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STEM Approaches in Teaching and Learning Process: Systematic Literature Review (SLR)

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Abstract

STEM is a field of knowledge that integrates learning for the fields of Science (S), Technology (T), Engineering (E) and Mathematics (M) to produce students who are creative, imaginative, inventive and have aesthetic value in finding solutions to a problem. Among the issues that often exist are the low level of achievement of students in Science and Mathematics in the TIMSS and PISA international assessments as well as the lack of interest of students in the teaching and learning process through conventional methods. The purpose of this study is to analyze the most frequently used STEM approach based on previous studies as well as identify the models used in the previous studies. The SCOPUS and ERIC databases were used in screening past articles from 2018 – 2023 using keywords such as STEM, STEM teacher teaching approach, project-based learning, inquiry-based learning, problem-based learning, multi-modal learning and collaborative learning. A systematic literature review (SLR) contains the search methods, selection criteria, selection process, data collection and data analysis for the articles produced. Year of publication and field of study are among the criteria that have been established in the selection of articles. A total of 21 articles were identified through criteria set such as year of publication and type of language. The findings of the study show that project-based learning has the highest number of references followed by inquiry-based learning, problem-based learning, multi-modal learning and collaborative learning. Further studies need to be continued to study in depth the STEM approach that is currently developing in the education system, which is integrated learning.

Keywords: Stem, Stem Approach, Project Based Learning, Inquiry Based Learning, Problem Based Learning, Multimodal Learning, Collaborative Learning.

Introduction

STEM is one of the efforts of the Malaysian Ministry of Education (MOE) to increase the resources of skilled professional workforce in research and manufacturing. STEM education teaches students the four disciplines of science, technology, engineering and mathematics

through integration and application in real world situations. According to Jemaah Nazir (2021) in a National Report on the Implementation of STEM Education, states that STEM education prioritizes balanced and holistic student development. STEM can help students understand the importance and increase interest in engineering. Universiti Teknologi Mara (UiTM) has organized a STEM Street Engineering 2022 program in collaboration with the National STEM Center as an effort to drive the country in the field of engineering. The objective of this program is to increase students' knowledge and understanding of job opportunities in the field of engineering. According to Prof. Datuk Ts. Dr Hajah Roziah (2022) the program can help UiTM build a network with the school to foster awareness of the STEM field among students.

According to Sabariah Sharif (2021) in her study, she proved that the organization of innovation-based programs can have an optimistic impact on the perception of rural students about STEM education. Early exposure to robotics activities to primary school students is very important in order to produce a generation that is literate in STEM education. The STEM approach is implemented from primary to secondary school using the Standard Curriculum for Primary School (SCPS) and Standard Curriculum for Secondary School (SCSS). First introduced in 2013, the STEM education approach has become the mainstay of education at the school level. This is to enable the country to produce young people who are skilled in both subjects and STEM fields to facilitate the rapid development of the national economy. The STEM education approach has led to changes and improvements in student achievement by combining technology and engineering disciplines in science subject activities.

According to the STEM Implementation Guidebook (MOE, 2016), there are six levels of STEM education implementation: early education, primary education, lower secondary education, upper secondary education, higher education, and industry or community. Early childhood STEM education focuses on the development and nurturing of students' interests through activities that stimulate students' curiosity. Students then learn the basics of STEM knowledge and concepts in primary school. Through exploratory inquiry activities at the elementary level, students can connect their knowledge with everyday situations. Meanwhile, student competence is developed through training and the development of STEM skills through research activities on local and global issues as well as problem solving at the secondary school level. At the upper secondary level, STEM education focuses on strengthening and enriching STEM competence through activities that can introduce STEM concepts at an advanced level. In this context, STEM education prepares students to face the challenges of STEM jobs at the higher education level and ultimately empowers students through a variety of international standard innovations at the industry and community level as well as contributing to society by leading to production, productivity, progress and national development.

In addition, the transformation of education is constantly changing. Fatahiyah Mohamed Hat and Siti Nur Diyana Mahmud (2020) argue that students who follow the STEM teaching approach achieve higher grades than those who do not follow the STEM learning and facilitation approach. Teachers are agents of change who are able to shape learning and facilitation practices more effectively (MOE, 2018). Teachers are implementers who can hone students starting from early childhood to achieve progress at the tertiary and industrial levels. This is so because teachers are one of the people who do lifelong learning to strengthen their knowledge and skills in their field of learning. Thus, teachers can do effective learning and facilitation to maintain students' interest and inspire them. As such, teachers can use various 21st century STEM approaches that can stimulate the nature of inquiry in students throughout their school years so as to produce a generation that is literate in innovation. The

types of STEM approaches that teachers can use in learning and facilitation sessions include multimodal learning, inquiry-based learning, problem-based learning, project-based learning and cooperative learning. All of these STEM approaches can integrate students' knowledge, skills and values through teacher-led activities.

In addition, Malaysia has participated in the International TIMSS Test (eTIMSS) in 1999, 2003, 2007, 2011, 2015 and 2019 and PISA in 2009, 2012, 2015 and 2018. This test evaluates students' Mathematics and Science performance in terms of content and cognitive aspects. Malaysia's position in 26th place out of 42 countries in the 2011 International Mathematical Science Learning Trends (TIMSS) proves that Malaysian students continue to perform poorly in Science and Mathematics subjects. Meanwhile, Malaysia ranked 57th out of 74 countries in the 2012 International Student Assessment Program (PISA) test. Malaysia's performance improved in PISA 2018 compared to 2009 and 2019. Malaysia increased by 36 points from 404 in 2009 to 440 in 2018. This performance placed Malaysia in 47th place out of 78 participating countries. However, this slight improvement requires more intensive efforts to educate and prepare students for international assessment. Therefore, Science subjects need to increase the application of STEM approaches in the learning and facilitation process (MOE, 2013).

Overall, based on MOE (2016), there are different STEM approaches that can be implemented by teachers in the learning and facilitation process such as multimodal learning, inquiry-based learning, problem-based learning, project-based learning and cooperative learning. STEM education can also be delivered informally through academic activities and co-curricular activities. STEM education helps build a STEM oriented society and provides highly skilled STEM talent that can contribute to new innovations. This systematic literature review (SLR) was conducted to analyze previous studies related to the STEM approach. The analysis performed helped to identify the most common STEM approaches and models used by previous researchers. Therefore, the results of the analysis and research conducted become a reference and guidance for future teachers and researchers regarding the STEM approach to education.

Problem Statement

STEM is an approach that has been around for a long time in Science and Mathematics but is still under-implemented in school education. There are several issues that cause the researcher to do this SLR study. Among the issues is that there are still many students who are lack of knowledge and exposure about the importance of STEM education. This is due to the lack of exposure and STEM courses to teachers in schools. When teachers are lack of knowledge about STEM education, this directly affects the mastery of STEM skills, values and knowledge among students. In addition, teachers face various challenges in integrating STEM concepts in the learning and facilitation process such as lack of ICT materials, science laboratories with insufficient materials and equipment and disorganized, lack of understanding of engineering elements and so on. This causes that there are still many teachers who use conventional methods in the learning and facilitation process. According to Lewis (2006), engineering elements teach children to see and understand things in the real world. Following that, the Malaysian MOE needs to improve the Science and Mathematics curriculum so that STEM elements can be applied more effectively and beneficially to students.

Objective

There are two objectives for this SLR study such as;

i. Identify the most frequently used STEM approaches in education based on past studies.
ii. Identify models or theories used in previous studies about STEM approaches in education.

Research Questions

There are two research questions for this SLR study such as;

i. What is the most frequently used STEM approach in education based on previous studies?
ii. Which models or theories were used in previous studies about the STEM approach in education?

Methodology

This SLR involves the process of identification, selection, evaluation, collection and analysis of evidence from previous studies (Kong Suik Fern, 2020). This study also uses the PRISMA 2019 flow chart (Priority Reporting Items for Systematic Reviews and Meta-Analyses) in selecting past studies that are relevant to the research questions presented. The article selection process has four stages: identification, screening, and eligibility, with the last step being the inclusion of previous studies in the conducted SLR study. Therefore, this SLR needs to carry out four steps: search process, selection criteria, selection process, data collection, and data analysis.

Article Search Strategy

The researcher found this SLR-related articles by searching well-known websites such as SCOPUS and ERIC. The keywords used are STEM approach and STEM approach in education. Both websites display articles related to STEM approaches in education based on keywords entered.

Article Selection Criteria

In order to obtain past studies that meet the research criteria, as shown in Table 1, the researcher set the article selection criteria from the perspective of year of publication, language, type of reference material, and research scope. The publication date is within the last 5 years that is from 2018 to the beginning of 2023. The selection of past studies is limited to 5 years, because 5 years is the period in which the research topic is still actively debated and contains the most discussions of recent issues. The selected articles are displayed in English because the selected database only publishes articles in English. During that period, only articles and journals that have references with complete and detailed reports will be used in the research conducted while proceedings, conferences, books and research highlights will be excluded when selecting references.

Table 1:
Article Acceptance and Rejection Criteria

Criteria	Acceptance	Rejection
Year of publication	Publications from 2018 to 2023.	Publications before 2018
Language	English	Malay, Indonesian and other languages.
Type of reference material	Article, Journal	Thesis, proceedings, conferences and books.
Research scope	In the field of Science, Technology, Mathematics and Engineering (STEM) and STEM approaches such as multi modal learning, inquiry-based learning, problem-based learning, project-based learning and collaborative learning.	Apart from the fields of Science, Technology, Mathematics and Engineering (STEM) and STEM approaches such as multi modal learning, inquiry-based learning, problem-based learning, project-based learning and collaborative learning.

Article Selection Process

The article selection process for this study was carried out in April 2023. Figure 1 shows the flow chart of the item selection process adapted from the PRISMA 2019 flow chart. This study used 7888 articles from the SCOPUS and ERIC databases. Articles were screened based on predefined criteria to allow clearer filtering. Next, based on the flow chart of the paper selection process, there are four additional criteria to remove previous studies before being included in this SLR study. Criteria include incomplete text, inconsistent with the context of the study, similar articles, articles that do not meet the study acceptance criteria, non-empirical data and in the form of reviews are also excluded. Acceptance criteria, on the other hand, include previous studies with full text and article titles matching the research context. Finally, after viewing and investigating the downloaded articles, the researcher was able to identify a total of 21 articles. All 21 papers met all selection criteria and were included in this SLR study.

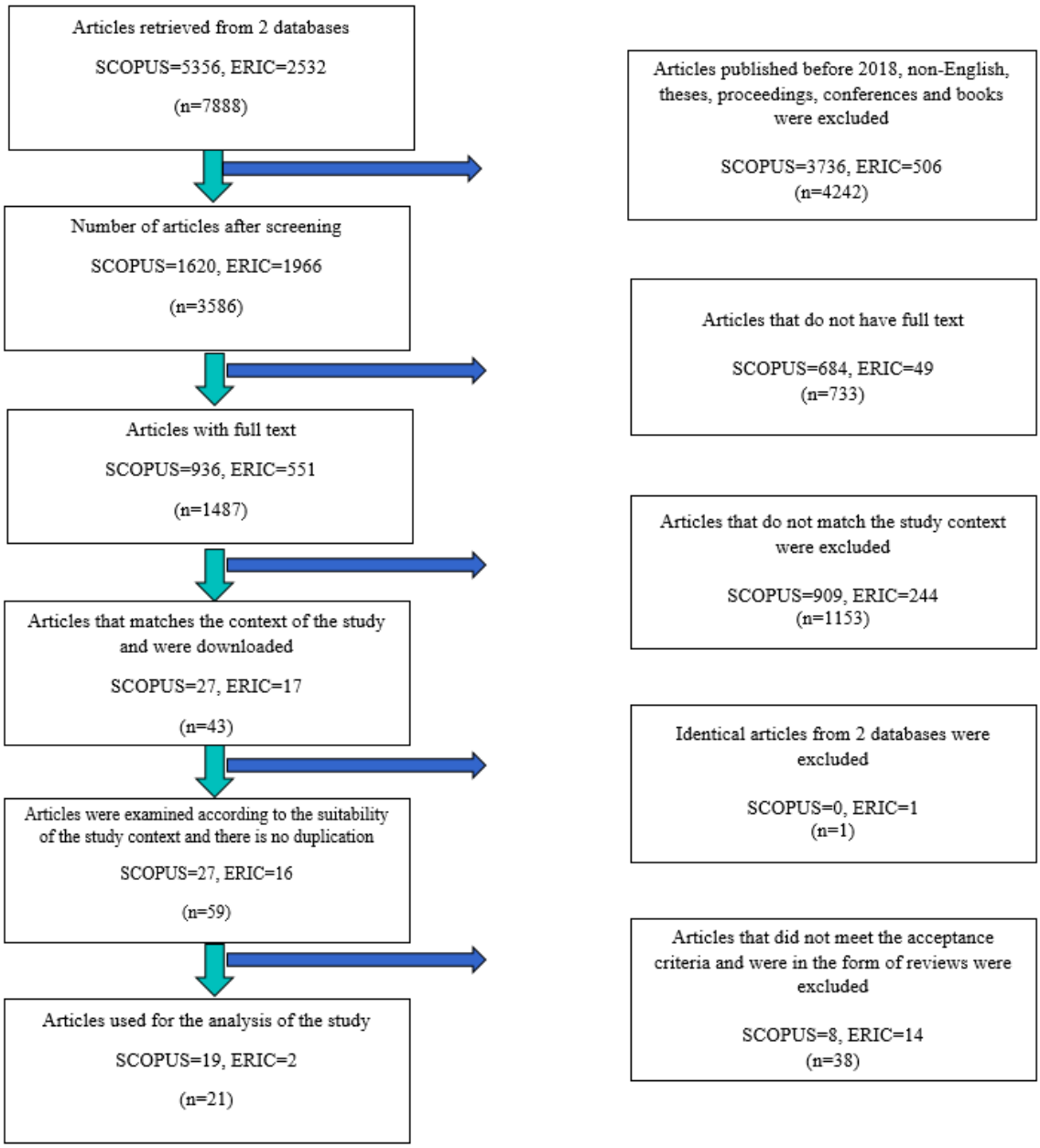

Figure 1: Picture of Article Selection Progress (Source: PRISMA 2019 Flow Diagram)

Data Collection and Data Analysis

Data collection is based on 21 articles from known databases: SCOPUS and ERIC. The data collected was extracted through Microsoft Excel 2013 software and then using Microsoft Word 2013 to build Table 2 which contains data collected from past articles such as the author's name, year, title and type of STEM approach. The results of data analysis are presented in the form of table 5 and chart 6. All items found are based on established acceptance and rejection criteria.

Table 2:
List of Past Research Articles

Num.	Author's Name & Year	Research Topic	Stem Approach
1.	Solomon et al. (2018)	A mixed-methods investigation of clicker implementation styles in STEM	Multi modal learning
2.	Dulai et al. (2022)	Collaborative Teaching plus (CT+): A Timely, Flexible, and Dynamic Course Design Implemented during Emergency Remote Teaching in an Introductory Biology Course	Collaborative learning
3.	Sulaiman et al. (2023)	The Effectiveness Of The Integrated STEM-PBL Physics Module On Students' Interest, Sense making and Effort	Project based learning
4.	Casey et al. (2023)	Motivating youth to learn STEM through a gender inclusive digital forensic science program	Problem based learning
5.	Pugh et al. (2023)	The Seeing Science Project: Using Design-Based Research to Develop a Transformative Experience Intervention	Project based learning
6.	Manishimwe et al. (2023)	Enhancing students' achievement in biology using inquiry-based learning in Rwanda	Inquiry based learning
7.	Rehmat & Hartley (2020)	Building engineering awareness: Problem-based learning approach for STEM integration	Problem based learning
8.	Yoel & Dori (2022)	FIRST High-School Students and FIRST Graduates: STEM Exposure and Career Choices	Project based learning
9.	Sudarmin et al. (2023)	Chemistry Project-Based Learning For Secondary Metabolite Course With Ethno-Stem Approach To Improve Students' Conservation And	Project based learning

		Entrepreneurial Character In The 21st Century	
10.	Fang et al. (2021)	New Technologies in Educational Solutions in the Field of STEM: The Use of Online Communication Services to Manage Teamwork in Project-Based Learning Activities	Project based learning
11.	Boateng & Nyamekye (2022)	Learning Sciences with Technology: The Use of Padlet Pedagogical Tool to Improve High School Learners' Attainment in Integrated Sciences	Multi modal learning
12.	Muzana et al. (2021)	E-STEM project-based learning in teaching science to increase ICT literacy and problem solving	Project based learning
13.	Prain et al. (2022)	Guiding Science and Mathematics Learning when Students Construct Representations	Inquiry based learning
14.	Hsin & Wu (2023)	Implementing a Project-Based Learning Module in Urban and Indigenous Areas to Promote Young Children's Scientific Practices	Project based learning
15.	Peng et al. (2023)	Predicting student science achievement using post-unit assessment performances in a coherent high school chemistry project-based learning system	Project based learning
16.	Tarres-Puertas et al. (2022)	Sparking the Interest of Girls in Computer Science via Chemical Experimentation and Robotics: The Qui-Bot H2O Case Study	Project based learning
17.	Soong et al. (2020)	Exploring the Maker Culture in Chemistry: Making an Affordable Thermal Imaging System for Reaction Visualization	Inquiry based learning

18.	Majid & Majid (2018)	Augmented reality to promote guided discovery learning for STEM learning	Inquiry based learning
19.	Hossain et al. (2018)	Design Guidelines and Empirical Case Study for Scaling Authentic Inquiry-based Science Learning via Open Online Courses and Interactive Biology Cloud Labs	Inquiry based learning
20.	Leung (2019)	Exploring STEM Pedagogy in the Mathematics Classroom: a Tool-Based Experiment Lesson on Estimation	Inquiry based learning
21.	Snell-Rood et al. (2021)	Bioinspiration as a method of problem-based STEM education: A case study with a class structured around the COVID-19 crisis	Problem based learning

FINDINGS AND DISCUSSION OF THE STUDY

The main purpose of this SLR study is to identify the most frequently used STEM approach in education. The second goal is to identify models or theories used in previous studies. There were 21 previous studies that met all the criteria set based on a review of previous research papers. According to Zulkafali (2022) in the article 'Dewan Masyarakat', STEM education is to show the right flow to shape student development to meet the talent needs of the future (MOE, 2022). KPM has introduced the 'Sekolahku SEJAHTERA' concept as a catalyst for student growth. Therefore, SJAHTERA elements such as fun, ethics, empathy, inquiry, and rationality support the improvement of STEM subjects. By applying such elements, students can instill a love for the pursuit of knowledge, and they strive to improve their understanding and mastery of knowledge and contribute to their own well-being and success. Continuous efforts to improve students' mastery and skills in STEM education through different learning approaches that focus on advanced thinking skills are important (YB Datuk Dr. Radzi, 2022).

STEM education approaches include multimodal learning, inquiry-based learning, problem-based learning, project-based learning and collaborative learning. The STEM approach to inquiry-based learning stimulates students' curiosity and fosters the instinct to explore in order to find solutions to problems. Problem-based learning helps students solve problems in a proactive, collaborative and student-centered way. Project-based learning is a learning activity that involves systematic tasks and investigations over a relatively long period of time, leading to specific goals. This approach integrates academic disciplines, is student-centered and connect with real life experiences. In addition, multimodal learning uses integrating more than one teaching technique (MOE, 2013). Collaborative learning is an educational approach that focuses on cooperation in groups of students.

Project-Based Learning

Project Based Learning (PBL) is a STEM approach that requires a certain or relatively long period of time compared to other STEM approaches. As defined in the Pak-21 Kit, PBL is a learning strategy that encourages students to review a specific topic and create a work product at the end of a learning session. Projects given to students in the form of assignments to solve problems and challenges and produce results and presentations (MOE, 2016). Chart 1 shows the PBL steps based on the Pak-21 kit of MOE (2017).

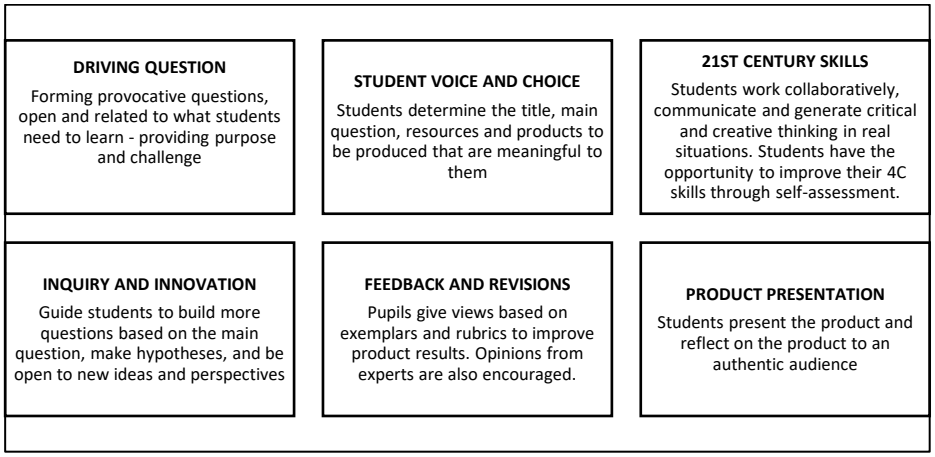

Chart 1: Steps of PBL (Source: Pak-21 Kit; MOE, 2017)

In addition, as a result of the review of past research articles, there are 9 researchers who use the STEM approach through project-based learning in the selected past research articles, namely Sulaiman et al. (2023), Pugh et al. (2023), Yoel and Dori (2022), Sudarmin et al. (2023), Fang et al. (2021), Muzana et al. (2021), Hsin and Wu (2023), Peng et al. (2023), and Tarres-Puertas et al. (2022). Assignments in the form of projects give students the opportunity to plan, investigate and carry out the given project.

Inquiry-Based Learning

According to the Inquiry-Based Learning Handbook (KPM, 2016), inquiry is the process of finding and investigating a problem, formulating hypotheses, designing experiments, collecting data, and drawing conclusions to solve problems (Shulman, 1968). Inquiry-based learning involves asking real questions, finding resources, interpreting information, asking real questions, thinking including doing. Chart 2 shows self-assessment in inquiry-based learning based on the Inquiry-Based Learning Guidebook (MOE, 2016)

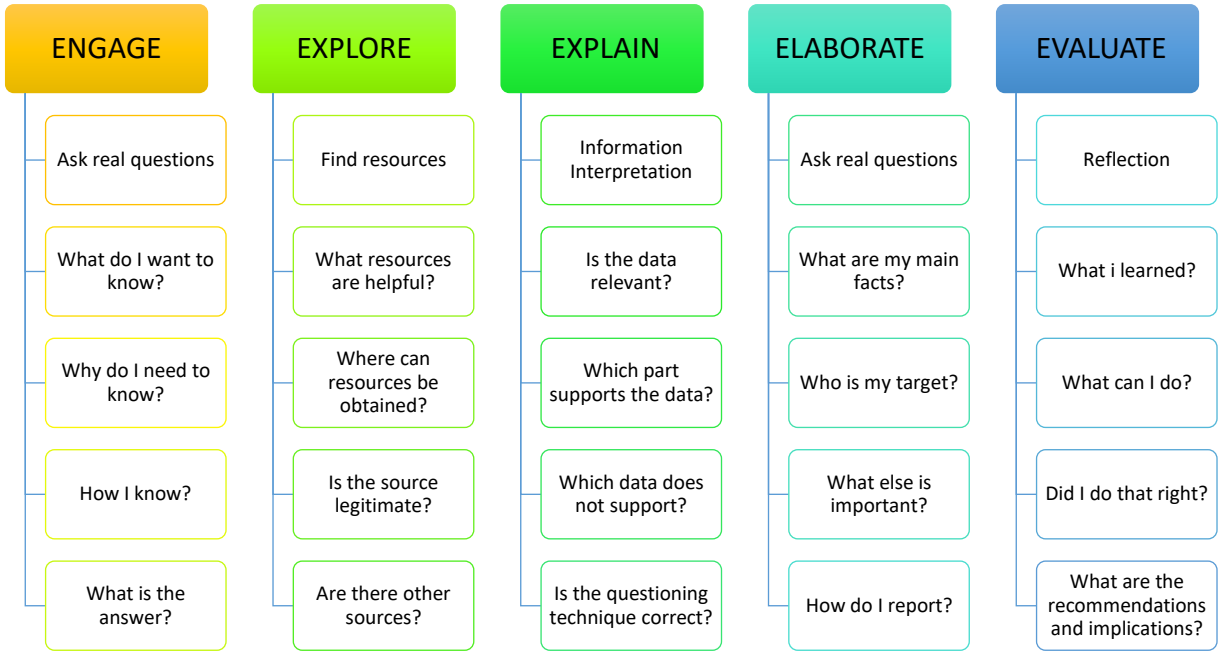

Chart 2: Self-Questioning In Inquiry (Source: Inquiry-Based Learning Guidebook, MOE 2016)

Inquiry also encourages students to question and investigate why something happened, rather than just knowing what happened. It can also stimulate students' creative and critical thinking, increase their curiosity, and encourage their independent learning. According to the Inquiry-Based Learning Guidebook (MOE, 2016), the general concept of inquiry consists of identifying problems, making assumptions, forming hypotheses, planning investigations, drawing conclusions, gathering evidence, and analyzing data. The guide also identifies four characteristics of inquiry-based learning and four types of inquiry-based learning. Characteristics of research on learning include: student-centeredness; stimulate interest and curiosity; questioning and drawing conclusions in the process of finding information; and involves cognitive, emotional, and psychomotor processes. In addition, types of learning inquiry include confirmatory inquiry, structured inquiry, guided inquiry and open-ended inquiry, as shown in chart 3. Teachers are encouraged to use appropriate inquiry types based on the subject area, interests and abilities of students. Teachers should also carefully consider the objectives of the teaching and learning process to be achieved when choosing the type of survey. However, teachers are encouraged to ask open-ended questions to give students the opportunity to be creative and innovative themselves.

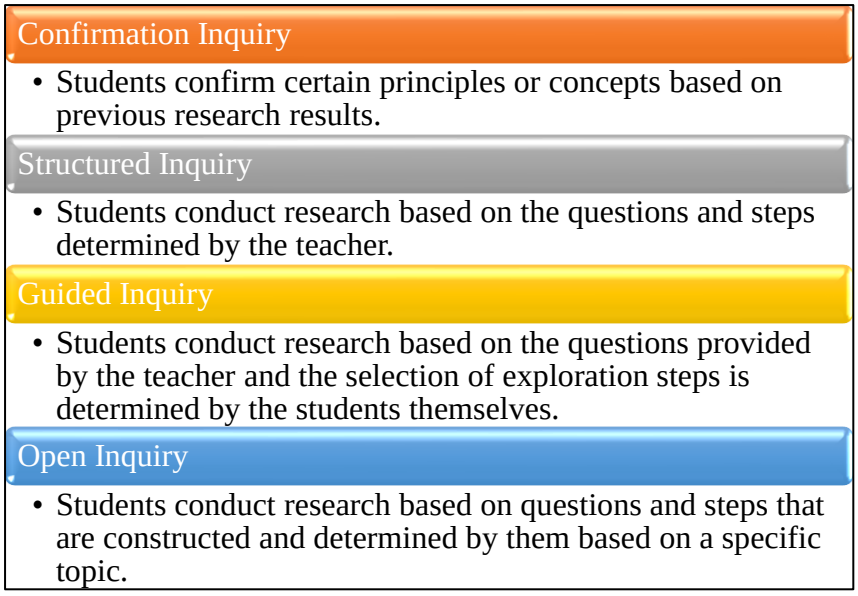

Chart 3: Types of Inquiry (Source: Herron, 2017; Inquiry-Based Learning Guidebook, MOE 2016)

Research can be conducted in learning and facilitation process using different models, depending on the appropriateness of the topic involved. Nevertheless, the 5E learning model is a general model that is suitable to be adapted to all subjects in the national curriculum. The 5E learning model is a model that is often used while conducting the survey. The 5Es refer to the five stages of learning: engagement, exploration, explanation, refinement, and evaluation. The 5E learning model includes student-centered activities. Table 3 shows the five phases of the 5E learning model and its description.

Table 3:
Description of the 5E Inquiry Learning Model
(Source: Inquiry-Based Learning Guidebook; MOE, 2016)

5E Phases	Explanations
Engagement	▪ The teacher stimulates the student's mind to arouse curiosity ▪ The teacher introduces the context. ▪ The teacher unearths the students' existing knowledge.
Exploration	▪ Pupils develop an understanding of concepts based on hands-on activities. ▪ Pupils carry out guided or open investigations to answer questions that have arisen. ▪ Students search for information/data using various sources. ▪ Pupils carry out investigations to generate new ideas or solve problems. ▪ Pupils design and carry out investigations.
Explanation	▪ Pupils develop further explanations and ideas through reflection on the investigation that has been carried out. ▪ The teacher gives input to check the understanding of concepts that have been formed by the students.

Elaboration	▪ Pupils develop understanding of concepts through application in new situations.
Evaluation	▪ Assessment occurs in each phase to assess student development. ▪ Encourage students to assess their understanding and abilities.

The inquiry approach can generally be implemented according to steps such as table 4 in the learning and facilitation process. The steps are adapted from the Inquiry-Based Learning Guidebook published by MOE in 2016.

Table 4:
Implementation Steps of Learning Inquiry
(Source: Inquiry-Based Learning Guidebook; MOE, 2016)

IMPLEMENTATION STEPS OF LEARNING INQUIRY
Before learning and facilitation process
• Identify topics/issues/questions, types of inquiries and sources of information that can be used as reference materials.
• Adapting the type of Inquiry to the topic to be taught.
• Identify students' existing knowledge.
• Plan the required time.
• Determining teaching aids, induction sets and learning objectives and outcomes.
• Designing Inquiry activities and designing assessments.
During learning and facilitation process
• Teachers create a conducive learning environment to arouse curiosity.
• Perform activities to solve problems and produce products.
• Collect and record data/information obtained.
• Analyze and interpret data/information.
• Share findings in various forms of media and be able to justify their findings.
• Be willing to accept the views of others on the findings obtained.
• Able to defend each other's ideas and findings prudently.
• Make a summary.
• Improve research.
• Conduct continuous assessment
After the learning and facilitation process
• Teachers assess the results of research work in the form of reports, portfolios or other assignments.

The learning and facilitation process of STEM subjects such as Science and Mathematics requires an approach that guides students to understand and master the concepts and principles of science and mathematics correctly. In addition, students should acquire scientific skills and skills in mathematical processes. The STEM approach with inquiry-based learning helps students understand and acquire scientific and mathematical process skills more effectively. The investigative approach in the science and mathematics learning and facilitation process can be applied through various strategies such as tests, experiments, exploration and information seeking, projects, problem solving, use of technology, simulations, visits, and the use of external resources. Through an inquiry-based approach,

students can improve thinking, creativity, collaboration, communication, decision-making and problem-solving skills.

Inquiry-based learning is a student-centered learning and facilitation strategy. Pupils are encouraged to question and find answers through activities such as observation, exploration, data collection, measurement, translating and making conclusions (MOE, 2016). Pupils will have a high degree of curiosity through inquiry-based learning. There are 6 past researchers who use inquiry-based learning in the research that has been carried out namely Manishimwe et al. (2023), Prain et al (2022), Soong et al. (2020), Majid and Majid (2018), Hossains et al. (2018) and Leung (2019).

Problem Based Learning

Problem-based learning (PBL) is one of the student-centered active teaching and learning methods (Kardoyo et al., 2020) which is based on the Theory of Social Constructivism pioneered by Leo Vygotsky. This theory also prioritizes three principles which are student-centered learning, social interaction through cooperative learning and the Zone of Proximal Development as well as scaffolding. This learning strategy has long been introduced by Howard Barrow from McMaster University Medical School, Canada in 1960 and is not a new method. According to Ulger (2018), teachers play a role in guiding students to manage and control their own learning throughout the problem-based learning process. Therefore, the PBM strategy aims to encourage students to take responsibility for learning through active involvement in problem solving tasks (Seyyedrezaie & Barani, 2017). PBL is a learning strategy that starts with a problem and uses existing resources, information and knowledge to help students generate new ideas. PBL is collaborative and the process encourages students to develop some skills and progress through the problem solving process. Chart 4 below shows the implementation steps for problem-based learning.

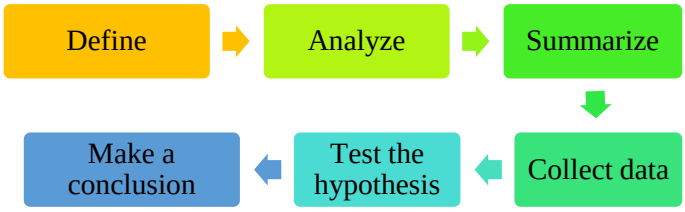

Chart 4: Implementation Steps of Problem-Based Learning
(Source: Inquiry-Based Learning Guidebook; MOE, 2016)

There are three past researchers who studied about problem based learning identified through this SLR namely Casey et al. (2023), Rehmat and Hartley (2020) and Snell-Rood et al. (2021).

Multimodal Learning

The STEM approach, which is multimodal learning, is teaching a concept or topic using more than one mode. This approach suggests that students will understand and remember better when several senses such as visual, auditory, reading or writing and kinesthetic are involved during learning. According to Darling Hammond (2010), this approach gives students multiple opportunities to demonstrate knowledge and skills, increases engagement and learning, and helps teachers better understand students' knowledge and skills. A multi-modal approach helps students learn in the way that best suits them in a fun and engaging way.

Multimodal learning was identified in two articles from this SLR. Among the articles related to multi-mode learning identified are titled '*A mixed-methods investigation of clicker implementation styles in STEM*' by Solomon et al. (2018) and '*Learning Sciences with Technology: The Use of Padlet Pedagogical Tool to Improve High School Learners Attainment in Integrated Sciences*' by Boateng and Nyamekye (2022).

Collaborative Learning

Collaborative learning is a teaching method where students help each other in small groups (Effandi Zakaria, 1998). In collaborative learning, students are usually in groups of 4-6 people. According to Sharan (1992), group members usually stay for a certain period of several weeks. Students work in groups to share ideas, help each other solve problems, and ensure that all group members master the material under the guidance of the teacher. Teachers give grades based on group performance and possibly individual performance. In addition, this collaborative learning method will only be successful if all students work together and focus not only on their own learning, but are also responsible for the learning of their classmates. According to Slavin (1990), collaborative learning also emphasizes the use of team goals to motivate all members to show the necessary commitment.

Furthermore, collaborative learning has four characteristics: positive interdependence, individual responsibility, group interaction, and social skills. According to Kagan (1992), listening to the opinions of others, especially heterogeneous groups, can increase the perception that there are different opinions compared to one's own. Kagan (1992) also thinks that the atmosphere of collaborative learning socially makes the school a happy place and interpersonal relationships improve. In order to realize 21st century learning, teachers must be creative in diversifying activities for students. There are several suggestions for 21st century collaborative learning strategies such as Jigsaw, Make a Match, Exchange Pairs, Share n Turn, Think Pair Share, Gallery Walk, Rally Robin, Ask and Guide, Idea Rush and Fan n Pick. Collaborative learning is the least studied approach by past researchers. Among the writers who studied about collaborative learning identified through the writing of this SLR is Dulai et al. (2022) only.

Models/Theories Applied in Previous Studies

The following table 5 shows the title of the previous studies, the number of types of STEM approaches identified through the writing of this SLR as well as the models or theories applied in the previous studies.

Table 5:
STEM Approach and Model/Theory Applied In Previous Studies

Num.	STEM Approach / Title of Previous Studies	Multimodal Learning	Inquiry Based Learning	Problem Based Learnign	Project Based	Collaborative Learning	Model/Theory Applied In Previous Studies
1.	A mixed-methods investigation of clicker implementation styles in STEM						Creswell Model of Qualitative Data Analysis
2.	Collaborative Teaching plus (CT+): A Timely, Flexible, and Dynamic Course Design Implemented during Emergency Remote Teaching in an Introductory Biology Course						CT+ Logic Model
3.	The Effectiveness Of The Integrated STEM-PBL Physics Module On Students' Interest, Sense making And Effort						ADDIE instructional design model
4.	Motivating youth to learn STEM through a gender inclusive digital forensic science program						Instructional model : Investigate and Decide Learning Environment (IDLE).
5.	The Seeing Science Project: Using Design-Based Research to Develop a Transformative Experience Intervention						Transformative experience theory (e.g., Pugh, 2011)
6.	Enhancing students' achievement in biology using inquiry-based learning in Rwanda						5Es instructional model (Engage, Explore, Explain, Elaborate and Evaluate)
7.	Building engineering awareness: Problem-based learning approach for STEM integration						Vygotsky's (1978) Sociocultural Theory
8.	FIRST High-School Students and FIRST Graduates: STEM Exposure and Career Choices						Social Cognitive Career Theory (Bandura)

9.	Chemistry Project-Based Learning For Secondary Metabolite Course With Ethno-Stem Approach To Improve Students' Conservation And Entrepreneurial Character In The 21st Century						Research and Development (R&D) model
10.	New Technologies in Educational Solutions in the Field of STEM: The Use of Online Communication Services to Manage Teamwork in Project-Based Learning Activities						Conceptual model for the development and management of educational innovations within the concept of STEM education
11.	Learning Sciences with Technology: The Use of Padlet Pedagogical Tool to Improve High School Learners' Attainment in Integrated Sciences						Online Collaborative Learning Theory (OCL) and the Technological Pedagogical Content Knowledge Theory (TPACK)
12.	E-STEM project-based learning in teaching science to increase ICT literacy and problem solving						E-STEM project-based learning model
13.	Guiding Science and Mathematics Learning when Students Construct Representations						An Interdisciplinary Mathematics and Science Pedagogical Model
14.	Implementing a Project-Based Learning Module in Urban and Indigenous Areas to Promote Young Children's Scientific Practices						Five essential features of the project-based approach for science learning by *Krajcik* and *Czerniak* (*2018*); Helm and Katz, (2016)
15.	Predicting student science achievement using post-unit assessment performances in a coherent high school chemistry project-based learning system						Vygotsky Social constructivism theory (1978)
16.	Sparking the Interest of Girls in Computer Science via Chemical Experimentation						Spanish academic curriculum of early childhood education

	and Robotics: The Qui-Bot H2O Case Study						
17.	Exploring the Maker Culture in Chemistry: Making an Affordable Thermal Imaging System for Reaction Visualization						Raspberry Pi Architecture Module
18.	Augmented reality to promote guided discovery learning for STEM learning						Somekh model
19.	Design Guidelines and Empirical Case Study for Scaling Authentic Inquiry-based Science Learning via Open Online Courses and Interactive Biology Cloud Labs						Design-based research approach (Anderson and Shattuck 2012; Edelson 2002)
20.	Exploring STEM Pedagogy in the Mathematics Classroom: a Tool-Based Experiment Lesson on Estimation						BSCS 5E Instructional Model in IBME
21.	Bioinspiration as a method of problem-based STEM education: A case study with a class structured around the COVID-19 crisis						Biomimetic process (Fayemi et al., 2017); Creative Exploration (Stretch & Roehrig, 2021)
Total		**2**	**6**	**3**	**9**	**1**	

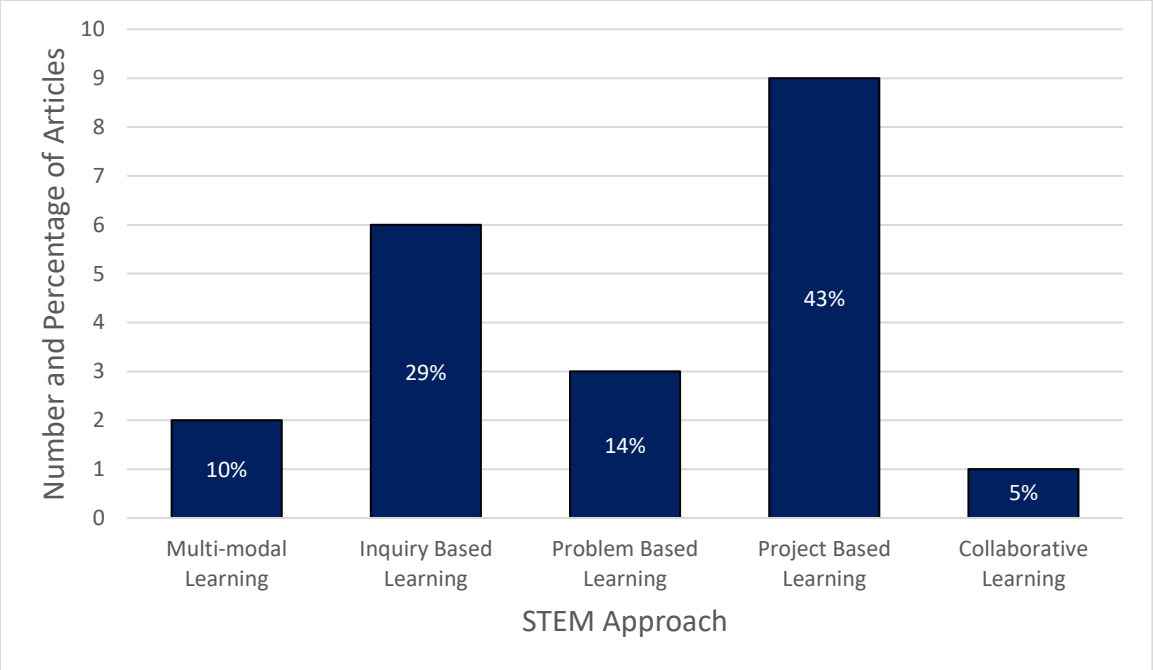

Chart 5: Number and Percentage of Articles by Type of STEM Approach

Based on table 5, there are five types of STEM approaches identified from previous research articles, namely multimodal learning, inquiry-based learning, problem-based learning, project-based learning and collaborative learning. The number and percentage of articles according to the STEM approach used by past researchers are displayed through chart 5 in the form of a bar chart. First of all, based on chart 5, it can be identified that project-based learning is the most frequently used STEM approach by past researchers, which is 9 articles equal to 43%. Meanwhile, inquiry based learning has the second highest percentage of articles with six articles (29%), followed by problem-based learning with three articles (14%), multi-modal learning with two articles (10%) and finally collaborative learning with an article (5%).

The main objective of this SLR is to identify and gather information about the STEM teaching approaches that are most frequently used by past researchers in education. All data regarding the STEM approach used in this study was obtained from the results of previous studies between the years 2018-2023. Moreover, through this SLR study, the researcher also identified the models or theories were used as a guideline in the previous studies. This approach is very effective in the learning and facilitation process of STEM, especially to integrate knowledge, values and skills among students and educators. Among the previous writers who studied about project-based learning is Fauziah Sulaiman (2023), Pugh K.J (2023), Yoel S.R (2022), Sudarmin,S. (2023), Fang (2021), Muzana,S.R (2021), Hsin,C.-T (2023), He,P.,Chen,I.-C (2023), and Tarres-Puertas M.I. (2022). Among the model or theories used by them are ADDIE Instructional Design Model, Transformative Experience Theory, Bandura's Social Cognitive Career Theory, Research and Development (R&D) Model, Conceptual Model For The Development and Management Of Educational Innovations, E-STEM Project-Based Learning Model, Five Essential Features Of The Project-Based Approach For Science Learning By Krajcik and Czerniak (2018); Helm and Katz, (2016), Vygotsky Social Constructivism Theory (1978), and Spanish Academic Curriculum Of Early Childhood Education.

According to a study by Sulaiman et al. (2023), integrated STEM modules with project-based learning have increased students' personal interest, senses and efforts after the intervention. The research uses a quasi-experimental model, using a two-group pre-survey and post-survey design. The study also proved the findings by collecting quantitative data using the Colorado Learning Attitude about Science Survey (CLASS) instrument in two selected schools in Sabah, Malaysia and Seoul, Korea. In addition, the PBL study made by Muzana et al. (2021) proves that the implementation of the E-STEM project-based learning model in science teaching improves information, communication and technology (ICT) literacy and problem solving. In addition, the study of Yoel and Dori (2022) proves that robotics programs increase creativity, problem solving, collaborative skills in groups to increase students' interest and motivation in the STEM field. The study uses data collected qualitatively, namely interviews and quantitative questionnaires.

A study conducted by Fang et al. (2021) states that the use of technology such as online communication services to manage teamwork helps develop and implement innovative projects in the realm of STEM education. Moreover, Pugh et al. (2023) proved that the Seeing Science project can support students in connecting mastery of learning in school to experiences outside of school and this can help them experience transformative experiences. Hsin and Wu (2023) to prove that the project-based learning module promotes the scientific practice of children of various ages and ethnic backgrounds through Anova tests and paired sample t tests. In addition, Sudarmin et al. (2023) carried out research aimed at

developing chemical project-based learning with an integrated Ethnoscience-STEM approach to improve conservation and entrepreneurial traits among students. A study by Peng et al. (2023) uses Vygotsky's theory of Social Constructivism to show that project-based learning has an impact on the development of science mastery among students. Finally, the study conducted by Tarrés-Puertas et al. (2022) also proved that students' interest increased in STEM activities after being involved in project-based learning. The project is also supported by the regional public administration's actions towards gender equality and the contribution of universities and humanitarian and technological entities specializing in education and business.

Based on reviews of past articles, the similarity that supports project-based learning is that the activities carried out can have a positive impact on shaping academic performance, group cooperation, critical and creative thinking skills, student talent and so on. The type of question and the way a question is expressed by the teacher has the ability to influence the cognitive process of students when they build scientific knowledge (Chin, 2007). In addition, project-based learning can increase the nature of inquiry and the tendency to make new discoveries among students. Student learning occurs through experience throughout the project. This can directly produce a generation that is literate in STEM education in the future.

Project-based learning can improve TIMSS and PISA performance through effective learning with direct student involvement when project-based learning for STEM subjects can be done by integrating various strategies such as experiments, handwork, craft making, tourism and discovery, and the use of technology. The PBP approach motivates students to master new ideas comprehensively through exploration, active participation and collaboration among group members. Therefore, project-based learning encourages students to fully master the concepts, applications and skills of scientific and mathematical processes. Pupils can also improve thinking, collaboration, communication, creativity, data recording, their decision-making and presentation skills. (MOE, 2016).

However, the Malaysian curriculum still faces some challenges in integrating STEM education with subjects such as Science and Mathematics. Challenges in integrating STEM education in the Malaysian curriculum include the appropriateness of integrating STEM education based on subjects in the learning and facilitation curriculum, the implicit content of STEM education, and the lack of teacher knowledge in engineering elements. Teachers need to creatively combine STEM education based on certain topics so that students are proficient in the skills and concepts they want to teach (Adam, 2019). In addition, the STEM approach in the curriculum is not holistic if the educational content is structured implicitly. The implicit teaching content of STEM education makes it difficult for students to fully master the goals presented in the learning and facilitation process. Furthermore, science and mathematics teachers find it difficult to incorporate engineering elements in the learning and facilitation process. Integrating STEM education in the curriculum in Malaysia is not easy, but it can be done. Productive efforts need to be made especially to help teachers strengthen this approach. To overcome the limitations above, the Malaysian MOE has nominated Excellent Teachers as STEM Icons and Guides to implement STEM education.

Next, this SLR study has several limitations. The first limitation is that this study only involves two databases to search for articles, namely Scopus. This is because researchers can find more relevant articles and according to the criteria set through Scopus and ERIC databases only compared to different databases such as WOS, Research Gate and PTSL UKM. The second limitation, the selection criteria of articles involving full text. Articles that do not have full text will be excluded when entering full text criteria. In fact, articles that do not have

full text are articles that need to be paid for and also articles that are required by researchers. This limitation of the full text caused a handful of articles related to this SLR study to be excluded because the researcher did not have the full text to refer to and analyze. The SLR study conducted can be improved in terms of finding previous studies on STEM approaches other than the five approaches mentioned in the study. Future researchers are encouraged to improve their data collection and analysis related to the integrated learning approach. The proposed improvements will make research results more reliable in the future and contribute to the implementation of the STEM approach in education.

Conclusion

This SLR study only used the SCOPUS and ERIC databases to find articles relevant to the STEM approach from around the world. A total of 21 articles can be identified based on the context and selection criteria set. All articles found are tabulated based on the STEM approach studied so as to facilitate understanding of the title, year, author's name and the approach used as a whole. The findings of the study show that project-based learning is the type of STEM approach most studied by past researchers. Then followed by inquiry-based learning, problem-based learning, multimodal learning and collaborative learning. Nevertheless, future researchers need to look for articles related to integrated learning approaches in order to further strengthen the findings of the study. With the proposed improvement, can further strengthen the findings of the study in the future as well as contribute to national education.

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