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A Systematic Literature Review on K-12 STEM Education Research in Saudi Arabia: The Story of Transformation Under Vision 2030

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Abstract
The study examines the integration of STEM (Science, Technology, Engineering and Mathematics) techniques into Saudi Arabia's K-12 curricula through a systematic literature review. This evaluation is crucial to assess the impact of STEM education in the country, particularly in the context of Vision 2030 reforms focusing on human capital development and knowledge-based industries. This current review has shown that interventions to change by way of implementing the new Science and Mathematics curriculum have brought about changes to the instructional strategies of the K-12 STEM teachers. The review of the selected paper highlights the importance shown towards providing professional development training for K-12 STEM teachers. The findings of this review stress the need for future research on barriers to implementation, integration and cultural acceptance of STEM Education in Saudi Arabia.

Keywords: K-12, STEM education, Saudi Arabia, Professional Development,

1. Introduction

Since its establishment by the late King Abdul Aziz bin Abdul Rahman Al-Saud, the objective of the Kingdom of Saudi Arabia has been to be the world leader in various fields. This has been emphasized by the Custodian of the Two Holy Mosques, King Salman bin Abdul Aziz: “My primary goal is for our country to be a successful, leading example in the world, in all aspects, and I will work with you to achieve that” (ETEC, 2018). The Social, Political, Economic, Cultural, Religious and Geographical importance of Saudi Arabia cannot be denied having influence on world affairs and the Arab world in particular. Every change, development or introduction of a policy is closely monitored and scrutinized by all the world's heads of state and government. Saudi Arabia aims to be a leader in providing opportunities for all through education and training, and high-quality services such as employment initiatives, health, housing, and entertainment (Council of Economic & Development Affairs. (2021). Scientific and technological advances are crucial for the growth of a nation's military defence capabilities, the creation of new industries, the productivity of already-existing sectors, the improvement of living standards, and the accessibility of education. Because of this, a nation's ability to innovate, develop, and manufacture scientific goods all contribute to its economic success (Brown & Aydeniz, 2017).

Education is the most prominent anchor of the Kingdom’s leadership, as it relates to the human being, who is the goal of development and is the basis for its construction, both present and future. His Royal Highness, Crown Prince, Deputy Prime Minister and Chairman Council of Economic & Development

Affairs states that: “We shall only accept that our country’s future, which we are building together, is made to be at the forefront of the world’s countries through education, training, opportunities for all, and advanced services.” Education and Training Evaluation Commission (2018). Saudi Arabia finds itself at a turning point in the rapidly changing global education scene, driven by the ambitious goals outlined in Vision 2030. This transformative agenda places a strong emphasis on the strategic necessity of advancing STEM (Science, Technology, Engineering, and Mathematics) education, given its critical role in forming a knowledge-based economy and educating the next generation of leaders.

In the past 20 years, science education has advanced, especially in Western nations, and student-centered learning has replaced teacher- and textbook-centered instruction. In Western nations, science education has shifted to a constructivist method, which is a communicative approach involving conversation and discourse that allows students to apply prior knowledge and experience to comprehend scientific concepts Alhammad (2015). Saudi Arabia has also developed and made changes to the Education policies through the years to keep up with the globalized and a technology driven economy. Alarfaj (2015) noted that Science education in Saudi Arabia has witnessed a substantial call to action to respond to the aims and challenges of the twenty-first century. Science curricula across all the 12 educational grade stages have been reformed, the national professional standards (NPS) including science disciplines developed cooperatively by TATWEER (King Abdullah bin Abdulaziz Public Education Development Project) and Qiyas. In line with the lofty objectives of Vision 2030, this research sets out to investigate and add to the conversation on STEM education in the Saudi Arabian context of implementation of Vision 2030 and the progress between 2016 - 2023. Saudi Arabia has revised the K-12 curriculum with the Vision 2030 to be more elaborate and expansive with revised textbooks and has substantially reduced the content of religious studies from the curriculum (Memri, 2022). The current curriculum reforms aim to experiment with new and more market-oriented forms of education and educational policies with the aim of implementing economic reforms that seek economic diversification and employment for Saudis (Al-Otaibi, 2020). Saudi Arabia aims to become a global center of innovation and knowledge, and a key component of this goal is the emphasis on STEM education. A comprehensive plan for the country's future, Vision 2030 presents a multimodal approach that includes social development, cultural enrichment, and economic diversification. The understanding that STEM education is not just an educational right but also a strategic necessity for ensuring sustained growth of the human capital.

This study was essential to evaluate the direction and effects of STEM (science, technology, engineering, and mathematics) education in Saudi Arabia, especially in light of the significant reforms indicated in Vision 2030. A key focus of Saudi Arabia's transformative Vision 2030 plan for the country's economic and social advancement is the growth of human capital, innovation, and knowledge-based businesses. To determine if educational programmes are in line with the more general objectives of Vision 2030, it is important to assess the current trends in STEM education research. The OECD report published in 2020 noted that Saudi Arabia has made tremendous progress in expanding access to education and has achieved universal enrolment rates at primary and lower secondary levels (Education in Saudi Arabia, 2020). This study provides valuable insights that can inform policymakers, educators, and stakeholders about the current state of STEM education research in Saudi Arabia, contributing to evidence-based decision-making for the future.

1.1 Problem Statement

Saudi Arabia has made substantial changes (Council of Economic & Development Affairs, 2021) in Science education and STEM education in particular through the years and it is 7 years past the launch of vision 2030. However, there is no literature providing information on the emerging trends in K-12 STEM Education through the ye. This calls for a study to review the literature and explore the emerging trends in STEM Education after the launch of vision 2030 in 2016 until 2023. The report published by Council of Economic & Development Affairs, 2021) claims to have published 915 scientific papers related to the coronavirus by 2020 and. However, there is no information about the research work done in the area of K-12 STEM Education. This calls for exploring literature related to K-12 STEM Education in particular to review the impact of changes made in the past 7 years towards actualization of development of human capital through K-12 STEM education in Saudi Arabia. The report published by Council of Economic & Development Affairs, (2021) also claims to have made improvements in education in providing infrastructure, online learning during the Pandemic era and also improvement in the overall education scene of KSA. However, there is no research conducted to provide evidence on the approaches adopted for these claims of improvements. This claim needs to be studied with reference to research work conducted in the area of K-12 STEM Education. The study shall pinpoint and evaluate the progress made in K-12 STEM education, illuminating the ways in which the policy measures have impacted K-12 STEM Education with vision 2030. This study shall analyze the most recent research (2016–2023) in K-12 STEM Education in Saudi Arabia. The study shall explore the general trends in publication, research approaches, research methods and approaches adopted for improvement in K-12 STEM Education research, with the following research questions:

RQ 1: What are the general trends of research publications in K-12 STEM Education research in Saudi Arabia between 2016 - 2023?

RQ 2: What research methods were adopted in K-12 STEM Education research in Saudi Arabia between 2016 - 2023?

RQ 3: What data collection methods were adopted for K-12 STEM Education research in Saudi Arabia between 2016 - 2023?

RQ 4: What were the approaches adopted for improvement of K-12 STEM Education in Saudi Arabia between 2016 - 2023?

1.2 Diverse Perspectives about STEM Education

Tenney et al. (2023) notes that STEM (science, technology, engineering, and math) although has no universally accepted definition, it is influenced by presumptions that teachers may have about their pupils and how they learn. Srikoom (2018) noted in his work on defining STEM education that Leon Lederman (1998), Nobel laureate physicist, provides STEM literacy as the ability to adapt to and accept changes driven by new technology work, to anticipate the multilevel impacts of their actions, to communicate complex ideas effectively to a variety of audiences, and perhaps most importantly, to find measured, yet creative, solutions to problems that are today unimaginable. Gonzalez, H.B., & Kuenzi, J.J. (2012) believed that STEM education is an interdisciplinary system that spans the whole educational process, from early childhood education to postsecondary education. STEM education, according to William (2011), is a methodology that enhances students' understanding of science and math while encouraging student involvement via the use of engineering and technology. It is defined by Israel et al. (2013) as collaborative, student-centered learning that goes beyond the four STEM domain settings. By allowing students to see the universe as a whole rather than as a collection of components, STEM education dissolves the barriers across disciplines (Lantz, H. B., 2009). The general consensus is that STEM education involves military, economic, and high-level thinking that brings together disciplines, leads to effective and qualified learning, and takes existing knowledge and applies it to everyday life (Yıldırım and Sevi, 2016), despite the fact that there is no consensus on the precise definition of STEM education (Thomas, 2014). By acquiring skills and knowledge with an authoritarian approach to teaching, STEM education seeks to empower people to view challenges from a different viewpoint across professions (Şahin, B. (2020). Over the years, STEM has been recognized as a field of study necessary to gain a competitive advantage on the world stage, leading to a global shift that highlights the importance of Science in education (Kaleci and Korkmaz, 2018). One of the drivers of this change will be STEM's ability to develop students into critical thinkers who can find solutions to today's challenges (Fadlelmula et al. , 2022). STEM education enables training of people who have high problem solving, critical thinking, teamwork skills and are needed to educate the human resource for the development of a nation's economy (Çınar, S. & Çiftçi, M., 2016). STEM education emphasizes abilities like problem solving, research, effective communication, and design rather than teaching the many subjects independently (Çevik, 2017). STEM Education can take place in a variety of settings, including informal settings that are casual, spontaneous, and unstructured, in addition to classrooms using pedagogical interventions (Kim & Dopico, 2014).

1.3 K-12 STEM Education

The STEM curriculum calls for extending learning beyond the classroom walls through the use of continually evolving teaching strategies and the incorporation of informal learning (Yaşar Kazu and Kurtoglu Yalcin, 2021). It is predicated on merging formal and informal activities, including using mobile devices or visiting museums, and it raises involvement and enhances students' motivation in learning (Wang & Chiang, 2020). The majority of the studies' implementation of STEM education and discipline occurs at the K–12 school level. This scope is regarded as the fundamental application of STEM education, which also happens to be the most important component (Hasanah, 2020). According to research, STEM instruction ought to begin earlier, say at an elementary school that also offers a strong environment and facilitates the application of STEM (Ching et al., 2019; English, 2017; Estapa & Tank, 2017). The National council found that numerous studies have connected STEM education in grades K–12 to the US economy's development and persistence as a leader in science (Council et al. (2011). Schreiter et al. (2023) noted that more focus is being placed on teachers' cognitive and emotional characteristics (such as attitudes, beliefs, and knowledge) and how they impact the way they instruct students as a result of recent demands to advance K–12 STEM education. STEM education began in higher education, according to Zhan and Niu (2023), but K–12 STEM education has developed quickly in recent years. Zhan and Niu (2023) also found that the roles performed by various subjects in K–12 STEM education were diverse. Students participating in STEM education have access to a wealth of information and experience thanks to science and technology. Mathematics offered the framework for quantitative and logical reasoning, while engineering helped students enhance their design thinking and problem-solving abilities. Researchers have concentrated on the integration of STEM educational techniques into environmental curricula and the inclusion of green skills aspects in STEM curricula at the K–12 level (Sümen and Çalisici 2016). According to Firetto et al. (2023) K–12 educators' utilization of small-group discussions in the classroom is influenced by a number of factors, including their perceived competence to lead talks and their own understanding of STEM subjects.

2. Methodology

2.1 Data Search Process

This study has adopted a Systematic Literature Review design to explore and analyze the research work done in the K-12 STEM Education. A systematic literature review (SLR) aims to retrieve, synthesize, and appraise existing knowledge on a particular subject Møller & Myles, 2016). Gough et al. (2012) states, a systematic review is a transparent and replicable method of literature review that answers research questions based on accountable methods with explicit criteria that include or exclude existing studies. Data are derived from the reports of published studies, systematically synthesizing existing knowledge on a particular issue and spotting gaps (Møller & Myles, 2016). To ensure credibility, consistency and transparency, this systematic review was conducted in concurrence with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the four-phase flow diagram (Liberati et al., 2009). In particular, the PRISMA consists of a detailed checklist addressing all the major sections of a systematic review, providing an evidence-based foundation for transparency in identifying, selecting, appraising, and synthesizing the studies being reviewed (Moher et al., 2009). The strategy for identifying the most relevant literature to address the research questions was defined at this stage. This resulted in emphasis on the database that would be searched. Journals, conference proceedings, and patents are among the academic literature that Scopus, ERIC and SpringerLink cover in great detail. Because of their broad indexing coverage, it is especially well-suited for interdisciplinary and multidisciplinary research, which is prevalent in scientific education. Hence, the search was conducted using Scopus, ERIC and SpringerLink databases, which are large, international, scholarly and multidisciplinary databases.

2.2 Search Method

In the search, Boolean operators (Grewal et al., 2016) were applied within each database, using specific search terms and limiters, as described in Table 1. In particular, the search terms were “science education” , “STEM education” and “Saudi” along with the acronym of “KSA” and for the context added “K-12”. The search parameters were set as follows. Document types: Article; Language: English; Country/ Territory: Saudi Arabia; year range between 2016 - 2023.

Table 1: Results of initial search

<table>
<tr><th>Search terms*</th><th>Search limiters</th><th>Database</th><th>Hits</th></tr>
<tr><td rowspan="3">("science education" OR "STEM education") AND ("Saudi Arabia" OR "KSA") AND (“K-12”)</td><td rowspan="3">1. Document type –Article
2. Language - English
3. Year range - 2016 to 2023
4. Discipline-Education, Social Sciences</td><td>Scopus</td><td>25</td></tr>
<tr><td>SpringerLink</td><td>23</td></tr>
<tr><td>ERIC</td><td>10</td></tr>
</table>

*Searches included Article titles, abstracts, and keywords

2.3 Eligibility Criteria

Globally, STEM fields have been the subject of a wealth of study, with an emphasis on either single STEM fields (science, technology, engineering, or mathematics) or interdisciplinary/cross-disciplinary combinations of several STEM fields (for example, "mathematics and science" or "science and engineering"). For scholars looking into STEM education, this inevitably presents significant obstacles that call for "careful thought and clearly specified scope to tackle the complexity." (Li et al., 2019). To address this challenge, this study, like earlier STEM reviews (Brown, 2012; Li et al., 2020; Mizell & Brown, 2016), only looks at papers that identify themselves as being related to STEM fields by mentioning STEM (science education) or by using the acronym STEM in their title, abstract, and keywords. Fadlelmula et al. (2022) mentions about Harden and Gough’s (2012), view that the review must "ensure that only the most appropriate, trustworthy, and relevant studies are used to develop the conclusions" (p. 154) to assess the quality and applicability of the studies. Scholarly papers that undergo peer review are recognized as the primary channels for sharing research findings (Li et al., 2019; Xu et al., 2019). The acceptable research in this study are peer-reviewed, academic publications written in English with a title, abstract, or keywords because of the strict guidelines that accompany their publication in academic journals (Nicholas et al., 2015).

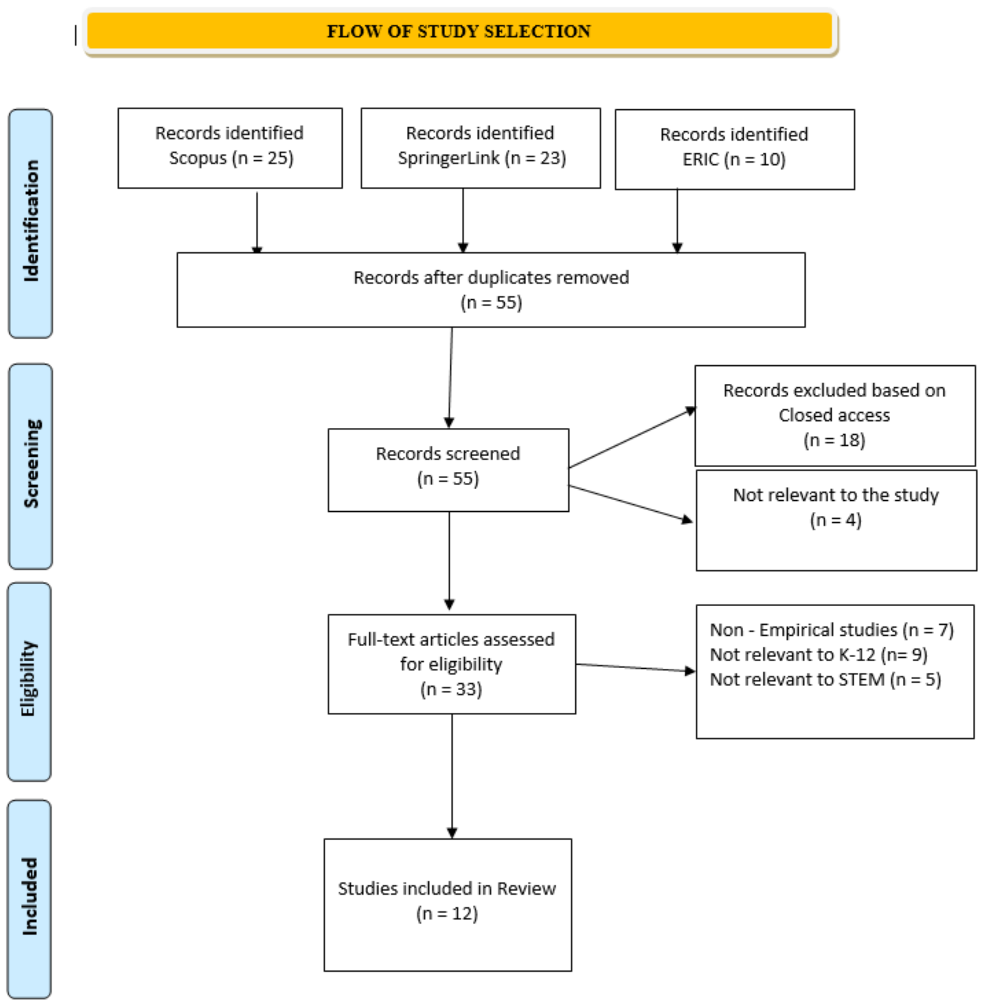
2.4 Inclusion/ Exclusion Criteria

The review examined studies specifically targeting K-12 student-centered trends in the context of science education. This evaluation process involved multiple stages to ensure the relevance and rigor of the selected studies. First, the title and keywords of all the studies were reviewed to exclude papers that appeared to be unrelated to the research questions. Then, the abstract of each study was read by the researcher. This allowed the researcher to exclude papers that did not address the study's purpose. Next, the selected studies that met the following criteria:

1) Empirical studies that include STEM education,
2) Studies that include K-12 education level
3) Studies that provide sufficient information for answering the research question, and

Finally, excluded papers that, despite meeting all the above criteria, did not focus on education.

Figure 1: PRISMA flow diagram



2.5 Data Extraction Process

The flow of the study selection process, including identification, screening, eligibility, and included studies, is illustrated in Fig. 1. The PRIMA model for study selection developed by Moher (2009) was used in this study. Briefly, using our search terms (see Table 1), the search based on the Scopus database generated 25 articles, ERIC database generated 10 articles and SpringerLink generated 23 articles. After removing duplication there were a total of 55 articles identified. 4 articles were excluded as they were not relevant to the study and 18 were excluded as they were closed access. A total of 33 full text access articles were analyzed based on eligibility criteria and 7 articles were excluded as they were Non-empirical studies, 9 articles were excluded as they were not relevant to K-12 education and 5 articles were excluded as they were not relevant to STEM education. Finally a total of 12 articles were retained for the systematic review which were published between 2016 and 2023, (see Fig 1) which were found to be relevant to the purpose of this study. The list of all the articles included in the study as presented in Table 2.

Table 2: Characteristics of the 12 research articles included in the review

Author and Year	Target Population	Research Methods	Data Collection Approaches	Approaches adopted for Improvement of K-12 STEM education
Aldahmash et al. (2019)	Teachers	Quantitative	One group (pre-experimental) design	Teacher Professional Development
Alghamdi and Kim (2019)	Teachers	Quantitative	One group (pre-experimental) design	Teacher Professional Development
Alghamdi and Alanazi (2020)	Students	Quantitative	Quasi Experimental	Teacher Professional Development
Alrawili et al. (2020)	Students	Quantitative	Quasi Experimental	Instructional strategy
Alshaikh (2021)	Teachers	Quantitative	Survey	TIMSS Assessment
Maashi et al. (2022)	Teachers	Quantitative	Survey and Interview	Teacher Professional Development
AlAli et al. (2023)	Teachers	Quantitative	Descriptive Survey	Instructional strategy
A. A. Alghamdi (2022)	Teachers	Quantitative	Survey Questionnaire	Instructional strategy
Elsayed et al. (2022)	Students	Quantitative	Large Scale Assessment	TIMSS Assessment
Aljuhani et al. (2018)	Students, teachers, experts in science education, parents of students	Mixed Method	Survey and Interview	Online Instruction

Madani (2020)	Teachers	Qualitative	Interview	Instructional strategy
Madani and Forawi (2019)	Teachers	Mixed Method	Survey and Interview	Instructional strategy

2.6 Limitations of the study

Despite the meticulous approach employed in conducting this study, every systematic review is limited by the search process. Specifically, publications published in other languages were excluded from consideration based on the criterion of peer-reviewed articles published in English, even though the two databases that were chosen had an international reach. This also holds true for works published in other media, including books, grant applications, conference proceedings, and unpublished articles from journals that are indexed in those two databases. Future reviews could consider using new databases, publication kinds, country of publishing and languages. The study is limited to the context of Saudi Arabia in terms of the country of publications, which may not be generalizable for other countries as it includes the study based on the policy changes made under vision 2030.

3. Results and Discussion

In the following sections, we report findings as corresponding to each of the four research questions.

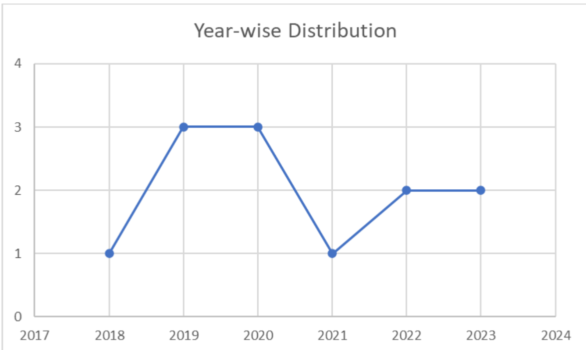
3.1 General Trends of Research Publications

In attempts to answer the research question on the general trends in K-12 STEM education, the data from research articles explored in this study have been presented according to the year-wise distribution of research and target population in K-12 STEM education in KSA.

3.1.1 Year-wise Distribution

To explore the general trends of research publications, year-wise publications and the study population in the research are considered in this study to address Research Question 1: “What are the general trends of research publications in K-12 STEM Education in Saudi Arabia between 2016 - 2023?” Figure 3.1.1 shows the trend in year-wise publication of research articles. As Fig. 3.1.1 shows the number of publications in the initial years of the launch of vision 2030 in 2016 and 2017 had no papers published. Although the number of papers published in 2018 (n=1, 8.3%) was less, it increased in 2019 (n=3, 25%) and 2020 (n=3, 25%). However, the number reduced in 2021 (n=1, 8.30%), and has started increasing again in 2022 (n=2, 16.7%) and 2023 (n=2, 16.7%). The result shows that research in K-12 STEM Education had grown significantly since 2016, and the most recent large number of K-12 STEM Education publications also suggests that K-12 STEM Education research gained its own recognition by many different journals for publication as a hot and important topic area.

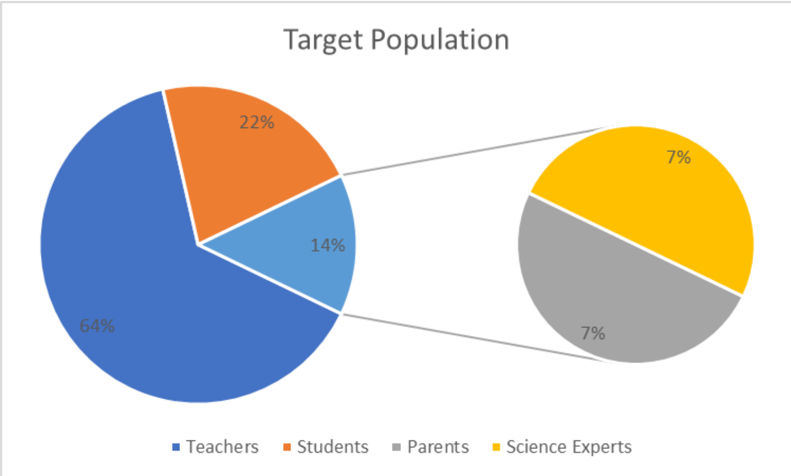
Figure 3.1.1: Year-wise distribution of research publications



3.1.2 Target Population

With regards to the study population, fig 3.1.2, the results show a strong focus on Teachers (n = 9, 64.3%) where as the focus on students was (n = 3, 21.4%). There have also been studies conducted which included Experts in Science Education (n=1, 7.1%) and parents (n=1, 7.1%). The primary focus on teachers shows that the researchers have made attempts to improve the instructional population which can be later translated and further make changes to how K-12 STEM education is approached in KSA. The additional research which is not directly linked to teachers or students, conducted for parents and science experts shows that researchers are trying to bring awareness among other stakeholders as well for bringing changes to the outlook of K-12 STEM education in KSA.

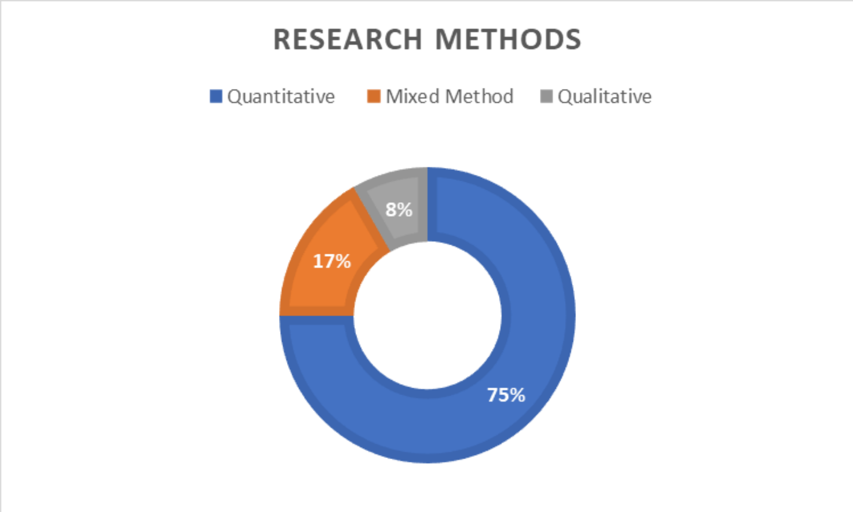
Figure 3.1.2: Target population



3.2 Methods in K-12 STEM Education Research

Concerning the research methods utilized in K-12 STEM Education research related studies addressing Research Question 2: "What research methods were applied for K-12 STEM education research in Saudi Arabia between 2016 - 2023?", as Fig 3.2 demonstrates, the results indicate that the Quantitative approach is the most widely used (*n* = 9, 75%), followed by Mixed Method (*n* = 2, 16.7%) and Qualitative (*n* = 1, 8.3%). The data suggests that quantitative studies have been adopted on a large scale which provides for statistical data and provide for much-needed clarity in terms of the effectiveness of the Policy in terms of numerical and quantifiable results. However, the inclusion of qualitative and a mixed method approach also suggests that research is not only for the purpose of fulfilling the goal, but to provide for more specific clarity and understanding on the implementation of the policy.

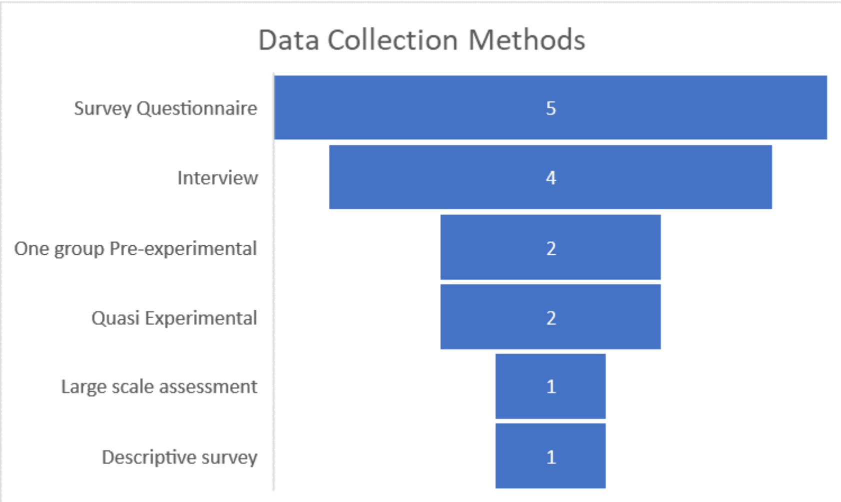
Figure 3.2: Research Methods in K-12 STEM Education



3.3 Data Collection Methods in K-12 STEM Education Research

The data collection methods frequently used by researchers investigating K-12 STEM Education are given in Fig 3.3. When the data collection methods of 12 studies were investigated it is observed that mostly survey questionnaire method (n = 5, 41.6%) and Interviews (n= 4, 33.3%) followed by one group pre-experimental method (n =2, 16.6%)and Quasi-Experimental method (n=2, 16.6%) are used. Descriptive survey (n=1, 8.3%) and Large scale assessment method (n=1, 8.3%) are also featured. The findings suggest that the researchers have adopted various methods in their research design and provide for a holistic view of K-12 STEM education changes in the country.

Figure 3.3: Data collection Methods in K-12 STEM Education research



3.4 Approaches adopted for improvement of K-12 STEM Education

In attempts to answer Research Question: 4 “What approaches were adopted for improvement of K-12 STEM Education in Saudi Arabia between 2016 - 2023?” The researcher looked at the various interventions implemented by the authors in their studies. Table 4 shows the approaches adopted for the improvement of K-12 STEM education. The data shows most studies have adopted an approach that leads to the attainment of the goal to transform education under vision 2030. Majority of the research approaches were addressed in improving the instructional strategy in K-12 STEM education (n=5, 41.6%) Alrawili et al. (2020), AlAli et al. (2023), A. A. Alghamdi (2022), Madani (2020), Madani and Forawi (2019). This is followed by providing professional development opportunities to teachers with innovative approaches in teaching for K-12 STEM subjects (n=4, 33.35) Aldahmash et al. (2019), Alghamdi and Alanazi (2020), Alghamdi and Kim (2019), Maashi et al. (2022). Along with this, researchers also studied and included TIMSS Assessment (n=2, 16.6%) Alshaikh (2021), Elsayed et al. (2022). The approaches also included online instruction (n=1, 8.3%) Aljuhani et al. (2018). By analyzing the approaches, we find that research conducted has been driven by the aim to improve human capital in the form of teachers and students collectively. The approaches have been holistic by including parents and experts as well in the research process.

Table 4: Analysis of Approaches adopted for improvement of K-12 STEM Education

Approaches Adopted for improvement of K-12 STEM education	**Number (N)**	**Research papers**
Instructional Strategy	5	1. Alrawili et al. (2020), 2. AlAli et al. (2023) 3. A. A. Alghamdi (2022) 4. Madani (2020) 5. Madani and Forawi (2019)
Teacher Professional Development	4	1. Aldahmash et al. (2019) 2. Alghamdi and Alanazi (2020) 3. Alghamdi and Kim (2019) 4. Maashi et al. (2022)
TIMSS Assessment	2	1. Alshaikh (2021) 2. Elsayed et al. (2022)
Online Instruction	1	1. Aljuhani et al. (2018)

4. Conclusion

This systematic review illuminates a number of features characterizing research on K-12 STEM education in Saudi Arabia and offers useful insights into the scope and complexity of research done on K-12 STEM Education in the context of vision 2030 in Saudi Arabia. The present study sought to provide a systematic review of K-12 STEM Education -related research done in Saudi Arabia between 2016 and 2023. The review of the selected paper highlights the importance shown towards providing professional development training for K-12 STEM teachers. Consequently, in order to be relevant to policy-making, future studies should focus on adding to the ongoing conversation and efforts in teacher professional development. This will contribute to human capacity building in Saudi Arabia and support the transition to a knowledge-based economy as envisioned in vision 2030. The findings of this review stress the need for future research on barriers to implementation, integration and cultural acceptance of STEM Education in a traditional society as Saudi Arabia. This current review has shown that interventions to change by way of implementing the new Science and Mathematics curriculum has brought about changes to the instructional strategies of the K-12 STEM teachers. Overall, the majority of the studies examined emphasize the importance of involving K–12 educators in STEM professional development programmes to enhance their knowledge, attitudes, and enthusiasm for teaching STEM subjects. Professional development programmes appear to be necessary for more pertinent STEM teaching and assessment techniques. Additionally, studies have demonstrated a favorable correlation between instructors' attitudes towards science and their selection of effective teaching strategies (Osborne et al., 2003). As a result, it is critical to create efficient STEM professional development programmes that meet the needs of educators and give them the resources they need to teach STEM subjects.

5. Recommendations

Although the data examined in this study is significant and offers valuable insights into K–12 STEM Education in the context of vision 2030 in Saudi Arabia, there are other aspects that remain unexplored and call for more investigation and examination. Based on the study's findings, certain significant gaps in the body of knowledge about STEM education in Saudi Arabia's K–12 classrooms were noted. A detailed analysis on changes in K-12 STEM education can be taken up for further studies. It would also be beneficial to study the curriculum changes in K-12 STEM education and at higher education in the context of vision 2030 policy implementation. When considered in entirety, the reviewed studies identified notable shortcomings. Firstly, research on K–12 STEM education highlights several significant methodological problems, such as a glaring absence of case study or comparison methodologies. Further studies can be expanded to longitudinal research which brings out the impact of the policy on K-12 education and how research has been instrumental in actualization of the goals of the policy. Secondly, the majority of research on K–12 STEM education in Saudi Arabia has come from the teacher's point of view; there is a conspicuous lack of studies that examine student involvement in STEM-related subjects. Future studies on K–12 STEM education in the nation will be of higher caliber if these components are included.

References

1. AlAli, R., Alsoud, K. M., & Athamna, F. (2023). Towards a Sustainable Future: Evaluating the ability of STEM-Based teaching in achieving sustainable development goals in learning. Sustainability, 15(16), 12542. https://doi.org/10.3390/su151612542
2. Alarfaj, M. M. (2015). Science education in Saudi Arabia. In SensePublishers eBooks (pp. 155–168). https://doi.org/10.1007/978-94-6300-049-9_8
3. Aldahmash, A. H., Naem, M. A., & Aljallal, M. A. (2019). Saudi Arabian science and mathematics teachers' attitudes toward integrating STEM in teaching before and after participating in a professional development program. Cogent Education, 6(1), 1580852. https://doi.org/10.1080/2331186x.2019.1580852
4. Alghamdi, A. A. (2022). Exploring early childhood teachers' beliefs about STEAM education in Saudi Arabia. Early Childhood Education Journal, 51(2), 247–256. https://doi.org/10.1007/s10643-021-01303-0
5. Alghamdi, A. K. H., & Alanazi, F. H. (2020). Process-Oriented Guided-Inquiry learning in Saudi Secondary school chemistry instruction. Eurasia Journal of Mathematics, Science and Technology Education, 16(12), em1920. https://doi.org/10.29333/ejmste/9278

6. Alghamdi, A. K. H., & Kim, S. Y. (2019). THE IMPACT OF a SCIENCE METHODS COURSE ON FEMALE PRE-SERVICE TEACHERS' BELIEFS WITHIN a SAUDI-ARABIAN CONTEXT. Journal of Baltic Science Education, 18(1), 19–38. https://doi.org/10.33225/jbse/19.18.19
7. Aljuhani, K., Sonbul, M., Althabiti, M., & Meccawy, M. (2018). Creating a Virtual Science Lab (VSL): the adoption of virtual labs in Saudi schools. Smart Learning Environments, 5(1). https://doi.org/10.1186/s40561-018-0067-9
8. Al-Otaibi, N. (2020). Vision 2030: Religious education reforms in the kingdom of Saudi Arabia (Special Report). King Faisal center for Research and Islamic Studies.
9. Alrawili, K. S., Osman, K., & Almuntasheri, S. (2020). EFFECT OF SCAFFOLDING STRATEGIES ON HIGHER-ORDER THINKING SKILLS IN SCIENCE CLASSROOM. Journal of Baltic Science Education, 19(5), 718–729. https://doi.org/10.33225/jbse/20.19.718
10. Alshaikh, A. a. N. (2021). A proposal for developing the performance of Intermediate Second-Grade students in science Tests in Trends in International Mathematics & Science Study (TIMSS). Journal of Education and E-learning Research, 8(1), 26–33. https://doi.org/10.20448/10.20448/journal.509.2021.81.26.33
11. Bramer, W. M., Rethlefsen, M. L., Kleijnen, J., & Franco, O. H. (2017). Optimal database combinations for literature searches in systematic reviews: a prospective exploratory study. Systematic Reviews, 6(1). https://doi.org/10.1186/s13643-017-0644-y
12. Brown, C. L., & Aydeniz, M. (2017). Maximizing Science Teachers' Pedagogical Potential for Teaching Science Literacy to ELLs: Findings from a Professional Development Program. In Springer eBooks (pp. 83–110). https://doi.org/10.1007/978-3-319-53594-4_5
13. Brown, J. (2012). The current status of STEM education research. Journal of STEM Education Innovations and Research, 13(5), 7–11.
14. Çevik, M. (2017). A study of STEM Awareness Scale development for high school teachers<p>Ortaöğretim öğretmenlerine yönelik FeTeMM Farkındalık Ölçeği (FFÖ) geliştirme çalışması. Journal of Human Sciences, 14(3), 2436. https://doi.org/10.14687/jhs.v14i3.4673
15. Ching, Y., Yang, D., Wang, S., Baek, Y., Swanson, S., & Chittoori, B. (2019). Elementary school student development of STEM attitudes and perceived learning in a STEM Integrated Robotics curriculum. TechTrends, 63(5), 590–601.https://doi.org/10.1007/s11528-019-00388-0
16. Çınar, S. & Çiftçi, M. (2016). Disiplinler Arası Stem Yaklaşımına Yönelik Yapılan Çalışmaların İçerik Analizi. 10th International Computer and Instructional Technologies Symposium (ICITS), Recep Tayyip ERDOĞAN Üniversitesi, RİZE.
17. Council of Economic & Development Affairs (2021). Vision 2030, story of transformation (No. 01). Council of Economic & Development Affairs.
18. Council, N. R., Education, D. O. B. a. S. S. A., Assessment, B. O. T. A., Education, B. O. S., & Education, C. O. H. S. S. O. P. F. K. S. (2011). Successful K-12 STEM education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics. National Academies Press.
19. Education and Training Evaluation Commission (2018, March). National Framework for public Education Curriculum Standards (1439 / 6097). King Fahad National Library.- Riyad1440 Education in Saudi Arabia. (2020). In Reviews of national policies for education. https://doi.org/10.1787/76df15a2-en

20. Elsayed, M., Clerkin, A., Pitsia, V., Aljabri, N., & Al-Harbi, K. (2022). Boys' underachievement in mathematics and science: An analysis of national and international assessment data from the Kingdom of Saudi Arabia. Large-scale Assessments in Education, 10(1). https://doi.org/10.1186/s40536-022-00141-9
21. Elshater, A., & Abusaada, H. (2022). Developing Process for Selecting Research Techniques in Urban Planning and Urban Design with a PRISMA-Compliant Review. Social Sciences, 11(10), 471. https://doi.org/10.3390/socsci11100471
22. English, L. D. (2017). Advancing elementary and middle school STEM education. International Journal of Science and Mathematics Education, 15(S1), 5–24. https://doi.org/10.1007/s10763-017-9802-x
23. Estapa, A., & Tank, K. M. (2017). Supporting integrated STEM in the elementary classroom: a professional development approach centered on an engineering design challenge. International Journal of STEM Education, 4(1). https://doi.org/10.1186/s40594-017-0058-3
24. Fadlelmula, F. K., Sellami, A., Abdelkader, N., & Umer, S. (2022). A systematic review of STEM education research in the GCC countries: trends, gaps and barriers. International Journal of STEM Education, 9(1). https://doi.org/10.1186/s40594-021-00319-7
25. Firetto, C. M., Starrett, E., & Jordan, M. E. (2023). Embracing a culture of talk: STEM teachers' engagement in small-group discussions about photovoltaics. International Journal of STEM Education, 10(1). https://doi.org/10.1186/s40594-023-00442-7
26. Gonzalez, H.B., & Kuenzi, J.J. (2012). Science, Technology, Engineering, and Mathematics (STEM) Education: A Primer Congressional Research Service
27. Gough, D., Thomas, J., & Oliver, S. (2012) Clarifying differences between review designs and methods. Systematic Reviews, 1(1). https://doi.org/10.1186/2046-4053-1-28
28. Grewal, A., Kataria, H., & Dhawan, I (2016). Literature search for research planning and identification of research problem. Indian Journal of Anaesthesia, 60(9), 635. https://doi.org/10.4103/0019-5049.190618
29. Harden, A., & Gough, D. (2012). Quality and relevance appraisal. In D. Gough, S. Oliver, & J. Thomas (Eds.), An introduction to systematic reviews (pp. 153–178). Sage.
30. Hasanah, U. (2020). Key Definitions of STEM Education: Literature review. Interdisciplinary Journal of Environmental and Science Education, 16(3), e2217. https://doi.org/10.29333/ijese/8336
31. Israel, M., Maynard, K., & Williamson, P (2013). Promoting Literacy-Embedded, Authentic STEM Instruction for Students with Disabilities and other Struggling Learners. TEACHING Exceptional Children, 45(4), 18–25. https://doi.org/10.1177/004005991304500402
32. Kaleci, D., & Korkmaz, Ö. (2018). STEM Education Research: Content analysis. Universal Journal of Educational Research, 6(11), 2404–2412. https://doi.org/10.13189/ujer.2018.061102
33. Kim, M., & Dopico, E. (2014). Science education through informal education. Cultural Studies of Science Education, 11(2), 439–445. https://doi.org/10.1007/s11422-014-9639-3
34. Lantz, H. B. (2009). Science, Technology, Engineering, and Mathematics (STEM) education: What form? What function? CurrTech Integrations: Baltimore.
35. Lewis, C. (2015). What is improvement science? Do we need it in education? Educational Researcher, 44(1), 54–61. https://doi.org/10.3102/0013189x15570388

36. Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L., English, L. D., & Duschl, R. A. (2019) Design and design thinking in STEM education. Journal for STEM Education Research, 2(2), 93–104. https://doi.org/10.1007/s41979-019-00020-z
37. Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C. D., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. The BMJ, 339(jul21 1), b2700. https://doi.org/10.1136/bmj.b2700
38. Maashi, K. M., Kewalramani, S., & Alabdulkareem, S. A. (2022). Sustainable professional development for STEM teachers in Saudi Arabia. Eurasia Journal of Mathematics, Science and Technology Education, 18(12), em2189. https://doi.org/10.29333/ejmste/12597
39. Madani, R. A. (2020) Teaching Challenges and perceptions on STEM implementation for schools in Saudi Arabia. European Journal of STEM Education, 5(1), 03.https://doi.org/10.20897/ejsteme/8468
40. Madani, R. A., & Forawi, S. (2019). Teacher Perceptions of the new Mathematics and Science Curriculum: A step toward STEM implementation in Saudi Arabia. Journal of Education and Learning, 8(3), 202. https://doi.org/10.5539/jel.v8n3p202
41. Memri. (2022, August 25). Saudi Arabia reforms school curriculum, cuts religion classes; journalists, intellectuals praise the. . . MEMRI. https://www.memri.org/reports/saudi-arabia-reforms-school-curriculum-cuts-religion-classes-journalists-intellectuals
42. Mizell, S., & Brown, S. (2016). The current status of STEM education research 2013–2015. Journal of STEM Education: Innovations and Research, 17(4), 52.
43. Moher, D. (2009). Preferred reporting items for Systematic Reviews and Meta-Analyses: the PRISMA statement. Annals of Internal Medicine, 151(4), 264. https://doi.org/10.7326/0003-4819-151-4-200908180-00135
44. Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for Systematic Reviews and Meta-Analyses: the PRISMA statement. PLOS Medicine, 6(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097
45. Møller, A. M., & Myles, P. S. (2016) What makes a good systematic review and meta-analysis? British Journal of Anaesthesia,117(4), 428–430. https://doi.org/10.1093/bja/aew264
46. Nicholas, J., Larsen, M. E., Proudfoot, J., & Christensen, H. (2015). Mobile Apps for Bipolar Disorder: A Systematic Review of Features and Content quality. JMIR. Journal of Medical Internet Research/Journal of Medical Internet Research, 17(8), e198. https://doi.org/10.2196/jmir.4581
47. Osborne, J., Simon, S., & Collins, S(2003). Attitudes towards science: A review of the literature and its implications. International Journal of Science Education, 25(9), 1049–1079. https://doi.org/10.1080/0950069032000032199
48. Şahin, B. (2020). The effects of STEM based outdoor activities on the prospective science teachers' academic achievement about the plants, and the opinions about the outdoor activities. Unpublished Master thesis. Sıtkı Koçman University, Department of Elementary Education, Muğla.
49. Schreiter, S., Friedrich, A., Fuhr, H., Malone, S., Brünken, R., Kuhn, J., & Vogel, M. (2023). Teaching for statistical and data literacy in K-12 STEM education: a systematic review on teacher variables, teacher education, and impacts on classroom practice. ZDM, 56(1), 31–45. https://doi.org/10.1007/s11858-023-01531-1

50. Srikoom, W. (2018). What is STEM EDUCATION? ResearchGate. https://www.researchgate.net/publication/346664196_What_is_STEM_EDUCATION
51. Sümen ÖÖ, Çalisici H (2016) Pre-service teachers' mind maps and opinions on STEM education implemented in an environmental literacy course. Educ Sci Theory Pract 16(2):459–476. https://doi.org/10.12738/estp.2016.2.0166
52. Tenney, K., Stringer, B. P., LaTona-Tequida, T., & White, I. (2023). Conceptualizations and Limitations of STEM Literacy across Learning Theories. Journal of Microbiology & Biology Education, 24(1). https://doi.org/10.1128/jmbe.00168-22
53. Thomas, T. A. (2014). Elementary teachers' receptivity to integrated Science, Technology, Engineering, and Mathematics (STEM) education in the elementary grades. https://scholarworks.unr.edu/handle/11714/2852
54. Wang, L., & Chiang, F. (2020). Integrating novel engineering strategies into STEM education: APP design and an assessment of engineering-related attitudes. British Journal of Educational Technology, 51(6), 1938–1959. https://doi.org/10.1111/bjet.13031
55. Williams, P. J. (2011). STEM Education: Proceed with Caution. Design and Technology Education : An International Journal, 16(1), 26–35. http://files.eric.ed.gov/fulltext/EJ916494.pdf
56. Xu, M., Williams, P. J., Gu, J., & Zhang, H (2019). Hotspots and trends of technology education in the International Journal of Technology and Design Education: 2000–2018. International Journal of Technology and Design Education, 30(2), 207–224. https://doi.org/10.1007/s10798-019-09508-6
57. Yaşar Kazu, İ., & Kurtoglu Yalcin, C (2021). The Effect of STEM Education on Academic Performance: A Meta-Analysis Study. Turkish Online Journal of Educational Technology - TOJET, V20, N4. https://eric.ed.gov/?id=EJ1313488
58. Yıldırım, B., & Sevi, M. (2016). Examination of the effects of STEM education integrated as a part of science, technology, society and environment courses. Journal of Human Sciences, 13(3), 3684. https://doi.org/10.14687/jhs.v13i3.3876
59. Zhan, Z., & Niu, S. (2023). Subject integration and theme evolution of STEM education in K-12 and higher education research. Humanities and Social Sciences Communications, 10(1).https://doi.org/10.1057/s41599-023-02303-8