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MEASURING STEM TEACHING PRACTICES AMONG MALAYSIAN SCIENCE, MATHEMATICS AND DESIGN, AND TECHNOLOGY TEACHERS

Sri Pharani Devi Ananthan
***Mageswary Karpudewan**
Mohd Norawi Ali
School of Educational Studies, Universiti Sains Malaysia
kmageswary@usm.my

Lay Yoon Fah
Faculty of Psychology and Education, Universiti Malaysia Sabah

ABSTRACT

This study measures the level of application of STEM teaching practices among Malaysian science, mathematics, design, and technology teachers. The STEM teaching practices are categorized into four components- the six primary elements outlined in the Framework of STEM Integration in the Classroom, nature of STEM disciplines, approaches to teaching STEM disciplines, and twenty-first-century skills. STEM teaching practices are exhibited when the subject matter teachers execute cross-disciplinary STEM teaching in the classroom. The four components of practices measured through this study are inevitable to effectively implement cross-disciplinary teaching and enhance students' learning experience. This study used a cross-section survey design to gauge STEM teachers' teaching practices. For this purpose, a questionnaire consisting of 61 items was administered to the 300 primary and secondary STEM teachers identified using a random sampling method. The questionnaire had two sections: Section 1 contained 11 demographic items, and Section 2 had 50 items that used 5 points Likert scale to measure the practices. The findings reveal that STEM teachers apply the key elements of STEM Integration at a moderate level. The teachers exhibited low-level application of the nature of STEM disciplines. The teachers, on the contrary, exhibited high-level applications of STEM integration approaches and skills. The findings of this study can be the yardstick for measuring teachers' STEM teaching practices. This study also facilitates the curriculum developers and stakeholders to understand the level of STEM teaching practices of teachers and to accommodate them with necessary professional development programs.

Keywords: *STEM Teaching Practices, Primary Elements, Nature of Disciplines, Approaches of Integrated STEM, 21st Century Skills.*

INTRODUCTION

The main objective of integrated STEM is to deliver the four disciplines together in the context of real-the world problems (Karahan et al., 2021). One of the vital goals of STEM education is to equip STEM-literate students with 21st-century skills and to prepare them for the future STEM workforce. Bybee (2013) denotes that STEM-literate students can identify problems and equip themselves with sufficient skills to develop evidence-based solutions to address STEM-related challenges. Moreover, according to Holmlund et al. (2018), the International Council of Associations for Science Educators (ICASE 2013) has solicited participating countries to collaborate and promote STEM education availability and its quality so that all children are prepared for global citizenry. The importance of integrating science, technology, engineering, and mathematics has been acknowledged, and several countries have embarked on initiatives to discover STEM to compete with the industrialized world.

STEM integration has attracted much interest in the last decade, and many teachers and academicians have focused on defining integrated STEM education. Several definitions and techniques to integrate STEM education are offered, depending on how formal classroom areas are linked and how much the lines between the disciplines are blurred. A high-quality STEM curriculum would allow students to build skills in STEM disciplines. Meanwhile, teachers play a significant role in developing STEM skills and knowledge among students by effectively implementing STEM teaching practices (Margot & Kettler, 2019). STEM teaching practices include components such as the six key elements of the STEM integration framework, the nature of disciplines in STEM integration, the approach to teaching STEM-related subjects, and twenty-first-century skills (Moore et al., 2016).

Moore and colleagues have designed a STEM integration framework, which has been used to drive the focus of the STEM Road Map. The STEM Road Map includes significant elements from the "Framework for STEM Integration in the Classroom": (a) Mathematics and science objectives should be included, (c) lessons are placed in an engaging and motivating context, (d) an engineering design should be included, (e) students learn from their mistakes, and (f) teamwork is emphasized (Moore et al., 2016). The next component of STEM teaching practices is the nature of disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary (Vasquez et al., 2013). Furthermore, several common approaches are used in the learning and teaching of integrated STEM, including problem-based learning, project-based learning, engineering design practices, and inquiry-based. The component of STEM teaching practices is the 21st-century skills that prepare students to cater to the twenty-first-century workforce. The twenty-first-century skills comprise of science process skills, communication skills, mathematical thinking, and computational thinking (Schnittka, 2017).

These STEM teaching practices must be implemented in the classrooms by the teachers to ensure students can solve real-world problems (Holmlund et al., 2018). According to a study conducted by Pau and Siti Mistima (2018), STEM education plays a significant role in designing and implementing the Primary School Standard Curriculum (KSSR) and Secondary School Standard Curriculum (KSSM). They also mentioned that teachers play a key role in implementing any policies closely related to teaching and learning. The research aimed to study secondary school teachers' attitudes towards integrated STEM in Malaysia.

In another study by Yusnidar Mohamed Junus et al. (2021), the competencies of STEM teachers were assessed as six competencies which are belief in STEM learning, STEM content skills and knowledge, STEM-related pedagogy, STEM and non-STEM integration ability, actual world application, and data literacy and lastly, digital and technology. Despite all the research mentioned above, there is still no valid instrument or study conducted to assess Malaysian teachers' STEM teaching practices that comprise all of the four components of STEM teaching practices as proposed. Therefore, it is necessary to document teachers' implementation of these STEM teaching practices in the classroom. In this study, we explored the extent to which these STEM teaching practices are being adopted by teachers in their classrooms using an instrument.

PROBLEM STATEMENT

STEM teaching practices are essential in ensuring STEM education attains its objectives. Thus, it is vital to understand how teachers practice STEM in their classrooms. Teachers' competency in the practice of STEM teaching implies the level of integration of the four disciplines, as proposed by Vasquez (2014). Çiftçi (2020) further mentioned that interdisciplinary teaching is the best approach for students to learn STEM education. In a different study, Nadelson (2010) measured how teachers adopted inquiry-based learning in their classrooms and the applications of 21st-century skills to deliver interdisciplinary teaching. The questionnaires employed by Ciftci (2020) and Nadelson (2010) focus on interdisciplinary education, student-centered learning of STEM education, and 21st-century skills. The measures do not imply the four components proposed in this study. Information on the four components is instrumental in preparing training materials for educating the teachers on effective STEM teaching practices.

In a most recent study, Karpudewan et al (2022) designed an instrument to measure the STEM teaching practices of Malaysian teachers. The study aimed to explore Malaysian science and mathematics teachers' perceptions of practicing STEM teaching. The study identified teachers' knowledge of integrating the four STEM disciplines in teaching and teachers' pedagogical techniques, perceived difficulties, and self-efficacy contributing to successful STEM education.

However, the study mentioned above has only focused on one of the four components of STEM teaching practices proposed in the current study. This indicates that information on the STEM teaching practices of Malaysian science, mathematics and design, and technology teachers as four components presented in the current study is scarce. Therefore, this study was conducted to fill the gap by measuring the level of STEM teaching practices implemented by the STEM teachers. The practices are measured as the key elements of Moore's STEM integration framework, nature of disciplines in STEM integration, approaches to teaching STEM subjects, and twenty-first-century skills.

LITERATURE REVIEW

STEM (Science, Technology, Engineering, and Mathematics) has become an important topic in education reform attempts and popular media worldwide. As mentioned in Hallinen (2019), a report titled "Rising Above the Gathering Storm" was published in 2005 by the U.S National Academies and highlighted that the U.S. lacked STEM expertise compared to other countries. It also reported that the U.S. economy relies on a comprehensive lesson plan, which prepares outstanding researchers and scientists to deliver significant inventions for the fast-growing economy in the 21st century. Therefore, educational research in Science, Technology, Engineering, and Mathematics was emphasized and viewed as essential to the country's continued success.

The Ministry of Education (MOE) in Malaysia initiated the Malaysia Education Blueprint 2013-2025 (PPPM) to equip students with the skills and knowledge needed to face the challenges of the 21st century through STEM integration. In the blueprint, MOE has also mentioned that only 45% of students have graduated from the science stream, which has raised concern about the ability of our education system to produce STEM literate graduates. Hence, MOE delivered STEM across education in three waves, respectively Wave 1 (2013-2015), Wave 2 (2016-2020), and Wave 3 (2021-2025). The imperative objective of Wave 1 (2013-2015) is to strengthen current programs' foundations and encourage secondary school students to join the science stream. In Wave 2 (2016-2020), the focus was on enhancing the teaching and learning of STEM by upgrading existing science equipment and implementing campaigns to promote STEM education. Wave 3(2021-2025) is aimed to develop a roadmap for Malaysian STEM education by evaluating the outcome of waves 1 and 2. Various initiatives have been implemented to promote integrated STEM and the development of future researchers. MOE introduced an integrated STEM.

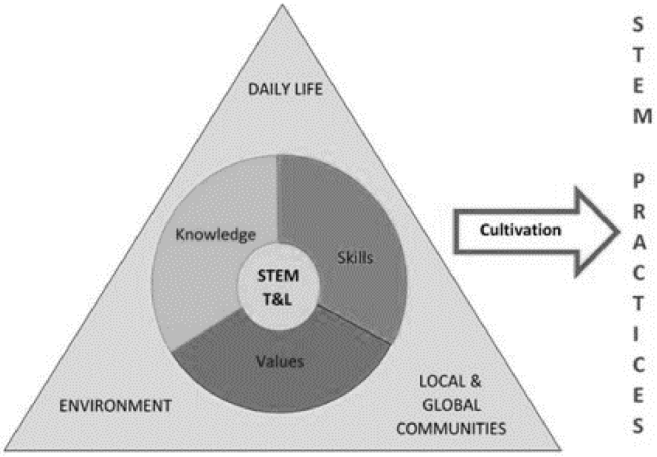

Figure 1. STEM Teaching Practices Framework (MOE, 2019)

The framework in Figure 1 represents the interdisciplinary approach to teaching and learning with integrated knowledge, skills, and STEM values in daily life and environmental, local, and global communities. According to the policymakers, the integration of science and mathematics can be effectively implemented through inquiry, problem-solving, and project-based learning that incorporates STEM knowledge, skills, and values. The framework can be found in the mathematics, science and design, and technology subjects' standard-based primary and secondary school curriculum as a guide for teachers' STEM teaching and learning. The blueprint shows the Malaysian government's motive to increase the STEM literate community.

STEM teaching practices function as a pedagogical approach to conducting integrated STEM. The STEM teaching practices consist of four main components. The components are the six primary elements of STEM integration by Moore and colleagues (2016), nature of disciplines, STEM approaches, and twenty-first-century skills. The six key elements of Moore's "Framework for STEM Integration in the Classroom" includes: (a) Math and science objectives should be included; (b) student-centered pedagogy should be used; (c) lessons should be placed in an engaging and motivating context; (d) an engineering design should be included; (e) students should be encouraged to learn from their mistakes, and (f) teamwork should be emphasized (Margot & Kettler, 2019). The key component of meaningful learning includes incorporating motivating and engaging contexts based on extensions of their self-constructed knowledge and experiences to help students make sense of the objectives of the Science curriculum (Moore et al., 2015). Students should be allowed to learn from their failures as the students can reflect, examine, and understand their errors while analyzing where they went wrong through failure. In integrated STEM, the curriculum and activities should be student centred. This is aligned with a study that proves involving in STEM-related programs, students' higher order thinking, learning, and motivation significantly improve in student-centred classrooms (Keiler, 2018).

The nature of disciplines, which are disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary, is the second component of STEM education approaches (Anderson & Li, 2020). Disciplinary integration is combining two or more interrelated contents from the same field of study to solve a problem, research a topic, or improve skills (Vasquez et al., 2013). For example, multidisciplinary techniques integrate different disciplines linked by shared themes. Students can use a multidisciplinary approach to reinforce their learning in all four STEM disciplines. Meanwhile, teachers intentionally coordinate the schedule and delivery of related subjects in this technique, but they do not attempt to integrate or bring together different subject area viewpoints. An interdisciplinary approach analyses a central theme, issue, problem, topic, or experience by integrating interdependent knowledge and abilities from multiple subject areas. Transdisciplinary is defined as "instinctive formations and practices" in which learning in one field can be strengthened by engaging with different disciplinary perspectives.

Furthermore, problem-based learning, project-based learning, engineering design processes, and inquiry-based learning are some approaches employed in learning and teaching STEM disciplines. Problem-based learning is a learning approach in which the problem serves as the beginning point for the learning process. This allows the learning content to be linked to the context, which helps students stay motivated and understand what they are learning (Graaff, 2003). In project-based teaching and learning styles, students gain skills and knowledge by studying and answering an authentic, engaging, and complicated question, problem, or challenge over an extended period (Vasquez et al., 2013). The STEM curriculum enables students to learn about engineering design processes. According to The Massachusetts Department of Education, as cited in (Siew, 2017), the engineering design process has eight steps. Those eight steps include identifying the problem (1), researching the problem (2), developing a possible solution (3), selecting the best possible solution (4), constructing a prototype (5), testing, and evaluating the solution (6), communicate the solution (7), and redesign (8). Inquiry-based learning is a method of teaching and learning that emphasizes student questions, ideas, and analyses (Nadelson et al., 2010).

The last component of STEM teaching practices is 21st-century skills, such as science process, communication, mathematical, and computational thinking, which enable students to solve real-world problems. STEM activities must emphasize teamwork and communication, an essential 21st-century skill. The ability to communicate effectively is a high-value skill in the STEM field, and as a result, it is becoming an essential 21st-century skill for students. Considering teamwork is also a crucial 21st-century skill, students should have many opportunities to participate in group activities (Guzey et al., 2016). STEM integration has developed students' science process skills which include observing, inferring, measuring, communicating, classifying, and predicting as basic science process skills (Setiawaty et al., 2018). Many aspects of mathematical thinking are included in learning outcomes, including reasoning, modelling, and establishing connections between ideas. Contextual education can help make science more meaningful because students understand how it is relevant to their daily lives (Lee et al., 2019; Li & Schoenfeld, 2019). Integrating STEM approaches such as mathematical analysis, which is required for analyzing design solutions, justifies for students to acquire science and understand the connections between the content and the application to their daily life. On the other hand, computational thinking is a fundamental skill that entails problem-solving, scientific reasoning, and problem formulation (Swaid, 2015). Computational thinking is a learning process that entails sub-skills and dispositions for controlling complex problem-solving and representing unobservable events (Li et al., 2020).

In this study, integrated STEM is achieved if the teachers apply all four components of STEM teaching practices.

THEORETICAL FRAMEWORK

Situated Learning Theory

Situated Learning Theory explains teachers' STEM teaching practices. Situated learning theory was first developed by Lave and Wenger (1991), where the aspect of learning is the situated activity, and the process is called legitimate peripheral participation (LPP). Legitimate peripheral participation emphasizes that learning occurs when new learners participate in the community of practitioners (Floding & Swier, 2012). A community of practitioners is referred to a group of people who share a passion or concern for a topic and who interact among the community regularly to develop their knowledge and competence in that field. Parallel to this, situated learning theory was used to discuss teachers' STEM teaching practices in this study. There have been several studies conducted using situated learning theory. Bell et al. (2013) conducted a study on the impact of a teacher preparation program based on situated learning theory on using technology by preservice science teachers during their lessons. The study found that situated learning theory could provide a conceptual guide for training preservice teachers to use technology in numeral ways that enhance students' learning. In this study, the science, mathematics and design, and technology teachers are referred to as the community of practitioners where they integrate STEM teaching practices which consist of four main components. Teachers can learn and practice STEM education as legitimate peripheral participation. The community of STEM teachers shares and develops methods in STEM teaching practices together and learn from idea sharing.

RESEARCH OBJECTIVES

This study is carried out to measure STEM teaching practices of science, mathematics, and design and technology teachers in the classroom presented as the following four components:

a. Key elements of Moore’s STEM integration framework
b. Nature of disciplines in STEM integration
c. Approaches in teaching STEM subjects
d. Twenty-first-century skills

Research Design and Sampling

This study employed the cross-sectional survey design to gather data from the participants. The research design is appropriate as it allows collection of data from multiple participants at a single point of time. A study's sample selection is a critical stage. If a sample is not typical of the population, it cannot be used in the study. In order to get the best results, a sample must be large enough to represent the total population and be appropriately chosen. According to Polit and Beck (2015), sample selection is the process of selecting a subset of a larger population. The sampling designs, sample sizes, and sampling phases all impact the selection process. According to Polit and Beck (2015), there are two types of sampling methods: probability sampling and non-probability sampling. Both systematic and basic random samples are included in the probability sampling content. Both deliberate and non-probability samples are included in non-probability samples. A non-probability sampling technique was used in this study's simple random sampling approach. Random sampling is the most effective and straightforward approach to collecting data from the entire population. 300 Malaysian science, mathematics, design and technology teachers made up the overall sample size for this study, which complies with Delice's (2010) recommendation for a minimum total sample size of 30.

Research Instrument

The questionnaire is utilized as a measuring tool in this study to gather all the required data. Since it is easier to administer and inexpensive, especially during the pandemic period, questionnaire was selected as the measuring tool in this research. The questionnaire consists of 5 sections which carries a total of 61 measurement items altogether. It was a 5-point Likert scale questionnaire with the scale ranging from "no practices" to "excellent practices".

The below table shows the section in the research instrument and the examples of measurement items utilized in each section.

Table 1
Examples of Items in the Questionnaire

Section	No. of Items	Example Items
Section 1 – Demographic Information	**5 items**	1. Age 2. Gender 3. School Location

		4. Type of School 5. State Education Department
Section 2 – Application of Key Elements of STEM Integration Framework	**3 items**	1. During my Science class, I provide activities for the students to stay motivated and engaged by allowing them to give their opinions, exchange ideas, and debate. 2. I encourage my students to solve the real-world problem that helps them to connect it to the context during my Science lesson. 3. In my Science class, I encourage my students to connect their own experiences and interests to the content of the lesson.
Section 3 – Application of Nature of STEM Disciplines	**3 items**	1. In the Science curriculum, students are able to integrate the skills and knowledge obtained from different contents of a single discipline to solve a scientific question or problem. 2. The standard Science curriculum enable students to incorporate the lessons learned throughout the subject to solve a scientific problem. 3. I encourage students to solve question from previous grade which is related to the content of the current grade within the same subject area.
Section 4 – Application of STEM Integration Approaches	**3 items**	1. I provide the students with real world problem that is related to the subject contents to be solved. 2. The students are encouraged to start the research or problem solving from a small brainstorming session. 3. I encourage students to create presentation that synthesize their research and solutions.
Section 5 – Application of STEM Skills	**3 items**	1. Science curriculum enable students to communicate the information and results obtained from a scientific research or experiment. 2. Science enables students to conduct the experiment using gathered information. 3. Science curriculum helps students to Identify the manipulated and the responding variables and suggest method for the control of variables in a given experimental situation.

Table below indicates the scale used in the questionnaire and their implications respectively.

Table 2

Scale Used in The Questionnaire

Score	**1**	**2**	**3**	**4**	**5**
Implication	**No knowledge**	**Low knowledge**	Basic knowledge	**Sufficient knowledge**	High knowledge

Validity and Reliability Analysis

Validity is the extent to which the results support the ideas underpinning the result (Knekta et al., 2019). Prior to the actual research, it is crucial to validate the questionnaires using face, content, and language validation. A total of 5 expert teachers with different levels of educational qualifications are chosen for validating the instrument. To ensure all the language was correct and accurate, a group of experts comprising senior academics and practitioners in STEM-related disciplines, reviewed the questionnaire. The terminology and constructs employed, as well as the information provided in the study instruments, also examined by the experts.

Reliability is the concept for the level of measurement used to assess whether an event has produced a steady stream of reliable data (Taherdoost, 2016). The reliability of the variables is assessed using Cronbach Alpha. According to Hair et al. (2010), a questionnaire is regarded as trustworthy if each variable examined using Cronbach Alpha receives a minimum value of 0.7.

A pilot study was conducted using 100 respondents to assess the reliability of the research instrument. The results of the reliability analysis are shown in the below table:

Table 2
Reliability Analysis for the Variables used in The Measurement Instrument

Variables	**Number of Items**	**Cronbach's Alpha**	**Description**
1. Application of Key Elements of STEM Integration Framework	**12 items**	**0.767**	**Excellence**
2. Application of Nature of STEM Disciplines	**13 items**	**0.786**	**Excellence**
3. Application of STEM Integration Approaches	**13 items**	**0.792**	**Excellence**
4. Application of STEM Skills	**12 items**	**0.775**	**Excellence**

The above table shows that all the items in the measurement tool recorded excellence reliabilities according to the Cronbach Alpha value obtained. Hence, the measurement items of the instrument are reliable to be used to collect the data in the actual study.

Data Analysis

The study utilized Statistical Package for Social Sciences (SPSS) software to perform data analysis. Measurements of the level of STEM teaching practices are determined using descriptive statistical approaches such as the mean score and standard deviation of the collected data. According to Table 3 below, the interpretation of the mean score value is based on Landell (1977):

Table 3
Mean Score Interpretation

Mean Score	Level
3.68 – 5.00	High
2.34 – 3.67	Moderate
1.00 – 2.33	Low

Source: Landell (1977)

FINDINGS

Demographic Information of the Respondents

Table 4
Percentage Analysis for the Demographic Information of the Respondents

Demographic Profile		Frequency	Percentage
Gender	Male	189	63.00%
	Female	111	37.00%
Age	25 years old and below	33	11.00%
	26 - 30 years old	39	13.00%
	31 - 35 years old	75	25.00%
	36 - 40 years old	54	18.00%
	41 - 45 years old	36	12.00%
	46 - 50 years old	36	12.00%
	51 years old and above	27	9.00%
Educational Level	Diploma	63	21.00%
	Bachelor's Degree	171	57.00%
	Master's Degree	66	22.00%
Years of Experience	Less than 1 year	27	9.00%
	1 - 5 years	54	18.00%
	6 - 10 years	66	22.00%
	11 - 15 years	48	16.00%
	16 - 20 years	42	14.00%
	21 - 25 years	30	10.00%
	26 - 30 years	24	8.00%
	31 years and above	9	3.00%
Often implement any of 4IR pillars in the lesson plan?	Often implement STEM education in the lesson plan?	240	80.00%
	No	60	20.00%

A total of 300 science, mathematics and design and technology teachers in Malaysia participated in this study. The above table shows the data of their demographic information collected. As shown in the table, most of the respondents are male with 63.00%, while the remaining are female respondents with 37.00% from the total respondents.

Meanwhile, many of the respondents based in the age are those from the age group of 31-35 years old which was 25.00%, followed by 18.00% from the age group of 36-40 years old, 13.00% are in between 26-30 years old, 12.00% from between 41-45 years old and 46-50 years old. Meanwhile, the least number of respondents are from the age group of 51 years old and above with 9.00% and 25 years old and below with 11.00% from the total respondents.

According to the teacher's education level, most of the respondents are bachelor's degree holders, who accounted for 57.00% of the total respondents. At the same time, teachers with diploma and master's degree accounted for 21.00% and 22.00% respectively.

Besides that, teachers with 6-10 years of experience are the majority participants with 22.00% from the total responses. Next, the data collected shows that teachers with 1-5 years of experience which was 18.00% from total respondent, teachers with 11-15 years of experience which was 16.00% of the total respondent and the teachers with 16-20 years of experience who accounted for 14.00% of the total respondent has also participated in the study. The least respondents that participated in the study was teachers with 31 years and above who were 3.00% of the respondents. We also had teachers with 26-30 years of experience and less than 1 year teaching experience who accounted for 8.00% and 9.00% of the total respondents respectively.

Level of Application of STEM Teaching Practices

Table 5

Mean Score Analysis for The Level of Application of STEM Teaching Practices

Application STEM Teaching Practices	Mean Score	Level of Application
1. Application of Key Elements of STEM Integration Framework	2.94	Moderate Level
2. Application of Nature of STEM Disciplines	1.88	Low Level
3. Application of STEM Integration Approaches	4.21	High Level
4. Application of STEM Skills	4.14	High Level

Table 5 above shows the mean score analysis to identify the level of application of STEM teaching practices among Malaysian science, mathematics and design and technology teachers. The finding above shows that the teachers have a high level of application of the STEM teaching practices in their classroom. The teachers recorded the highest mean score for the application of STEM integration approaches which was 4.21. This was followed by the score of 4.14 in the application of STEM skills and the score of 2.94 for the application of key elements of STEM integration framework. Lastly, the teachers scored the least mean score for the application of nature of STEM disciplines with a score of 1.88.

DISCUSSION

STEM education is a pedagogy focused on educating students in four primary fields, science, technology, engineering, and mathematics, through an interdisciplinary and practical manner. It mainly focuses on overcoming the learning gap by bringing students to the centre of the experience, transforming them from passive listeners to active learners (Hom, 2014). Therefore, teachers need to have a high level of application of STEM teaching practices in their classrooms.

The findings of this study reveal that the teachers are found to have a high level of application of the STEM integration approaches in their classrooms. The STEM integration approaches are closely associated with students' understanding of STEM subjects. A few approaches are used in the learning and teaching STEM education: problem-based learning, project-based learning, engineering design practices, and inquiry-based learning. Firstly, problem-based learning is a learning approach in which the problem serves as the beginning point for the learning process. The tasks are based on real-world problems identified and adjusted to fulfill learning objectives and standards of the science curriculum. Project-based teaching and learning style is an approach in which students gain skills and knowledge by studying and answering an authentic, engaging, and complicated question, problem, or challenge over an extended period. The project-based learning process starts with driving questions from the Science curriculum posted in the project assigned to the students. An engineering design process is commonly used in teaching and learning STEM subjects. As for the engineering design process, the students start by defining the problems given by identifying the constraints and need. The student will then research the problem to understand the task further and continue to imagine or come up with possible solutions for the problem. Inquiry-based learning is the other common approach to teaching and learning STEM education. Inquiry-based learning is a method of teaching and learning that emphasizes student questions, ideas, and analyses. These approaches also allow the learning content to be linked to the context, which helps students stay motivated and understand what they are learning (Graaff, 2003).

It was found that the teachers have a high level of STEM teaching practices in applying STEM skills in their classrooms. STEM education prepares students to face the challenges of the global economy in the twenty-first century by developing their 21-st century skills. These 21-st century skills encourage teachers to strategically implement STEM education to enhance students' understanding and interest in learning STEM education. STEM education has developed students' science process skills which include observing, inferring, measuring, communicating, classifying, and predicting as basic science process skills. The ability to communicate effectively is a high-value skill in the STEM field, and as a result, it is becoming an essential 21st-century skill for students. STEM education has played an important role in improving students' communication skills through project-based learning.

However, the study has also recorded that the teachers have a moderate application of the key elements of the STEM integration framework in STEM teaching practices. According to the framework for quality STEM education, the six key elements are crucial for meaningful integrated STEM teaching and learning (Moore, 2014). Firstly, the incorporation of a motivating and engaging context is a unique characteristic of an integrated STEM curriculum that helps students make sense of unit activities that are based on extensions of their own personal knowledge and experiences. Second, the STEM curriculum should enable students to learn about engineering design processes and engineering practices while participating in engineering design problems. A good engineering design challenge allows students to experiment with or build technologies to tackle the problem while also requiring them to think about restrictions, safety, hazards, and alternate solutions. Third, failure is an opportunity to learn an important part of the engineering design process, as well as a student learning. The next element is the integrated STEM unit includes information that is appropriate for each grade level in science and mathematics. Fifth, in an integrated STEM program, the curriculum and activities should be student centred. Previous research has demonstrated that active participation in learning events helps students gain greater comprehension and skills. Lastly, STEM activities must emphasize teamwork and communication. To accomplish the engineering challenge and other science or mathematics exercises, students should work as a team. Considering teamwork is a crucial 21st-century skill, students should have many opportunities to participate in it. The unit should also encourage the development of communication skills.

Lastly, the finding showed a low level of STEM teaching practices in applying the nature of STEM disciplines. Vasquez's use of an inclined plane to show a continuum of rising levels of STEM integration—from disciplinary to multidisciplinary to interdisciplinary to transdisciplinary approaches—captures the nature of disciplines in STEM education (Anderson & Li, 2020).

Disciplinary approaches, in which disciplines are taught individually, can leave students with little opportunity to connect STEM subjects**.** Disciplinary integration is combining two or more interrelated contents from the same field of study to solve a problem, research a topic, or improve skills. This technique emphasizes the subject's unique understanding of conceptual frameworks and inquiry processes. However, multidisciplinary techniques educate different disciplines linked by shared themes. Students can use a multidisciplinary approach to reinforce their learning in all four STEM fields. Meanwhile, teachers intentionally coordinate the schedule and delivery of related subjects in this technique but do not attempt to integrate or bring together different subject area viewpoints (Aguinaldo, 2022).

Interdisciplinarity refers to integrating two or more disciplines, whereas transdisciplinary goes beyond it. An interdisciplinary approach analyses a central theme, issue, problem, topic, or experience by integrating interdependent knowledge and abilities from multiple subject areas (Takeuchi et al., 2020). Transdisciplinary is defined as "instinctive formations and practices" in which learning in one field can be strengthened by engaging with different disciplinary perspectives. According to Gordon as cited by Sengupta (2020), the act of dialectical suspension, which occurs "when a discipline suspends its centering because of a commitment to matters greater than the discipline itself," is fundamental to such transdisciplinary encounters.

CONCLUSION

The primary focus of this study is to measure the level of application of STEM teaching practices among Malaysian science, mathematics and design, and technology teachers. In order to measure the science, mathematics, design, and technology teachers' STEM teaching practices, a questionnaire with measurement items was employed. The teachers must implement STEM teaching practices in their classrooms to prepare STEM-literate students with 21st-century skills and engage them in the STEM workforce. STEM education prioritizes the application of understanding to real-world situations, and as a result, it promotes critical thinking, problem-solving, and creativity, all of which are important for any country's development (Machuve & Mkenda, 2019). According to the findings of this research, it is notable that Malaysian science, mathematics, design, and technology teachers highly apply the STEM integration approaches and STEM skills. However, the study documented that the teachers poorly applied the key elements proposed by Moore in their Integrated STEM Education Framework and moderately applied the nature of STEM disciplines. Thus, this study can be the pioneer in measuring teachers' STEM teaching practices in their classrooms.

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