

The Development of STEM Education Under TVET in Malaysia: Insights from a Local and Global Perspective

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ABSTRACT

Against the backdrop of global digital transformation and industrial upgrading, STEM education (Science, Technology, Engineering, and Mathematics) has become a key driver for educational modernization and vocational skills development worldwide. As an emerging economy, Malaysia has actively aligned itself with global trends by integrating STEM education into its national education blueprint, with particular emphasis on integration with TVET. This study adopts a content analysis approach to systematically review the developmental trajectory of STEM education in Malaysia over the past 15 years—from initial attention to its current status as a national strategic priority. The analysis highlights Malaysia's notable progress in policy support, curriculum development, teacher training, and technological integration. Initiatives such as the “Program Duta Guru” and the establishment of digital education centres demonstrate the country's alignment with international trends emphasizing interdisciplinarity, digitalization, and lifelong learning. However, persistent challenges—including unequal distribution of educational resources between urban and rural areas, disparities in teacher quality, and low student participation and STEM career identity—remain particularly acute at the secondary education level.

Keywords: TVET; STEM Education; Malaysia; Situation and Challenge; Interdisciplinary

INTRODUCTION

Since the 21st century, the tremendous progress of information technology has brought unprecedented challenges to society. Humanity has achieved important progress in several technologies like Artificial Intelligence (AI), Big Data, Cloud Computing, Internet of Things (IoT) and other fields (Dai et al., 2023; Paul et al., 2020). However, there is still a huge gap in the demand of employers for 21st century talents, especially in the domains of STEM (science, technology, engineering and mathematics), because STEM education offers students the opportunity to master 21st century skills and knowledge and to cope with the fourth industrial revolution (van Laar et al., 2017; Wahono et al., 2020).

The concept of STEM education has a long history, and after several decades of development, more and more countries and regions have realized the importance of STEM education for talent training and national development (Bybee, 2010, 2013), STEM education is also proven to help students improve complex problem solving skills, more and more STEM-centered learning practices are being developed, and evidence has shown that STEM education has a positive effect on students' overall career development (Yip & Chan, 2019). The concept of STEM education plays a key role in the

development of talents and skills in the 21st century (Clark et al., 2021; Kelley & Knowles, 2016).

In recent years, new technologies and global events have brought new influences to STEM development (Gomoll et al., 2018), many countries have elevated STEM to the level of national strategy, and the promulgation of STEM act has greatly stimulated the development of STEM related fields, such as the United States, China, the United Kingdom, Australia, Japan, etc (Simpson & Bouhafa, 2020; Wahono & Chang, 2019). Many countries have formulated STEM development strategies and carried out STEM in various school sections, it covers from birth, K12 education, postsecondary to adult education and lifelong learning, advocating the combination of new technology and new industrial structure (Leung, 2020; Li et al., 2020; Roehrig et al., 2021). So as to better fit the labor force needs and industrial development status in the 21st century, and cope with the opportunities and challenges in the growth process of STEM talents (Anderson et al., 2020; Charania et al., 2021; Miller et al., 2021). Malaysia also pays attention to STEM, Malaysia is a multi-ethnic and diverse Southeast Asian country, its economy has developed rapidly in recent years, but it also facing problems such as unbalanced regional economic development and low matching between vocational education and training system and market demand (Cuberes et al., 2023). The Malaysian government is seeking ways to solve these social problems.

In 2011, the Malaysian government encouraged public schools and private schools to cultivate STEM talents by establishing the TVET system (Razali et al., 2022). In 2013, the Malaysian Education Blueprint (MEB) was published by Malaysian Ministry of Education (MOE), which regarded STEM education as an important education reform and set STEM transformation into three stages. The first stage (2013-2015) is to strengthen curriculum reform and provide appropriate teacher training, the second stage (2016-2020) is to further improve the curriculum, raise public awareness of STEM and enhance teachers' teaching skills and knowledge, the third stage (2021-2022) is to cultivate STEM related skills and knowledge development, focus on student's innovation ability. However, from the results of reform, students' interest in STEM related fields is still low, especially in the middle school stage, and students' STEM performance is not excellent (Idris et al., 2023). Programme for International Student Assessment (PISA) results show that in mathematics and science courses, the performance of Malaysian students is far from that of Singapore, China, and the United States (Zhu & Li, 2020). Therefore, the number of students choosing STEM majors in higher education stage is insufficient, which is not enough to support the development of STEM field (Ismail et al., 2019). Some evidence shows that in different countries not just Malaysia, but others like the United States, Australia, India, etc., where learners' interest and motivation in STEM is declining (Kurniati et al., 2022).

In Malaysia in particular, the School Operations Sector of the Ministry of Education explained that the Ministry is actively taking measures to address new challenges in the education system in the post-pandemic era to ensure the stable development of the national education ecosystem, and to promote the achievement of the objectives of the MEB (Ministry of Malaysia, 2021). According to the data, only 50.83% of Malaysian students choose to study STEM subjects, which is lower than the target of 60% expected by the national policy (Ministry of Malaysia, 2018). In order to improve the proportion of this data, the Ministry of Education has launched many programs to encourage more students to choose STEM related subjects. For example, the Program Duta Guru, which targets teachers, aims to enhance the teaching abilities of STEM teachers, foster diverse learning methods, attract students to STEM programs, and so on (Ministry of Malaysia, 2024).

In 2023, the government is also investing about \$100 million in the construction of Digital Education centres, which aim to use digital technologies to empower teaching practices and improve

teachers' teaching standards. At the same time, in order to strengthen exchanges and cooperation with various industries, the government has conducted a large number of market demand surveys and established a lot of TVET programs to encourage students to choose more types of jobs related to STEM fields (Razali et al., 2020). But there are still some realities, such as the difficulty of interdisciplinary implementation of STEM education, the difficulty of evaluation of STEM education results, and the unbalanced development of educational resources still exist (Zainal et al., 2018).

So, analysing the development status and trend of STEM education in Malaysia, and putting forward targeted suggestions according to the existing situation, plays an important role in the development of STEM education in Malaysia and the development of the entire national economic level, and potentially help other countries in similar situations.

METHODOLOGY

This study adopts a content analysis approach to systematically review the developmental trajectory of STEM education in Malaysia. By reviewing the development of STEM in the context of TEVT in Malaysia and integrating an international perspective, we will conduct an evaluation and reflection on the development and existing problems of STEM. This study followed a rigorous systematic review approach by screening the literature according to the 3-step PRISMA process, 1 to identify the literature relevant to this study, 2 to use the criteria determined by the authors for screening, and 3 to determine inclusion in the total literature (Page et al., 2021).

2.1 Identification

SCOPUS database was used as the source of literature retrieval because of its wide coverage, high academic recognition, and wide range of disciplines. Screening STEM related literature in the SCOPUS database can retrieve all disciplines, and at the same time, it can also perform preliminary screening according to keywords, for example, STEM keywords may contain unrelated topics such “stem cell”. Literature screening journals that are published and do not contain literature reviews are identified using the title, abstract, and keywords. Search the SCOPUS database for STEM or STEAM, or STEM education, or Science education, Technology education, Engineering education, Mathematics education, because our research object is Malaysia, the country “Malaysia” is set again. A total of 879 articles were preliminarily obtained.

2.2 Screening

In the screening stage, we mainly excluded 1: articles that did not match the year of publication, 2: articles from non-English journals, and 3: articles not relevant to this review. The relevance of the articles was determined by double-checking the title, abstract, keywords, research methods, etc. Any article that did not meet the screening criteria was excluded.

2.3 Inclusion

In this stage, multiple researchers from the education profession repeatedly checked and deleted incomplete data and articles that did not meet the requirements to ensure the integrity and consistency of data. The VOSviewer software was used for bibliometric analysis of the search results. After importing the cvs of documents into the tool, co-occurrence graphs in various fields such as keywords, journal citation counts and publications were created to perform bibliometric analysis.

RESULTS AND DISCUSSION

In the analysis of keywords in 116 articles in VOSviewer, a total of 391 keywords were used, of which 54 were used more than 2 times. Table 1 shows the top 10 keywords used most frequently. STEM (22) has the highest frequency, followed by STEM education (17), Science education (12) and Engineering education (9), Project-based learning (6), Education (6), Problem-based learning, E-learning, Secondary school, and Gender are all 4. Table 1 shows the cluster graph of keywords that appear more than twice. All keywords are divided into 8 clusters, including STEM-related items, mainly related to STEM disciplines and implementation level, learning theory, learning technology, student development level and learning effect, and teacher training.

Table 1. Top 10 Popular Keywords

No	Keywords	Occurrences
1	STEM	22
2	STEM education	17
3	Science education	12
4	Engineering education	9
5	Project-based learning	6
6	Education	6
7	Problem-based learning	4
8	E-learning	4
9	Secondary school	4
10	Gender	4

Through literature analysis and VOSviewer visualization, we sorted out 8 main themes of concern in the field of STEM education in Malaysia. Table 2 introduced the 8 main themes and their subtopics, along with brief descriptions.

Table 2. Main Topics of STEM Education in Malaysia

No	Main Theme	Sub Theme	Description
1	STEM Curriculum	1. Curriculum Design 2. Framework of STEM	1. Discuss the way to design suitable courses. 2. Construct STEM Curriculum frameworks.
2	STEM Fields	1. Preschool 2. Primary School 3. Secondary School 4. University	Discuss different situations in different fields.
3	STEM Learning Theory	Theoretical Basis	Discuss theories on STEM.
4	Technology in STEM	1. Applications of Learning Method 2. Software in Learning	1. Discuss impacts of technologies on STEM. 2. Discuss the application of new technologies in STEM learning.

5	STEM Outcomes	1. Academic Performance 2. STEM Literacy 3. STEM Identity	Discuss 21st century skills and Career competencies.
6	STEM Development Level	Student Performance Level	Measures performance based on students' grades.
7	Teacher's Training	STEM Teacher Training	Discuss situations of STEM teacher and ways they instruction.
8	Assessment	STEM Results Evaluation	Discuss STEM curriculum evaluation and learning tools in STEM.

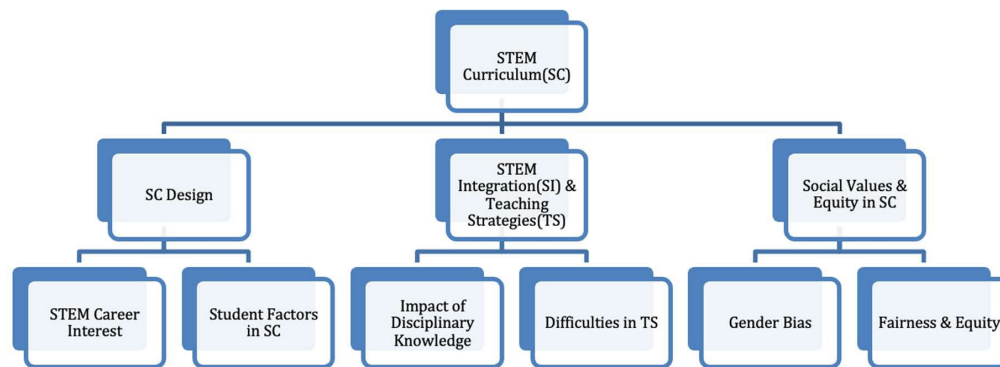


Figure 1. STEM Curriculum Research Focus in Malaysia

3.1 STEM Curriculum

STEM curriculum discussions have focused on STEM curriculum design and STEM curriculum models. Razali et al. designed a curriculum model for measuring STEM career interest, and verified the relationship between STEM career interest and STEM, 21st century skills, scientific motivation and family influence by using S-STEM and interest in STEM careers, Science Motivation Questionnaire II (SMQ II) and Parental Authority Questionnaire (PAQ) measuring tools, finally verify the effectiveness of STEM career interest model for STEM learning (Razali, 2021); Endot et al. studied the student factors affecting the STEM curriculum system in primary schools (Endot & Jamaluddin, 2023). Karpud et al. discussed the influence of knowledge of different disciplines on teaching strategies, perceived difficulties and self-efficacy in STEM curriculum integration, and put forward guidance for subject integration (Karpudewan et al., 2023). Nasri et al. focused on the value issues involved in STEM curriculum communication and proposed strategies to address gender bias in STEM curricula (Nasri et al., 2023). These discussions discussed the design process, effectiveness and development of STEM framework in the implementation of STEM curriculum from different perspectives. Figure 1 visually shows the core content of STEM Curriculum in Malaysia, including STEM curriculum design, STEM Integration, Teaching Strategies, Social values, Equity in STEM Curriculum.

3.2 Conceptual Framework of STEM Learning Theory and Technology

In STEM education research in Malaysia, different learning theories provide a rich theoretical basis for educational practice. Constructivism, Behaviourism, Cognitivism, Socialized learning theory and Situated learning theory are the most common in STEM education. These learning theories provide a

wealth of teaching strategies, from strengthening basic skills to cultivating higher-order thinking and problem-solving ability. For example, constructivism learning theory and PBL learning method are used in many learnings, which emphasis is placed on solving real-world problems through hands-on practice and cooperative learning applied in scientific experiments, engineering design projects, etc. (Navy & Kaya, 2020). These theoretical backgrounds each emphasize different learning mechanisms and teaching methods, which promote students' comprehensive understanding and application of STEM knowledge. Researchers should focus on exploring how to effectively apply these learning theories in localized teaching practices. In the STEM education research in Malaysia, various technological means are widely used to enhance students' learning experience and learning effect. Based on data analysis, we find that augmented reality (AR), smart phone applications and online learning platforms are commonly used technical tools. For example, Ng et al. research on enhancing story telling through the combination of virtual and reality, to enhance student interest and engagement (Ng et al., 2023). Chu et al. mentioned in their study that sound experiments enhance flexibility and interactivity in STEM learning (Chu et al., 2023). In addition, online learning platforms have gained widespread popularity in recent years, especially after the COVID-19 pandemic, with the rapid development of basic education and higher education in Malaysia. Krishnan et al. pointed out that in STEM learning, online platforms not only promote collaboration and communication among students, but also promote communication among students, it also provides teachers with a wealth of teaching resources and assessment tools (Krishnan et al., 2019). The integration of technological in STEM has played a positive role in STEM education in Malaysia, promoting the innovation of teaching methods and the optimization of teaching resources.

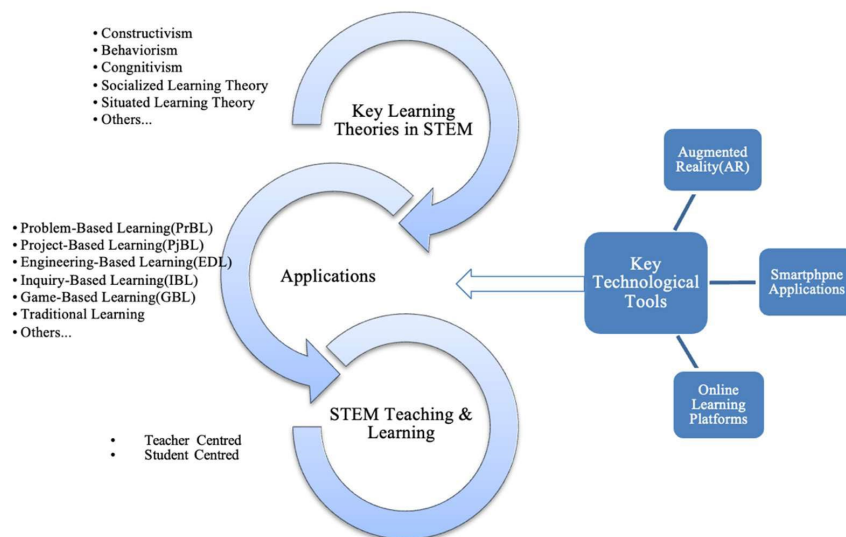


Figure 2. STEM Learning Theory and Technology

3.3 Four Dimensions of STEM Evaluation

The evaluation of STEM education in Malaysia is mainly divided into evaluation standards, evaluation methods, evaluation tools and evaluation feedback, shows like Figure 3. Assessment methods such as formative assessment, through classroom tests, project reports and other forms of timely understanding of students' learning progress and learning effects, summative assessment through the end of the semester or the end of the large exam and final study report, a comprehensive summary of the

performance of students in the whole STEM cycle (Tak C.C. et al., 2023). Assessment tools may use standardized tests, such as PISA and TIMSS, to assess math and science literacy, and program assessments assess students' performance over the course of the program, including program design, implementation, and outcome analysis (Ismail et al., 2019). Technology assisted assessment uses online test platforms and educational software to increase the feasibility and interactivity of the assessment. As for the evaluation feedback, teachers mainly provide feedback to students through written comments, oral feedback and grading, so as to help students correct their shortcomings in time, so as to encourage students to self-reflect and improve their learning initiative.

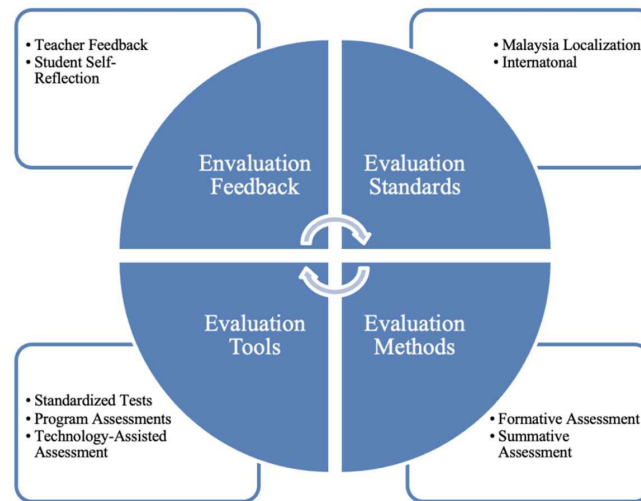


Figure 3. STEM Evaluation in Malaysia

3.4 STEM Education Realities in Malaysia: Alignments and Differences with Global

STEM education in Malaysia has been shaped by both global influences and localized factors. While the government has made significant strides and keep the main directions with global, but conflicts exist compared to global trends. Malaysia has been working on STEM curriculum reform to align with the global emphasis on interdisciplinary learning (Leung, 2020), and the competency-based STEM reform reflects international efforts in the US, Europe and East Asia (Freeman et al., 2019). The promotion of STEM literacy by integrating computational thinking and problem-solving skills into various education sections is consistent with international goals. At the level of technology integration, Malaysia has adopted digital learning resources such as online learning platforms, AR, and interactive tools, like during the covid-19 pandemic, the development of STEM in Malaysia is in line with the international trend of distance learning and digital learning (Miller et al., 2021). In addition, the emphasis on 21st century skills, initiatives to address the workforce needs in STEM fields, and the exploration of student-centered teaching and learning approaches to STEM are also aligned with the international framework.

Despite these alignments, there are still several aspects diverge from global. Urban-rural disparities exist in Malaysia, rural schools often lack access to advanced STEM facilities and trained teachers, leading to disparities in learning outcomes (Abdullah et al., 2021; Ong et al., 2015). In contrast, countries with developed STEM systems, like Germany and Finland, have implemented nation policies to make sure equitable STEM opportunities (Ishmuradova et al., 2023; Mäkelä et al., 2022). In terms of STEM career interest and STEM workforce, Malaysia and global face the challenge of low interest, the local job market for STEM graduates faces challenges such as limited industry absorption, which

different from the strong STEM employment ecosystems in the US and Germany (Akcan et al., 2023; Kersanszki & Nadai, 2020; Reider et al., 2016). By addressing these differences and keeping to adequate attention on STEM, Malaysia can continue to consolidate its position in STEM education and workforce development.

CONCLUSION

From a global perspective, Malaysia's STEM reform has drawn inspiration from leading countries such as the United States and the United Kingdom, incorporating practices like project-based learning (PjBL), problem-based learning (PrBL), and digital pedagogy. Nevertheless, gaps remain in areas such as labour market alignment, educational equity, and regional balance, especially when compared to STEM-advanced countries like Germany and Finland. This study recommends that developing countries strengthen policy implementation and regional coordination, foster industry-educator collaboration in teacher training, and enhance student engagement and career identity to improve educational quality and workforce readiness. The findings offer practical insights and strategic implications for other nations seeking to localize and globalize STEM education in tandem with vocational education reform.

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