A Systematic Review of the Stem Self-Efficacy Assessment for Elementary School Children

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ABSTRACT

Self-efficacy is an important determinant of a child's motivation and academic performance. In STEM education, self-efficacy was commonly employed as a moderator element that influenced children's interest in STEM careers and achievement in STEM fields. Many works of literature have emphasized the importance of increasing children's self-efficacy. This work aims to conduct a systematic literature review (SLR) of the STEM self-efficacy assessment in order to evaluate the factors utilised by researchers to assess STEM self-efficacy in elementary school children. Five databases, namely Scopus, WOS, ProQuest, ERIC, and Springer, were used to identify related articles from 2018 to 2023. Following the screening and eligibility phase, based on the inclusion and exclusion criteria, 25 articles were chosen for further analysis. According to the results of the SLR analysis, there are no specific methods for measuring children's STEM self-efficacy. Aside from that, resources in promoting STEM self-efficacy were significantly reliant on mastery experience; however, verbal persuasion in STEM self-efficacy was not measured, despite being one of the most essential resources in self-efficacy for children. These findings are expected to provide educators with useful information on the affective domain divide, particularly in developing positive expectations for STEM education.

Keywords: self-efficacy, primary school students, STEM

INTRODUCTION

Self-efficacy is the belief in one's ability to perform the behaviours necessary to achieve specific outcomes (Bandura, 1977, 1986, 1997). Research by Pajares (2000) supports this, indicating that 25% of students' academic success is influenced by self-efficacy. Other researchers such as Britner and Pajares (2001), Bryan et al., (2011), and Glynn et al., (2009) have mentioned that self-efficacy is widely used to predict academic performance and attitudes toward science. The research reflects the statement mentioned by Zimmermann (2000) that students with higher levels of self-efficacy are more engaged in learning and more persistent when facing challenges or problems. Additionally, self-efficacy and intrinsic motivation are positively associated with engagement and cognitive performance (Pintrich & De Groot, 1990).

Talib et al. (2009) argue that self-efficacy, active learning strategies, science learning values, achievement goals, and simulated learning environments can significantly boost students' motivation to engage with science learning. A number of studies indicate that self-efficacy in student learning serves as a crucial predictor of achievement and academic performance (Lau, Roeser & Kupermintz 2002). It is clear that self-efficacy in STEM learning significantly influences performance and the attainment of student learning outcomes. The belief in one's capabilities significantly influences academic success, choices in courses, career transitions, and developmental stages. Understanding self-efficacy can assist science educators in promoting student advancement in the field of science (Britner & Frank Pajares, 2005).

Researchers acknowledge the necessity of examining the significance of self-efficacy factors in the field of science learning. Studies in STEM education have shown that self-efficacy also functions as a predictive factor for the expected value variable within the engineering and technology domain (Fouad & Smith, 1996; Zhou et al., 2021). High-expected value beliefs correlate with students' academic success in STEM disciplines. Bong (2001) posits that a more precise measurement of self-efficacy strengthens the correlation between self-efficacy expectations and academic performance, consistent with Bandura's (1997) theory of context-specific self-efficacy. Although many self-efficacy domains show a positive correlation with performance, it does not necessarily mean that increased self-efficacy results in improved performance. Students may overestimate or underestimate their performance, which can hinder optimal outcomes.

The National Research Council (2014) argued that STEM education (science, technology, engineering, and mathematics) has been typically measured in separately. Therefore, assessing students' learning in STEM is challenging because it includes both subject-based learning and integrated learning across multiple disciplines (National Research Council, 2014). Only a few measuring instruments are available to measure how confident primary school students are about their abilities in STEM as an integrated subject. Thus, this literature review aims to explore the instruments used to measure elementary school students' self-confidence (self-efficacy) in STEM. We will also examine the specific construct these instruments consider when evaluating students aged 7 to 12 in integrated STEM disciplines.

The National Research Council (2014) highlighted that STEM education—encompassing science, technology, engineering, and mathematics—is often assessed in disciplinary silos rather than as an integrated approach. This fragmented measurement poses significant challenges in evaluating students' learning experiences in STEM, as it involves both subject-specific knowledge and interdisciplinary competencies. Despite the growing emphasis on integrated STEM education, there is a notable scarcity of instruments specifically designed to measure primary school students' self-confidence (or self-efficacy) in STEM as a cohesive subject area. This gap underscores a critical need for research to identify and evaluate existing instruments that address this issue. Therefore, this literature review aims to investigate the available instruments for assessing elementary students' self-efficacy in STEM and to analyze the constructs these instruments target, particularly for students aged 7 to 12 within integrated STEM contexts. This exploration seeks to fill the gap in understanding how self-confidence in STEM can be effectively measured at the elementary level.

LITERATURE REVIEW

Self-efficacy, based on Bandura's Social Cognitive Theory (1986, 1997), pertains to students' assessments of their ability to execute tasks or accomplish goals in their learning process, shaped by cognitive, emotional, and decision-making processes. This theory posits that four resources can enhance self-efficacy: mastery experience, vicarious experience, verbal persuasion, and physiological or affective factors. The conviction students possess in their ability to complete assignments underscores the need to take necessary actions to achieve their goals. Researchers in STEM education have extensively utilized self-efficacy to assess student improvements in science (Bryan et al., 2011), technology (Shank & Cotten, 2014), engineering (Brown & Burnham, 2012), and mathematics (Rozgonjuk et al., 2020). Moreover, self-efficacy is vital in advancing student career growth (Luo et al., 2020). From a theoretical social standpoint, self-efficacy affects students' assessment of the task's worth and importance. When students recognize the significance and value of assessment tasks, they may cultivate a robust sense of self-efficacy (McMillan & Workman, 1998; Wigfield & Eccles, 1992).

In an earlier study, Pintrich and De Groot (1990) explored the relationship between motivation, self-regulated learning, and academic performance among 173 students aged 12 years and six months. Using the Motivational Strategies for Learning Questionnaire (MSLQ), they identified positive relationships between self-efficacy, intrinsic motivation, and academic achievement. Male students demonstrated higher self-efficacy than their female counterparts, and students with higher self-efficacy and intrinsic motivation achieved better academic outcomes. The study also highlighted that self-efficacy influences cognitive engagement and students' perceptions of task value, underscoring its importance in learning environments.

Ahmad Saifi and Mohd Matore (2020) analyzed 30 articles to explore trends in mathematics self-efficacy research, noting a rise in studies from 2015 to 2020, underscoring its growing importance in education. They identified several variables correlated with self-efficacy, including academic achievement, mastery experiences, self-confidence, thinking skills, attitude, teacher support, and trust, with the United States being the most studied country in this area. Meanwhile, Md Idrus and Maat (2021) reviewed 20 articles and categorized self-efficacy into four types: mathematical, technological, academic, and teaching self-efficacy. They observed that most studies employed quantitative methods and were primarily conducted in Asian countries, revealing a regional focus and highlighting gaps in qualitative research and global representation.

Another research by Luo et al. (2020) addressed a critical gap in assessing primary school students' self-efficacy in STEM activities by developing and validating a survey instrument. The study, involving 844 students from grades 4 to 6, used So et al.'s (2018) framework to measure self-efficacy in integrated STEM activities. The results revealed distinct yet interrelated constructs of science and mathematics self-efficacy, demonstrating that student participation in STEM activities—both inside and outside of school—positively impacts their STEM self-efficacy. These findings align with prior studies by Dabney et al. (2012) and Dou et al. (2019), which underscore the significance of out-of-school STEM education in fostering students' attitude and developmental growth in STEM learning.

Together, these studies highlight the growing recognition of self-efficacy as a vital factor in education, particularly in STEM disciplines. However, gaps remain in developing robust, comprehensive instruments for assessing self-efficacy, particularly in integrated and cross-disciplinary contexts. Additionally, the regional concentration of studies and the predominance of quantitative methodologies suggest a need for more diverse and inclusive research approaches to deepen our understanding of self-efficacy across varied educational settings.

RESEARCH QUESTIONS

The purpose of the systematic literature review is to identify the aspects that have been used to measure the STEM self-efficacy of elementary school children. Therefore, the research questions of this study are:

1. What are the general characteristics of previous studies on STEM self-efficacy?
2. What are the instruments used to measure STEM self-efficacy among elementary school children?
3. What are the components measured in STEM self-efficacy for elementary school children?

METHODOLOGY

A systematic Literature Review (SLR) was conducted to identify gaps and directions that need to be addressed in future studies. This aim can be implemented by critically evaluating, analyzing, and interpreting the relevant and good quality of previous studies to research questions. There are four phases in conducting SLR in this study as follows: (i) identification, (ii) screening, (iii) eligibility, and (iv) data analysis. This study also utilized the PRISMA checklist and flowchart as a guideline, to ensure the accuracy and quality of the SLR process.

Identification

The first step in the identification process was to identify the relevant keywords based on the research questions. In this study, the keywords that have been used were "self-efficacy" AND ("primary school" OR "elementary school" OR "primary education" OR "elementary education") AND (pupil* OR student* OR children) AND (science OR Mathematic OR STEM). Meanwhile, the databases used for this study were Scopus, WOS, ProQuest, ERIC, and Springer. These databases were used to collect scientific resources in the form of article journals and theses related to this study.

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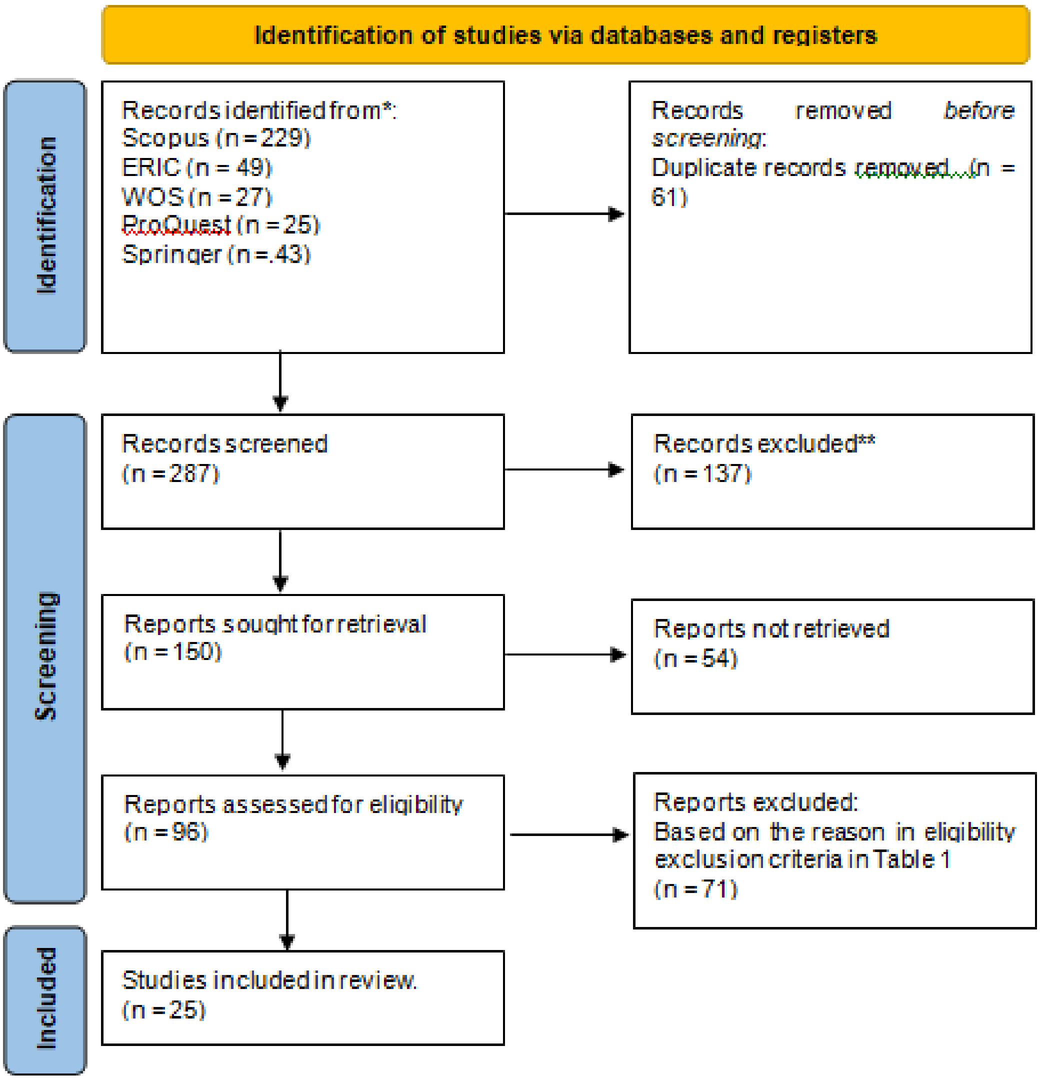
Screening and Eligibility

Based on Table 1 and Figure 1, inclusion and exclusion criteria were used during the Screening and Eligibility process. This process was to make sure only relevant articles would be used as data to answer the research questions. Based on this process, only 25 articles were us for analysis purposes.

Table 1. Inclusion and exclusion criteria for screening and eligibility process

Screening		**Eligibility**	
Inclusion	**Exclusion**	**Inclusion**	**Exclusion**
Year: 2018 to 2023	Less than 2018	Subject: Mathematics, Science, STEM	Other than Mathematics, Science and STEM
Language: English and Malay	Other than English and Malay	Level of education: Elementary school	Preschool, Secondary school, higher education
Articles and Thesis	Books, Proceeding, Review paper	Age: 7 to 12 years	Lower than 7 years and higher than 12 Years
		Respondents: Elementary school children/ students	Preservice or in-service teachers, children with disabilities

Figure 1 shows the number of articles based on the steps in the SLR.



Source: Adaptation from PRISMA 2020 flow diagram for new systematic reviews (McKenzie et al. 2021)

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RESULTS

The findings in this study were shown by research questions as follows.

What are the general characteristics of previous studies on STEM self-efficacy?

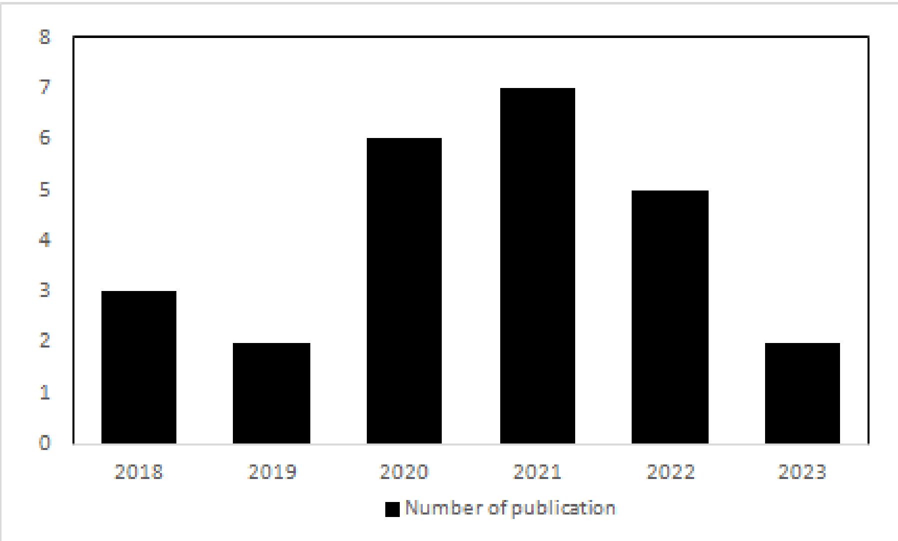
General characteristics of STEM self-efficacy studies were analyzed based on: (i) the number of research by year, (iii) types of research design, and (iv) respondents involved.

Number of research by year

In studies reporting the results of experimental manipulations or interventions, clarify whether the analysis was by intent. This explanation is important to ensure transparency in the research process. By clearly stating whether the analysis of the article related to the STEM self-efficacy of primary school pupils is in line with the intentions and objectives of the study that has been set, the researchers provide the reader with valuable insights into the rigor and validity of the study. It allows for a better understanding of the methodology used and the extent to which the findings can be applied with confidence to the stated research objectives. In addition, this information helps in a critical assessment of the internal validity of the study, contributing to the overall reliability of the reported results.

The graph in Figure 2 shows the highest number of articles in 2021 with seven articles followed by 2020 with 6 articles, and 2022 with five articles, while for 2018 and 2023 it was the same as three articles, and 2019 recorded the least number of two articles. The data shows that there has been an increase from 2019 to 2021 but there is a decrease for 2023 compared to 2021 and 2022. This is because this research using article searches up to May 2023 which is in mid-2023 led to limited article searches until May 2023 for the year 2023.

Figure 2 Number of studies on STEM self-efficacy across years (2018-2023).



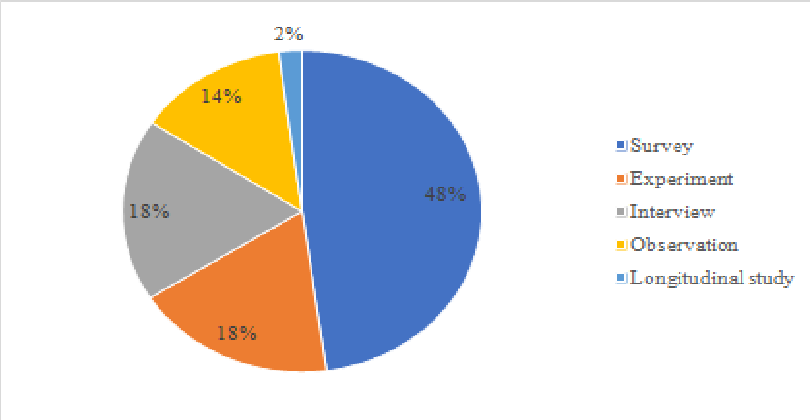
Types of Research Design

Figure 3 illustrates the predominant application of quantitative and qualitative research methodologies in the self-efficacy study. The research design based on the quantitative method, employs surveys, and quasi-experiments. A qualitative method includes interviews, observations, and longitudinal analysis. The survey was a primary method used to assess the self-efficacy of elementary school children in 23 articles (45.65%). A quasi-experimental study (17.4%) and interviews (17.4%) followed. Six articles (13.4%) employed the observation approach, and one article (2%) utilised the longitudinal method. The data shows that surveys are the most commonly used methods for assessing primary school students' self-efficacy in STEM followed by quasi-experiments, interviews, observations, and longitudinal studies.

The findings underscore the lack of longitudinal studies employing mixed-method approaches. The longitudinal study design, which inspects children's self-efficacy over an extended period, is appropriate for investigating self-efficacy. Additionally, it can integrate observational methods alongside the utilisation of both quantitative and qualitative data (Coggon, Geoffrey Rose, & Barker, 2024). This approach is considered appropriate and effective for analysing the correlation between primary school students' STEM self-efficacy and their academic performance in STEM over different time frames.

Mixed-method research employs both quantitative and qualitative data to generate robust results that aid in comprehending the broader picture, derived from interviews or observations, and the common traits within the population, discovered are more meaningful rather than surveys alone (Wasti et al., 2022). This approach may yield new findings and studies concerning the STEM self-efficacy of primary school children, making it a compelling area for exploration and the development of research related to STEM self-efficacy and academic achievement.

Figure 3. Percentages of types of research in STEM self-efficacy



Respondents

Table 2 presents the general characteristics of the respondents based on age; they are primary school students aged 7 to 12 years. The data shows that the majority of respondents were 10 years old, and 18 studies were conducted. Eleven-year-old respondents followed, contributing to 16 studies. Nine and 12-year-old students each contributed to 9 studies, while 5 studies included 8-year-old students. The least number of studies, 4, involved 7-year-old students. This finding indicates that 10-year-old students are the most age-related respondents for a study on primary school self-efficacy in STEM, followed by 11-year-olds. Conversely, 9- and 12-year-olds, along with 8- and 7-year-olds, make up the least number of respondents for this research. In studies concerning STEM self-efficacy among primary school students, the research revealed that 12-year-old students exhibited the lowest number of respondents compared to 10- and 11-year-old pupils.

Table 2. Percentages of respondents based on age

Age of children	Number of research (n)	Percentages (%)
7	4	11.5
8	5	8.2
9	9	14.75
10	18	29.51
11	16	26.23
12	9	14.75

What are the instruments used to measure STEM self-efficacy among elementary school children?

Table 3 outlines the instruments employed to evaluate elementary students' self-efficacy in STEM education. These instruments include surveys, testing, observations, and longitudinal designs. Among these, the most frequently utilized is the self-efficacy questionnaire, adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) in eight articles. This is followed by instruments derived from other previous studies or developed independently in seven articles, interview and observation tools in four articles, the General Self-Efficacy Scale (GSE) and test instruments in three articles, and the Self-Efficacy Questionnaire for Children (SEQ-C), which was used in only two articles.

The MSLQ, modified to align with specific domains and dimensions of self-efficacy, is widely used to examine students' motivation and self-efficacy levels (Ntourou, et al. 2021; Cengiz-Istanbullu et al., 2022). Similarly, the GSE, developed by Schwarzer and Jerusalem (1995), is a prominent tool, often standardized and adapted for STEM-related contexts to measure elementary students' self-efficacy in this domain. The GSE demonstrates strong internal reliability, with Cronbach's alpha values ranging from 0.76 to 0.90. The SEQ-C, created by Muris (2001, 2002), assesses children's self-efficacy across academic, social, and emotional domains. It provides insights into students' perceptions of challenging tasks. For studies investigating science-specific self-efficacy, modifications of the SEQ-C have been made to align with the academic context. The SEQ-C exhibits robust internal reliability, with a Cronbach's alpha value of 0.868.

Several studies have utilized instruments either developed independently or constructed based on Bandura's social cognitive theory, which identifies four sources of self-efficacy: mastery experiences, vicarious experiences, emotional and physiological states, and verbal persuasion. These instruments are typically subjected to face and content validity testing, with Cronbach's alpha values ranging from 0.61 to 0.91. In addition to surveys, some studies have employed observational and interview methods or comparative approaches using achievement tests between control and experimental groups. Pintrich and De Groot (1990) highlighted that self-efficacy measures could be derived from students' classroom performance, perceived competence, and confidence in completing assignments.

For instance, Feille et al. (2020) employed the ESPOSi ("Elementary Student Perceptions of Science") instrument, which incorporates observational data, field notes, informal interviews, and student project presentations. This tool captures students' understanding of science as a process for explaining the natural world, their attitudes toward science, and their perceptions of formal science education. Researchers supplemented observations with detailed field notes, reflections, and video recordings to analyse student interactions and learning processes. Interview protocols, developed based on theoretical frameworks and prior literature, were adapted for each study. Interviews were conducted on school premises, lasting no longer than 15 minutes each, with video recordings used to generate transcripts. Social media applications also facilitated communication and data collection, ensuring comprehensive evaluations.

These findings highlight the absence of a standardized instrument for measuring elementary students' self-efficacy in STEM education. Future researchers are encouraged to develop tools grounded in Bandura's self-efficacy theory or adapt existing instruments, such as the MSLQ, GSE, or SEQ-C, to suit their specific research contexts.

Table 3: The instrument used to assess the level of student STEM self-efficacy.

Types of instruments	**Instrument**	**Number of studies**
Survey instrument	MSLQ	8
	GSE	3
	SEQ-C	2
	Develop	7
Non-survey	Test	3
	Interview	4
	Observation	4

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What are the components measured in STEM self-efficacy studies for elementary school children?

Table 4 shows the summarised of components derived from the STEM self-efficacy domain namely: (i) Science Self-Efficacy or Science-Specific Self-efficacy, (ii) Technology-Specific Self-Efficacy, (iii) Engineering self-efficacy or self-efficacy of engineering, and (iv) Mathematical Self-efficacy or Mathematics-specific self-efficacy.

Table 4. Self-efficacy constructs obtain from STEM self-efficacy domains

STEM domain.	**Science Self-Efficacy or Science-Specific Self-efficacy**	**Technology-Specific Self-Efficacy**	**Engineering self-efficacy or self-efficacy of engineering specialty engineering**	**Mathematical Self-efficacy or Mathematics-specific self-efficacy**
Component under the STEM domain	1. Trust and ability to understand concepts and knowledge of science,	1. high technology self-efficacy is associated with experience with computer use.	1. The ability to create new models or robots is either simple or complex.	1. The ability of pupils to solve math problems.
	2. Ability to complete projects well,	2. 2. To build robots, build machines, be proficient in ICT, and have skills in computer programs and laptops.	2. Capable of fixing the manipulation machine.	3. Confidence in the ability of students to face challenges.
	3. Always strive hard in performing tasks,		3. Ability to think creatively and critically in solving problems related to technology.	4. The level of effort of pupils in solving mathematical problems even if it is difficult
	4. Capable of facing challenges in completing tasks,		4. Skilled in performing the assigned tasks.	5. have good performance in mathematics,
	5. Getting good achievements in science,		5. Feel the project or task is important and beneficial to the pupil.	6. Aspiring with a career related to mathematics,
	6. Trying to get solutions when faced with challenges.		6. Be confident and able to apply creativity and innovation in tasks.	7. Confident to apply knowledge in everyday life
			7. Be positive about tasks.	
			8. Be confident and capable of facing related challenges in completing tasks.	

Constructs grounded in mastery experiences pertain to the development of abilities and skills, achieving exceptional academic performance, completing complex projects, acquiring new skills, and successfully addressing increasingly challenging tasks or activities. The physiological or emotional state of an individual also significantly influences self-efficacy assessments, particularly in situations involving difficult tasks; for instance, a pupil's emotional response when encountering a challenging assignment can impact their perceived

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efficacy. Vicarious experiences, on the other hand, involve students observing peers or other individuals successfully performing tasks. Such observations enable students to evaluate their own capabilities in comparison to those of the model, which subsequently influences their self-efficacy.

Table 5. Self-efficacy sources in the student STEM self-efficacy studies

Self-efficacy sources in studies	Number of studies	Percentages
mastery experiences	22	57.89
physiological and affective states	14	36.84
vicarious experiences	2	5.26

Table 5 presents the constructs utilized in instruments designed to measure student self-efficacy. Analysis of 25 journal articles revealed that the mastery experience construct was the most frequently employed, appearing in 22 studies. This was followed by the physiological and emotional state construct, featured in 14 articles. Conversely, the vicarious experience construct was the least utilized, appearing in only two studies. Notably, no articles incorporated the social persuasion construct to assess primary pupils' self-efficacy in the context of STEM education.

DISCUSSION

The findings reveal that the number of articles on STEM self-efficacy among primary school pupils increased from 2019 to 2021 but declined between 2021 and 2023, as the search only covered articles up to this year. Quantitative methods, particularly surveys, dominate these studies, with a notable scarcity of mixed-method and longitudinal approaches. Qualitative studies employing observation and interviews often adapt or develop instruments from past research, following rigorous procedures like interview protocols, triangulation, and data verification to ensure validity and consistency. However, survey data from young respondents often exhibit lower reliability due to limited answer diversity (Newman & McNeil, 1998). Future research should prioritize mixed and longitudinal methods to generate more robust findings.

Studies indicate that 12-year-old students, despite being underrepresented, are ideal respondents due to their developmental stage, which aligns with Piaget’s formal operational stage. At this age, pupils can think abstractly, reason inductively and deductively, and explore concepts independently (Rusche and Jason 2011). This aligns with self-efficacy theory by Bandura (1977), which emphasizes belief in one’s ability to perform tasks and achieve goals. The overlap between Piaget's and Bandura's theories underscores the importance of active learning, where pupils construct knowledge through problem-solving and experiential learning rather than passive instruction.

Despite significant research, there is lack of standardized instruments to measure STEM self-efficacy specifically for elementary school students Luo et. al. (2020). Most researchers adapt tools like the MSLQ, GSE, or SEQ-C, based on Bandura’s self-efficacy theory. While these instruments demonstrate acceptable reliability which is more than 0.61 (Mohd Salleh & Zaidatun, 2001), their limitations constrain STEM education development. Two primary constructs—academic self-efficacy and task-specific self-efficacy—are commonly used, alongside domain-specific constructs for mathematics, science, engineering, and technology. However, self-efficacy assessments generally focus on mastery experiences, physiological states, and vicarious experiences, neglecting social persuasion.

Social persuasion, including verbal encouragement and positive feedback, is crucial for enhancing STEM self-efficacy (Kuchynka et. al. 2021). Bandura (1977) emphasized its role in shaping behavior and fostering success, though its influence on primary school pupils may be limited. Therefore, future research should incorporate social persuasion in STEM self-efficacy frameworks to provide a more holistic understanding of its impact on primary school pupils’ motivation and performance.

CONCLUSION

This systematic literature review highlights the study on STEM self-efficacy among elementary schools regarding study features, instruments used, and elements in measuring STEM self-efficacy. According to the reviewed-on research design, longitudinal and mixed-method studies are absent in the study of STEM self-efficacy, and there is a lack of specific instruments tailored for this purpose, necessitating the adaptation of existing tools such as the MSLQ, GSE, or SEQ-C, which are often based on Bandura's self-efficacy theory. A limitation of this research is its reliance on articles available only up to 2023, potentially omitting newer developments. Future studies should focus on designing standardized instruments tailored to elementary school students' STEM self-efficacy and exploring how social persuasion as a source of self-efficacy could be implemented. These findings provide a foundation for stakeholders to employ targeted strategies to measure and improve STEM self-efficacy in developing interest and performance, ultimately boosting participation in STEM fields.

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