tanenbaum, C., & Burr, L. (2024). The Development of Children's Gender Stereotypes About STEM and Verbal Abilities: A Preregistered Meta-Analytic Review of 98 Studies. *Psychological Bulletin*, *150*(12), 1363–1396. https://doi.org/10.1037/bul0000456

Mulas, O., Pili, I., Sanna, M., & La Nasa, G. (2023). Systematic Review and Meta-Analysis of Health-Related Quality of Life in Patients with β-Thalassemia that Underwent Hematopoietic Stem Cell Transplantation. *Clinical Practice and Epidemiology in Mental Health : CP & EMH*, *19*(Suppl-1), e174501792301031. https://doi.org/10.2174/17450179-v17-e211208-2021-ht2-1910-4

Musso, P., Ligorio, M. B., Ibe, E., Annese, S., Semeraro, C., & Cassibba, R. (2022). STEM-Gender Stereotypes: Associations With School Empowerment and School Engagement Among Italian and Nigerian Adolescents. *Frontiers in Psychology*, *13*, 879178. https://doi.org/10.3389/fpsyg.2022.879178

Parno, Yuliati, L., Munfaridah, N., Ali, M., Rosyidah, F. U. N., & Indrasari, N. (2020). The effect of project based learning-STEM on problem solving skills for students in the topic of electromagnetic induction. *Journal of Physics: Conference Series*, *1521*(2). https://doi.org/10.1088/1742-6596/1521/2/022025

Prajoko, S., Sukmawati, I., Maris, A. F., & Wulanjani, A. N. (2023). PROJECT BASED LEARNING (PJBL) MODEL WITH STEM APPROACH ON STUDENTS' CONCEPTUAL UNDERSTANDING AND CREATIVITY. *Jurnal Pendidikan IPA Indonesia*, *12*(3), 401–409. https://doi.org/10.15294/jpii.v12i3.42973

Priemer, B., Eilerts, K., Filler, A., Pinkwart, N., Rösken-Winter, B., Tiemann, R., & Zu Belzen, A. U. (2020). A framework to foster problem-solving in STEM and computing education. *Research in Science and Technological Education*, *38*(1), 105–130. https://doi.org/10.1080/02635143.2019.1600490

Rafiq, K. R. M., Hashim, H., & Yunus, M. M. (2022). New Qualitative Perspective in Human–Computer Interaction: Designing Mobile English for STEM. *Frontiers in Psychology*, *13*, 863422. https://doi.org/10.3389/fpsyg.2022.863422

Rogosic, R., Heidt, B., Passariello-Jansen, J., Björnör, S., Bonni, S., Dimech, D., Arreguin-Campos, R., Lowdon, J., Monroy, K. L. J., Caldara, M., Eersels, K., van Grinsven, B., Cleij, T. J., & Diliën, H. (2020). Modular Science Kit as a support platform for STEM learning in primary and secondary school. *Journal of Chemical Education*, *98*(2), 439–444. https://doi.org/10.1021/acs.jchemed.0c01115

Sapounidis, T., & Alimisis, D. (n.d.). *EDUCATIONAL ROBOTICS FOR STEM: A REVIEW OF TECHNOLOGIES AND SOME EDUCATIONAL CONSIDERATIONS*.

Solihin, A., Wibowo, F. C., & Astra, I. M. (2021). Review of trends project based learning (PjBL) integrated STEM in physics learning. *Journal of Physics: Conference Series*, *2019*(1). https://doi.org/10.1088/1742-6596/2019/1/012031

Sulisworo, D., Kaliappen, N., History, A., Winarti, W., Sulisworo, D., & Kaliappen, N. (2021). Indonesian Review of Physics (IRiP) Evaluation of STEM-Based Physics Learning on Students' Critical Thinking Skills: A Systematic Literature Review Article Info ABSTRACT "Evaluation of STEM-Based Physics Learning on Students'' Critical Thinking Skills: A Systematic Literature Review." *Indones. Rev. Phys*, *4*(2), 61–69. https://doi.org/10.12928/irip.v4i2.3814

Susanti, E., Maulidah, R., & Makiyah, Y. S. (2021). Analysis of problem-solving ability of physics education students in STEM-based project based learning. *Journal of Physics: Conference Series*, *2104*(1). https://doi.org/10.1088/1742-6596/2104/1/012005

Widiyawati, Y., Nurwahidah, I., Sari, D. S., Masykuri, M., & Budiyanto, C. W. (2021). The 21 st century science learning: HOTS and digital literacy among junior high school students in Semarang, Indonesia. *Journal of Physics: Conference Series*, *1842*(1). https://doi.org/10.1088/1742-6596/1842/1/012081

E-ISSN: 3031-9277
P-ISSN: XXXX-XXXX
VOL 2 NO 2 JULI 2025

Wise, K., MacDonald, A., Badham, M., Brown, N., & Rankin, S. (2022). Interdisciplinarity for social justice enterprise: intersecting education, industry and community arts perspectives. *The Australian Educational Researcher*, *49*(3), 595–615. https://doi.org/10.1007/s13384-022-00516-5

Yamani, N., & Almazroa, H. (2024). Exploring career interest and STEM self-efficacy: implications for promoting gender equity. *Frontiers in Psychology*, *15*, 1402933. https://doi.org/10.3389/fpsyg.2024.1402933

Yulianti, D., Sugianto, & Ngafidin, K. M. (2022). SCRATCH ASSISTED PHYSICS LEARNING WITH A STEM APPROACH IN THE PANDEMIC ERA TO DEVELOP 21ST CENTURY LEARNING SKILLS. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 185–194. https://doi.org/10.15294/jpii.v11i1.32607