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STEM education in Malaysia: An organisational development approach?

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ABSTRACT

A new breath has taken place to re-position STEM education based on its importance in providing a skilled STEM workforce, which is crucial for Malaysia. The Ministry of Education (MoE) and the Ministry of Science, Technology, and Innovation (MOSTI) have launched strategic plans to boost students' enrolment in Science, Technology, Engineering, and Mathematics (STEM) to develop a STEM-literate society with a high-quality and sufficient workforce in Malaysia. Institut Aminuddin Baki (IAB), the leadership training centre in MoE, collaborates with Curriculum Development Division (BPK) have piloted a Science, Technology, Engineering, and Mathematics Executive Consultation (STEMEC) project under the Malaysia Educational Blueprint 2013-2025 (MEB) Initiative #49 in 2019. The project aims to strengthen integrated STEM Education in 32 primary and secondary schools by providing pupils with continuous meaningful STEM learning experiences. The STEMEC conceptual framework is grounded in the organisation development approach to develop model STEM schools that others can benchmark on holistically implementing integrated STEM education. In addition, the pilot project introduced an instrument that can assist schools in planning, implementing, and accessing integrated STEM education, impacting their strategically crafted integrative learning experiences.

Keywords:
Science, Technology, Engineering, and Mathematics; education; integrated STEM; Malaysia; leadership; organisation development

1. Introduction

The 21st century has seen Science, Technology, Engineering, and Mathematics (STEM) education gaining more importance in the global arena [2]. Hence, the Malaysian government is committed to ensuring STEM education is on par with other developed countries. It is highlighted in Malaysia Educational Blueprint 2013-2025 (MEB) with a projected ratio of 60 per cent of Science / Technical against 40 per cent of Arts. This agenda aims to strengthen STEM education to boost students' interest and teachers' competency in teaching STEM subjects. On top of that, implementing STEM curriculums ensures its elements are met.

In 1970, the idea of STEM education started in Malaysia. However, the MoE has officially used the term STEM in MEB to highlight Programme for International Student Assessment (PISA) assessment in 2015. In addition, various curriculum restructuring programmes have been introduced

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to improve student learning. Nonetheless, only in 2017, with the Secondary School Standard Curriculum (KSSM) and Primary School Standard Curriculum (KSSR) revision, the theory and concepts of integrative STEM education are placed as core elements [2]. Consequently, the teaching and practice in science and mathematics, engineering, and technology are without interdisciplinary connections among those fields. Many pupils opt out of "rigorous" science and mathematics middle and high school courses, and many who graduate high school with relatively low science and/or mathematics ability are the challenges for worldwide STEM education [33]. The report of MEB (Wave 1) supported the above phenomena and found that the declining number of pupils' enrolment for STEM subjects is due to a lack of interest among secondary pupils. Limited awareness and low exposure to STEM subjects, especially in secondary schools, are the main reasons [30,39]. In addition, the lack of school leaders' support, time constraints coupled with the heavy workload, insufficient budget, and lack of facilities contribute to the teachers' performance [17]. They view the syllabus in science subjects as heavy and complex. On top of that, STEM education with an interdisciplinary approach faces an uphill task among educators as they need more integrated STEM exposure and training. As a result, their knowledge and skills need to be included in this new advancement in STEM education and updated rapidly [35].

Therefore, MEB again introduced various initiatives to increase pupils' interest, motivation, attitude, and career awareness related to the STEM field. A worldwide STEM-focused educational movement has spawned those challenges [22]. Pupils' interest and skills in STEM can be enhanced through integrative STEM education when the pedagogy is a purposeful design to engage pupils in scientific inquiry situated in the context of real-life problem-solving. To improve pupils' interest, understanding, and abilities in each STEM discipline, the best practice model is the project method that allows teachers to teach science and mathematics in the context of technological / engineering design integratively [34]. He further highlighted seven principles of learning, drawing from various literature that the Integrative STEM education pedagogy enhances students' learning:

i. Provide timely opportunities for pupils to activate prior knowledge.
ii. Provide a unique and powerful context for meaningful organising STEM knowledge for future retrieval/use.
iii. Generate high levels of interest and motivation among a wide range of pupils of all ages and abilities.
iv. Immerse pupils in applying and integrating S, T, E, & M knowledge, skills, and practices over time.
v. Provide pupils with a specific goal and ongoing feedback from peers and teachers, designed/made solution self-evaluations.
vi. Create conditions for pupils to engage in ongoing positive, non-threatening, and reflective social interaction with their teachers, teammates, and classmates.
vii. Engage pupils in a group design challenges them to take responsibility for their planning, self-assessing, self-monitoring, and reflection.

Integrated STEM education is mentioned by the Malaysia Ministry of Education (MoE) for educating learners with the acquired skills for them to become productive citizens. Moreover, the inception of the new curriculum in the current system for government schools, i.e. Primary School Standard Curriculum (KSSR) and Secondary School Standard Curriculum (KSSM), a lot more considering steps need to be taken to ensure the implementation phase is successful.

2. STEM Education in Malaysia

STEM education is viewed as a lifelong education inculcated through formal learning based on curriculum, non-formal through co-curricular activities, informal through indirect learning from early age till tertiary and finally, at the community and industry level. The primary focus is creating a STEM literacy society and a highly skilled STEM workforce that can contribute to innovations. (Implementation policy for science, technology, engineering, and mathematics (STEM) in teaching and learning, *Dasar Pendidikan Kebangsaan, Edisi Keempat, Kementerian Pendidikan Malaysia,* 2017).

This guideline has indicated that implementing STEM education in Malaysia "*is a built-in organisation quality, not an individual happenstance*" [8] because cultivating pupils' STEM literacy needs sufficient experiences that should provide formal, non-formal and informal learning. Moreover, teachers from different disciplines must collaborate to provide integrated STEM education that requires the school leaders' support and approval. Therefore, integrated STEM education needs to be led by school leaders who can inspire all the organisation members to share the same vision and work collaboratively to ensure every pupil has sufficient integrated STEM learning experiences. Consequently, the organisational development approach focuses on implementing integrated STEM education, allowing schools to profoundly transform the teachers' and pupils' integrative STEM teaching and learning process and outcomes.

2.1 National STEM Vision

According to Malaysia's STEM vision, our country's competitiveness depends on the quantity and quality of the STEM workforce that our country's education system can produce. Therefore, all the educational organisations in Malaysia are responsible for equipping pupils with the skills needed to face the challenges in the fast-changing world by applying STEM. Thus, the role of the school is crucial in providing all the pupils with adequate integrative STEM learning experiences to allow them to be competent industrial workforce to drive the Malaysian economy. It is one of MoE's efforts to improve the quality of pupil development in line with the aspiration of placing Malaysian education in the top third of the Education system in the world.

Pupils' quality learning experiences in STEM education matter a lot. They need to apply the content and practice to solve authentic problems in the rigorous, high-quality integrated STEM learning experiences that maintain the integrity of grade-level standards [3]. Moreover, pupils with access to and engage in more authentic learning experiences have a higher literacy rate [18]. In essence, relevant STEM learning experiences and practices make profound differences when they are rooted in equity and access.

2.2 National Action Plan

The global socio-economic landscape has changed with the rapid acceleration and innovation of knowledge based on mobile internet, Big Data, and the Internet of Things (IoT). A new generation breed who can adapt to the grand challenges of the future is needed to combat these technological breakthroughs. The skills and mastery in various technology fields, especially mobile internet, IoT, and automation of knowledge-related work, are crucial to compete in the global market. Hence, plans for human capital development in advanced technology are called to face these challenges of socio-economic landscape change.

In 2018, the Minister of Energy, Science, Technology, Environment and Climate Change launched the STEM National Strategic Action Plan 2018-2025. The action plan has outlined STEM education as an integrated field to produce a STEM-literate workforce for nation-building. Therefore, structured and comprehensive programs are formulated in the National STEM Strategic Action Plan 2018-2025 to ensure the STEM literate workforce is produced via mastery STEM ecosystem. Integrated strategies involving various levels of society and stakeholders in the ecosystem settings. In short, seven (7) focus areas with 13 strategies and 34 initiatives are gazetted in this strategic action plan to spearhead the nurturing of STEM talents in a conducive and supportive ecosystem (Fig. 1).

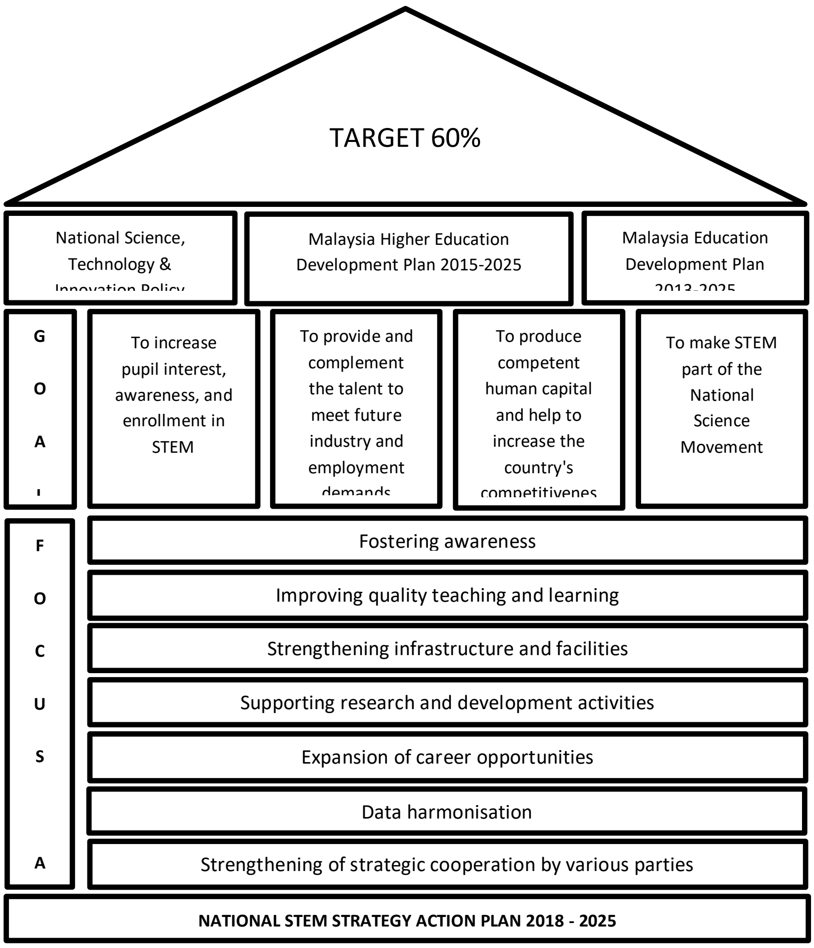

Fig. 1. The STEM Nasional Strategic Action Plan 2018-2025 (Source: MoESTEC-The STEM National Strategic Action Plan 2018 – 2025, 2018)

2.3 Goal of STEM Education

MoE is accountable for laying a solid foundation at the school level to ensure that Malaysia has many qualified, competent, and sufficient graduates to meet future workforce needs. STEM education is one of the six characteristics of student development, as contained in the fourth shift of MEB 2013-2025 [25]. Through this initiative, MoE ensures that students are equipped with the skills needed to meet the challenges of the Volatility, Uncertainty, Complexity, and Ambiguity (VUCA) world with STEM applications. Therefore, STEM education in Malaysia aims to guide the schools in producing skilled STEM talent to meet future industry and employment demands and improve Malaysia's competitiveness (Fig. 2).

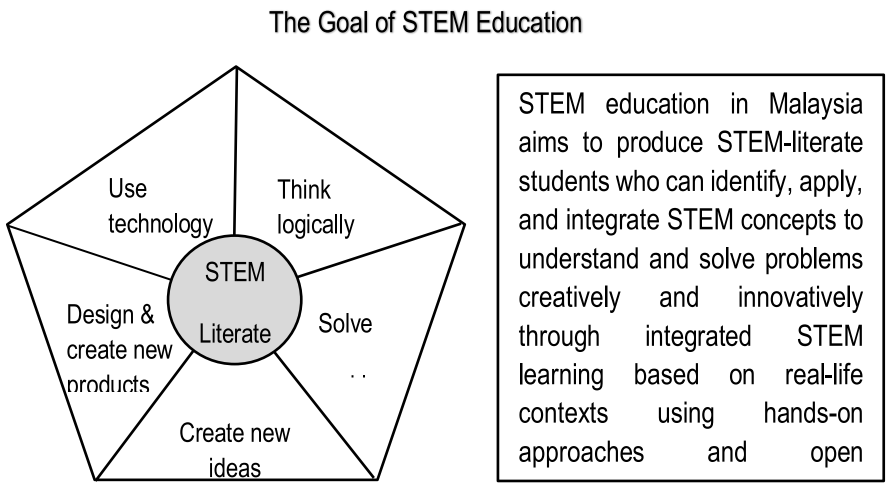

Fig. 2. The Goals of STEM Education (Source: MoE- Report of Initiative MEB #49: Strengthen STEM Education 2017, 2018)

The goal of STEM education will be achieved when the implementation of integrated STEM education is strengthened by focusing on four target groups: students, teachers, school leaders, and parents. Each target group has a specific objective, namely:

i. Students – to increase students' interest and inclination towards STEM education.
ii. Teachers – strengthen their knowledge and skills, especially in integrating Science, Technology, Engineering, and Mathematics subjects.
iii. School leaders - strengthen their knowledge of STEM-related initiatives implemented by MoE.
iv. Parents – increase their level of awareness of STEM-related fields and their importance.

2.4 STEM Education Policy

MoE made a significant curriculum transformation by introducing the Secondary School Standard Curriculum (KSSM) and revising the Primary School Standard Curriculum (KSSR) in 2017. It aims to meet student aspirations and national needs sketched in MEB. The learning program and student outcomes have been influential in this curriculum transformation. Students aspire to have the knowledge, thinking skills, leadership skills, bilingual proficiency, ethics and spirituality, and national identity as recommended in the Malaysian Education Blueprint (MEB) 2013 - 2025. This transformation is performed on content, pedagogy, and assessment as follows:

i. Content is restructured and improved to ensure students are provided with the knowledge, skills and values relevant to the current needs for the challenges of the 21st century.
ii. Pedagogical emphasis on learning a depth approach to teaching and learning based on higher-order thinking skills (HOTS). The focus is on inquiry-based learning, problem-solving, contextual learning, collaborative learning, project-based learning and STEM approach.
iii. Assessment is carried out continuously to ensure the progress and achievement of student learning. Assessment in teaching and learning is conducted in the form of summative and formative. Teachers assess the extent to which students master the learning standards regarding the prescribed performance standards. Students' development and actual achievement level were recorded and reported descriptively to students and parents.
iv. The STEM approach has been a core element in the construction and implementation of the curriculum. The pedagogical emphasis in teaching an in-depth approach to teaching and

learning based on higher-order thinking skills (HOTS). The focus is on inquiry-based, problem-solving, contextual, collaborative, and project-based learning, which aligns with the STEM approach. Given that the Malaysian government has started to show interest in the STEM approach at the school level, the government should ensure that the curriculum implementation meets explicit STEM integration characteristics.

3. The Science, Technology, Engineering and Mathematics Executive Consultation (STEMEC) PROJECT

Malaysia's STEM education aims to produce STEM literate pupils is aligned with Sanders's assertion of "integrative STEM literacy". A person in the 21st century should possess the knowledge and ability to apply basic math, science, and engineering concepts and practices in designing, making, and evaluating a solution to authentic problems [34]. Therefore, schools must provide integrative STEM education to cultivate pupils' integrative STEM learning. Pupils acquire the STEM elements: the knowledge, skills, and values through intentionally situating the teaching/learning of STEM by intertwining in designed-based activities with "real-world problems", which have a formative effect on how one thinks, feels, or acts. Consequently, the experiences should be continuously given to all the pupils throughout the formal, non-formal even informal learning activities. Hence the school's involvement must be as the organisational development approach led by the school leaders and inspiring and mobilising all the teachers, the parents, and the communities to ensure the cultivation of STEM practices among pupils is happening.

Subsequently, the STEM Executive Consultation project (STEMEC) is proposed as a pilot project to develop a model STEM school that other schools can benchmark for holistic implementation of Integrative STEM education. The STEMEC project is a collaborative project between Institut Aminuddin Baki (IAB) and Curriculum Development Division (BPK) under the Initiative MEB #49: Strengthen STEM Education, guided by the five objectives as below:

i. lead the implementation of (integrated) STEM education in schools
ii. ensure that the (integrated) STEM approach is implemented periodically according to the school term
iii. ensure the implementation of authentic assessment in teaching and learning
iv. ensure the application of STEM elements in co-curricular activities
v. increase the involvement of parents and the community in STEM education

3.1 Integrated STEM Education Framework

The Integrated STEM Education Framework (Fig. 3) serves as the conceptual framework for this project. It illustrates the relationship between Integrated STEM Learning (ISL) and Meaningful STEM Milieu (MSM) for the primary and secondary schools implementing integrated STEM education. The Integrative STEM Education framework was piloted by 32 primary and secondary schools throughout the 13 states and three federal territories in Malaysia from 2019 to 2021.

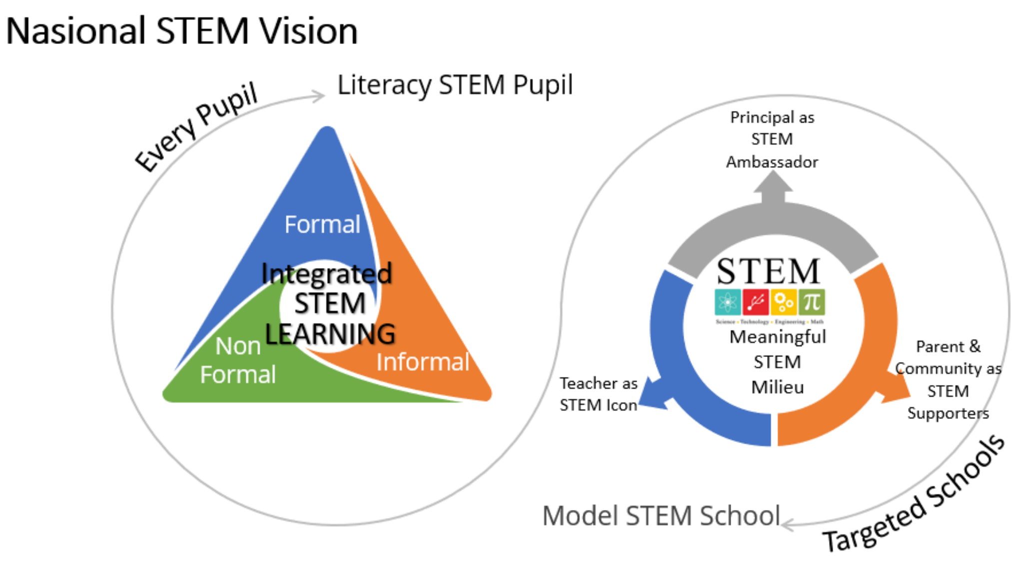

Fig. 3. Integrated STEM Education Framework (Source: IAB-MoE-Proceeding of National STEM Education Leadership Colloquium in 2022)

The Integrative STEM Education framework formulates to support Malaysia's STEM vision to ensure every pupil is a literacy STEM pupil. Therefore, Integrated STEM Education (ISE) aims to give every pupil sufficient ISL experience through formal, non-formal, and informal learning, as illustrated in Fig. 3.

Consequently, the adequate ISL experience for all students needs to be provided by all teachers through the curriculum and co-curriculum activities. This type of holistic implementation with the full participation of teachers and pupils must be led by school leaders who embrace the STEM educational leadership and set the change vision of the school as a STEM Sustainable School. The principal or headmaster shared and led the change vision to the organisation community by enacting a STEM ambassador towards the whole school community. The school leaders must buy in and enable the implementation of ISE coherently and holistically, as organisational development (OD) is supported by individual development (ID).

Subsequently, they empower teachers as the icon STEM who embrace PBL STEM as their chosen pedagogy to ensure the pupils will engage in deep STEM learning. Pupils are capable of solving real-world problems which will be complex and utilising the interdisciplinary approach to produce a product as the solution. The outcome and satisfaction of deep learning demonstrated by the pupils are good reasons to convince other teachers to make PBL STEM their chosen pedagogy.

The pupils will be literate in STEM if their learning experiences, either formal, non-formal, or informal, are continuously engaging them to solve problems related to real-world situations. The learning becomes relevant because the knowledge and skill taught are practical and meaningful to them. However, the real-world problem is complex and needs to be solved by integrating knowledge and methods from different disciplines, using a natural synthesis of approaches [20]. Therefore, the pupils will work in a team to solve the problem collaboratively by applying the interdisciplinary approach to produce an innovative product.

The ISE will be sustainable in the school when the school communities: the principal or headmaster, teachers and pupils are enacted as the ambassador of STEM, the Icons of STEM and the citizens of literacy STEM (Fig. 3). Clearly, the entire process of STEMEC project is a whole school improvement process where all the school communities are involved. They must change their practices to implant the ISE and create a STEM milieu to transform their schools become model STEM schools. OD change collectively enhances the system's effectiveness and develops the potential of all the individual members in the system.

3.1.1 Organization Development Approach for STEMEC Project

School improvement is an organisational change process that must work under collaboration between the school leaders and the organisation's members because the school is a social organisation. The improvement allows schools to optimise the normative and cultural level development in the OD manner. The school culture indicates the health of the school organisation, which is reflected in the quality of the psychosocial climate as the ability of the schools to adapt to the changing educational and social needs of the pedagogical and social environment continuously and adequately, with relevant short, medium, and long-term development trends [36].

School improvement is a profound collective scale exercise for all individuals involved with mentalities restructuring. Therefore, school improvement is measured by the efficiency criterion in addressing the school's core issues and objectives through resource orientation. It measures how those resources are converted to results, as mentioned in the objectives. Any value change is either an efficient positive or inefficient negative change.

Consequently, the design of the STEMEC project is grounded in the OD approach within the psychosocial climate. The development of education is led by professional, competent leaders who understand and can communicate the importance of change to the entire actors of the organisation for adapting and initiating the happening of change in the school with short, medium, and long-term planning. Therefore, the success of the school improvement mainly depends on continuous staff development to support progressive school improvement. The organisational development process is situational with the organisation member's responses to the change. This type of organisational change needs structural and behavioural interdependent staff development plans to assimilate new values and practice the associated behaviours of the organisation members in a structured and guided manner.

Thibaut *et al*. [40] highlighted that implementing integrated STEM teaching is iterative and requires cooperation between teachers of different disciplines. Therefore, ISL needs more than one teacher to collaborate to integrate the concepts and practices of S, T, E, & M, which may be enhanced through further integration with other non-STEM subjects [32]. In short, two factors are concerned: i) the school leadership to facilitate the cross-subject teachers' collaboration and creating a meaningful STEM environment to support integrated STEM teaching and learning; ii) teachers' competencies in assisting pupils to acquire the STEM knowledge, skills, and values through inside and outside the classroom learning activities [35].

Therefore, the focus of a model STEM school with those characteristics-based OD models needs to be worked out properly. The involvement in changing the milieu is "*improving the way people work together in teams, and the way team activities are integrated with organisational goals*" [4]. As a result, the model STEM schools need leaders with visionary and collaborative leadership, competent and robust beliefs towards Integrative STEM education teachers, and solid support for STEM education parents and community.

Correspondingly, IAB has defined STEM Education leadership as the leader who sets the vision of school change as a STEM Sustainable School and inspires and mobilises school staff to progressively move the school to a better STEM implementation status. The whole organisation's involvement must lead by the school principal, who can inspire and mobilise teachers, pupils, parents, and the community to work together to improve STEM performance as the quality of the organisation rather than individual happenstances. The school principals are geared as STEM ambassadors. They are to ensure that all school activities (formal and non-formal) support STEM education. They ensure formal learning in the classroom is pupil-centred, having fun learning activities and solving real-life problems. They encourage Science and Mathematics teachers to collaborate with other subject teachers by having Professional Learning Community (PLC), pupils learning in Project-based Learning (PBL), and parental involvement in parent support groups. Schools are encouraged to collaborate within the district, states, Malaysia, and internationally (Fig.4).

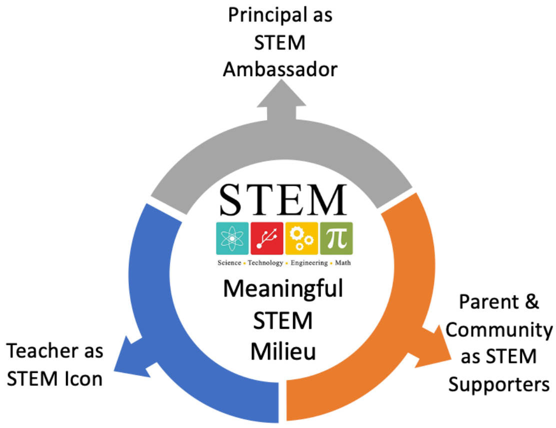

Fig. 4. Organisation Development Approach for Integrated STEM Education (Source: IAB-MoE-Proceeding of National STEM Education Leadership Colloquium in 2022)

The STEM teacher sets out as the icon and is responsible for activities in the classroom. The teacher plays a vital role in pupil learning by fostering a meaningful learning milieu. Curriculum activities involving teachers from all subjects besides Science and Mathematics are an added value for STEM education. These activities are STEM teaching and learning integrated activities involving all pupils. It adds value to strengthening the school's teaching and learning process in the formal setting. The pupil can understand the concepts and apply them to real-life applications in a conducive learning environment. Herein pupils are blended in an environment that applies the scientific method in everyday life. Critical and creative learning and challenging activities using High Order Thinking Skills (HOTS) are given priority when pupils' autonomy and collaboration are emphasised in all activities. Thus, a fun, problem-solving environment encourages pupils' computational and engineering thinking skills to grasp different sectors better.

Parents and the community as STEM supporters signify outreach activities involving parents and the community. The community comprises local government bodies, non-government organisations (NGOs), private sectors, and alums who can contribute in the form of expertise, time, and support. They are to observe and keep children curious and ready to expand enthusiasm and interest in STEM learning experiences by supporting their engagement. Pupils' curiosity and inquisitive minds about their real-life and natural environment are kept high in local community learning contexts. Thus, pupils can engage their thinking and inspire them to investigate natural phenomena.

3.1.2 Empowering Learning in STEMEC Project

STEM literacy is applying science, technology, engineering, and mathematics concepts to solve problems that cannot be solved using a single discipline [19]. Thus, STEM literacy is an outcome developed inside the student, the knowledge, skills, and attitudes they gain through STEM integrative education.

BPK [26] defines Malaysian education's STEM teaching and learning approach in Fig. 5. They delineate that knowledge in STEM education is all about ideas, theories, principles and understanding of the STEM field. Therefore, the STEM curriculum design and integration purposely cultivate pupils' knowledge, skills, values, and ethics.

This aim can be achieved through a series of classroom activities developed by teachers during the T&L process. However, Bahrum *et al.*, [2] have pointed out that Malaysian teachers faced challenges in implementing STEM integration. Therefore, teachers need continuous STEM knowledge and exposure to ensure that everybody is equipped with updated STEM knowledge [7] and development in STEM education.

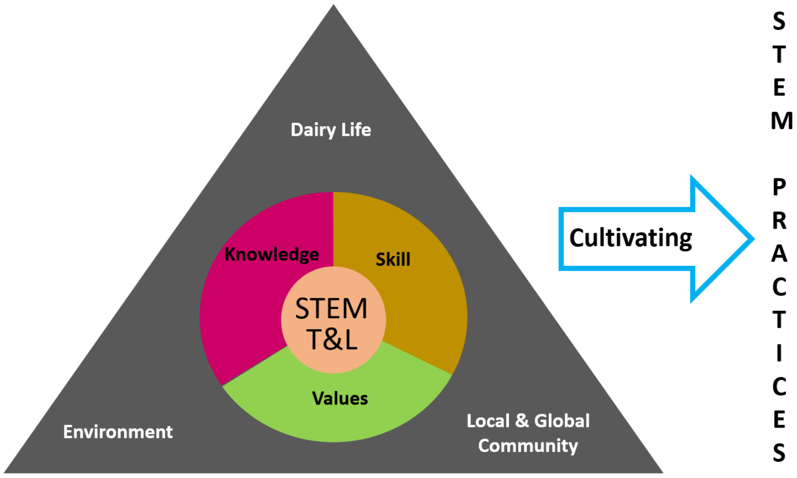

Fig. 5. STEM as a Teaching and Learning Approach (Source: BPK – MoE - Implementation Guide for Science, Technology, Engineering, and Mathematics (STEM) in Teaching and Learning, 2017)

Skills in integrative STEM education can be defined as the ability of the pupils to identify and solve the problem and design and produce a product. These skills can be developed through a series of activities and projects planned in the curriculum. There are two elements in STEM skills, i.e. process skills and technical skills.

Process skills are used in active-learning techniques that often require cognitive (higher-order thinking) and interpersonal skills (peer interaction) during class activities. The cognitive skills are:

i. computational thinking skills (information processing);
ii. mathematics thinking skills (critical thinking process);
iii. engineering design thinking skills (problem-solving approach);
iv. technical skills (manipulative & management skills in handling materials, tools and machines correctly and safely).

Interpersonal skills include interpersonal communication, teamwork, and management. Thus, process skills, known as soft skills, professional or transferable, are essential components of the learning environment in STEM classrooms [19].

On the other hand, technical skills, sometimes referred to as hard skills or manipulative skills, are the practical skills involved in completing tasks. Technical skills are the diverse specialised expertise and knowledge required to perform specific tasks and manage specific tools and machines.

Process and technical skills are the cornerstones of Malaysia's STEM ecosystem in producing STEM talent for future industry employment. Moreover, with IR 4.0, these skills are highly desirable in new hires. Therefore, pupils need these skills to apply and create new knowledge through problem-solving in integrative STEM education.

However, in reality, our teachers overly emphasise the attainment of curriculum content as the classroom's learning goal. Thus, a more explicit focus on these skills should be addressed. So, it is vital to bring forth an integrative STEM education where the pupils are engaged in hands-on and open-ended investigations about their daily real-life problems that put them at the centre of the experience and STEM learning meaningful and fun. The pupils, in turn, can cultivate STEM practices. Fig. 5.

Integrative STEM Education also indicates the importance of values and ethics for being professional STEM practitioners. The crucial values, i.e. systematics, objective, reasoning, consistent, innovative, challenging, open-minded, and others, are pertinent for the STEM practitioners in their problem-solving process. In contrast, ethical examples that should be followed are workshop rules, laboratory regulations, and safety precautions for the STEM practitioners performing hands-on STEM activities. Therefore, good morality and values must be practised during teaching and learning sessions. In addition, it is vital to have pupils who are both knowledgeable and have a good personality.

Krajcik and Czerniak [23] highlighted that project-based learning (PBL) is the pedagogical strategy that allows pupils to get higher engagement and a deeper understanding of content knowledge. Furthermore, PBL enables the consolidation of knowledge and skills from multi disciplines (different subjects) for real-time collaboration and communication. Therefore, information dissemination gear for HOTS can be managed more constructively in the classrooms guided by the teachers. Additionally, PBL allows integrative STEM Education and workflow more efficiently and effectively. Hence, the PBL STEM is proposed and piloted in the STEMEC project based on the IDEAL concept (Fig. 6) to guide school principals and teachers to support and deliver the best possible integrated STEM learning experiences for pupils. Ultimately, pupils can engage and propose their project ideas with an in-depth understanding of the world around their community that can considerably improve deep and meaningful learning.

With effective execution, the PBL guided by the IDEAL concept in integrated STEM education provides elements like:

i. integrative approach and interdisciplinary
ii. real world and contextual
iii. engineering design thinking with economic value
iv. students' autonomy with creative and critical thinking
v. curriculum coverage by adhering to standard curriculum and assessment

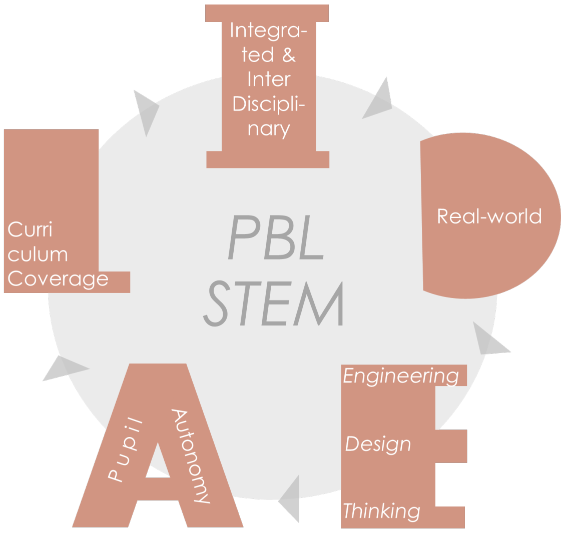

Fig. 6. PBL STEM Concept (Source: MoE- IAB Micro-Learning eModule: Fundamental STEM Education Leadership, 2022)

Interdisciplinary is crucial and coherent to give pupils the experience of working in a team collaboratively in terms of cross-disciplinary content learning and its underlying teaching, bonding to specific learning objectives. These guided classroom practices are needed as the real-world experience in STEM fields is a seamless integration of materials from different domains in the VUCA world and the development of IR 4.0 and perpetually IR 5.0. Moreover, the pupils need the entire process of scientific inquiry that requires linking several disciplines to problem-solve a real-life situation and cannot always be compartmentalised in such a tidy manner by a single discipline. The fast-changing VUCA world problems have become more and more complex. The solutions for such problems must be interdisciplinary rather than intradisciplinary or even cross-disciplinary because interdisciplinary techniques go beyond these two techniques by allowing pupils to see different perspectives, work in groups, and suggest innovation by synthesising disciplines as the ultimate goal. The interdisciplinary approach allows pupils to master higher-order thinking skills. The most crucial impact is that it leads pupils to a future of discovery and innovation [42]. However, many scholars debate whether the specific interdisciplinary technique of "team teaching" is the best approach for student progress in the classroom [21].

When preparing pupils for the real world, meaningful and authentic learning experiences in PBL are essential. When the learning materials derived from the outset fall within the scope of pupils' everyday life experience, the learning is thus meaningful [6]. Similarly, if the learning materials are no connection with pupils' real-life experience, the T&L is meaningless. Therefore, learning happens when pupils are involved in complex intellectual operations by blending prior knowledge with the desire for a concrete experience into higher-order purposeful action [6]. In short, PBL STEM learning is meaningful to pupils because they apply the knowledge to solve their concrete real-life experience problems.

Engineering design thinking encourages the pupils to have higher economic value for their innovations. Empathy helps pupils to determine the problem they need to solve is valuable because it is a real problem faced by the targeted group. Subsequently, data-driven problem identification allows the root of the problem is uncovered. Pupils are encouraged to ideate a solution based on STEM theory or disciplines because innovation is valuable when it can solve the problem effectively. Lastly, prototype testing ensures that their design is practical and satisfies the customers' needs. In short, engineering design thinking supports pupils in assessing knowledge contextually, reasoning with and evidence sense-making. Pupils are challenged to expand their knowledge with critics and innovative and creative thinking practices when their products are innovated by practising knowledge-based decisions, resulting in better economic values. Over time, pupils use engineering design thinking routines to think critically and problem-solving strategies in the complex content area. Therefore, engineering design thinking defines PBL or PBM in our project.

To prepare pupils for emerging challenges in the workplace, they must be autonomous and life-long learners. To start, in PBL STEM, pupils are given a choice to direct their learning process. The key element is the responsibility for their learning and optimally using their talent and abilities. They are given real-life problems that require decision-making. When pupils start analysing their learning strategies and making decisions, they are in control of the process of learning and thus making it more purposeful and self-directed. Autonomy in decision-making enables them to connect disparate information and execute the critics and creative thinking skills. They practise thinking skills and gauge their learning progress toward achieving intended outcomes. On top of that, pupils' PBL products are often presented as showcases in school galleries and public events. Thus, the pupils are motivated to discuss and work collaboratively with their peers in several ways.

Curriculum coverage is the crucial element of PBL STEM because the PBL must intentionally design to meet the curriculum standards. In reality, many teachers believe that PBL needs more breadth of information. Therefore, they are reluctant to employ PBL as their chosen pedagogy because they perceive PBL is unable to cover as much material as a traditional lecture-based style [1]. In PBL STEM, implementation of curriculum coverage is done by:

I. Vertically align through exploratory learning; that is, the curriculum is taught according to the same learning framework but across different years/levels, taking into account the continuity and complexity of the content. Therefore, vertical curriculum coverage needs to be planned based on the teacher's professional judgment. The vertical curriculum coverage can be implemented in one subject or across several subjects through PBL. For example, in T&L Mathematics Level 1 (years 1-3), curriculum coverage vertically for whole number topics is carried out by teaching Year 1 pupils the whole numbers up to 100, expanded to 10 000 to encourage exploratory learning and save time for T&L Year 2 & 3 for whole number topics.

II. Horizontal alignment, on the other hand, joins the curricular objectives transversely between subjects. Horizontal integration may also mean integrating basic concepts from one subject or discipline into another. Horizontal alignments enhance the mutual relations of the curriculum and the instructions of the curriculum through testing what is taught. Pupils are the primary beneficiaries of the horizontal alignment because learning changes to new environments, and they realise the importance of knowledge. For example, certain fundamental concepts in studying biology may be relevant to studying multiple disciplines, such as physical education, chemistry, Islamic study and more. Conversely, topics such as finance and ethics from other disciplines may be integrated into the study of biology. When the pupils can

Teachers should choose PBL as their T&L approach as pupils achieve equivalent competency with less instruction time [9] and stimulate profound learning [5]. Indeed, curriculum coverage is necessary, and teachers must take full advantage of vertical and horizontal integration rather than the traditional approach. Malaysian teachers are to embrace PBL as their chosen daily pedagogy approach.

3.2 The STEMEC Project Design

The STEMEC project was set up as a pilot project in 2019 under the MEB #49 Initiative: Strengthen STEM Education to build 32 model STEM schools that can provide pupils with continuous Integrative STEM learning experiences. Therefore, the project is designed by including school leaders and teachers from the same school to help them share the same understanding of integrated STEM education as the OD approach to school is maximised.

The formulation of institutional and human capital to support the organisation's change in implementing integrated STEM education is illustrated in Figure 8. The project's input is the primary and secondary schools from the program Transformation School 2025 chosen by the Daily School Management Division.

IAB initiates the staff development process of the school organisation focused on leadership, and BPK focuses on instructional in the review of managerial strategies, training and motivation for acceptance and implementation of the integrated STEM education in school organisation. The process is constituted by training and consultation in a structured and guided manner. The staff development process starts with training to improve the actors' skills and capabilities. Then, they are trained to adapt to the change continuously, which is assisted by adequate consultation activities that can assist the actors in assimilating new values and practices. This behavioural change requires adequate time for the actors to demonstrate their values and existential behaviours in a real-world situation (Fig. 7).

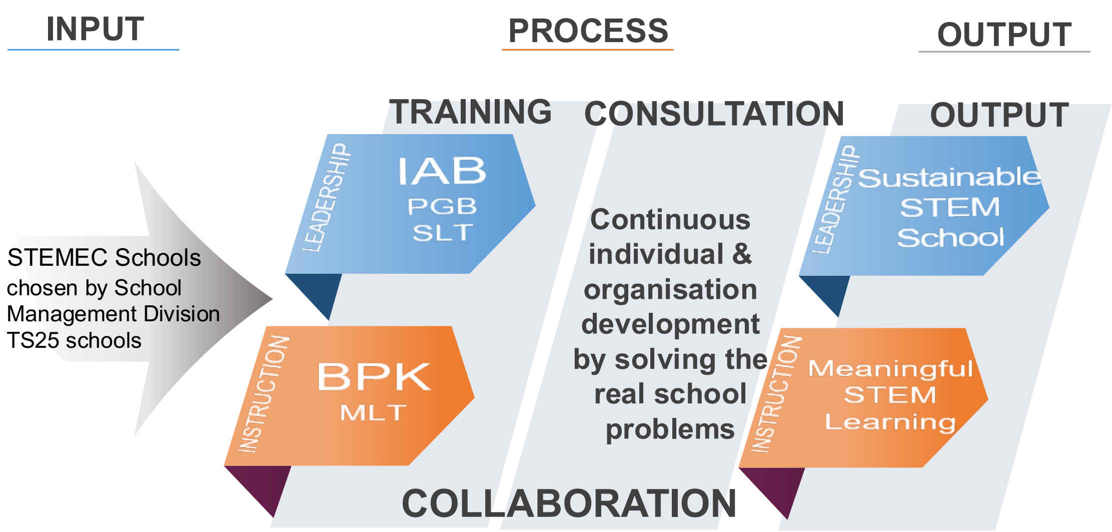

Fig. 7. STEMEC Project Design (Source: IAB-MoE-Proceeding of National STEM Education Leadership Colloquium in 2022)

The outcomes of this project will result in two aspects: the practical, Sustainable STEM school where the school leaders work collaboratively to ensure the formal, non-formal, and informal learning of integrated STEM education is happening in the school for all the pupils in their school. The second aspect is that the learnings are always meaningful to the pupils because their learning is to solve the real-world problems they identify and discover in their daily life by applying more than one STEM discipline to solve them practically and creatively. This strategy is aligned with shift 1 of the MEB 2013-2025 Blueprint, which provides equal access to quality education of an international standard by strengthening the quality of integrated STEM education.

3.3 STEMEC Instrument (Pengesanan Kepimpinan dan Pengurusan Pelaksanaan Pendidikan STEM Bersepadu di Sekolah, PKP-PPSBS)

In this project, the organisational development process is guided by an instrument: the Leadership and Management Tracking of (Integrated) STEM Education Implementation in Schools (PKP-PPSS). The instrument consists of five domains: leadership, teaching and learning, assessment, authentic assessment, co-curricular, and resources & support, which are aligned with the five objectives of the STEM project (refer to section 3.1). There are five domains, and they constitute 11 elements, as illustrated in Fig. 8.

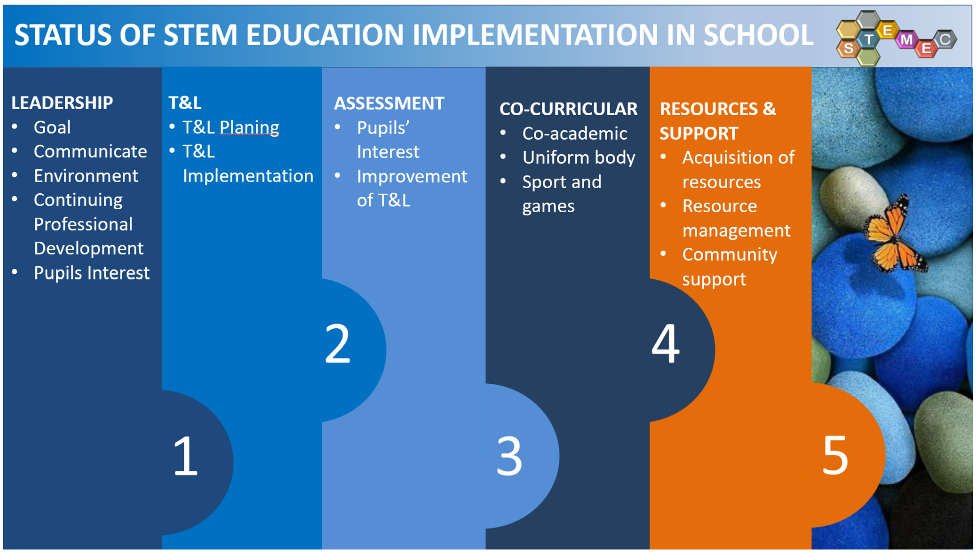

Fig. 8. Status of STEM Education Implementation in School (Source: IAB-MoE-Proceeding of National STEM Education Leadership Colloquium in 2022)

The first domain of leadership is to assist the principal and headmaster in leading the implementation of STEM education in school. It consists of five elements there are visualising the STEM goal, communicating to the whole school community to share the same goal, preparing a conducive environment to allow STEM education to be conducted, and empowering the teachers by involving in the Continuous Professional Development (CPD) activities, ensuring the school has sufficient programs to promote pupils' interest in STEM, and eventually adopting STEM profession.

The second domain, T&L, is referred to as the second objective, ensuring that the STEM approach is implemented periodically according to the school semester. Therefore, two elements are utilised by the school leaders to supervise teachers to achieve the objective: the STEM Integration planning in T&L and the implementation of STEM Integration in T&L.

The third domain is authentic assessment, referred to as the third objective, ensuring the implementation of authentic assessment in T&L. Pupils' interest has a direct relationship with their academic performance. Therefore teachers should use authentic assessment data rather than examination results to convince pupils of their ability to learn STEM subjects. The continuous low achievement in the summative assessment has contributed to the pupils' perception that they are poor in command of STEM subjects. Therefore, teachers should use authentic assessment data such as the achievement in Project-based learning and classroom assessment to demonstrate the pupils' authentic ability to learn STEM subjects which will increase pupils' interest in STEM subjects. On top of that, teachers should make use the authentic assessment data to design their T&L methods in STEM subjects is being cultivated. For example, observations, simulations, questioning, product survey, portfolio, and self-assessments are a few assessment methods used in the STEM project.

The fourth domain is ensuring STEM elements are embedded in co-curricular activities. Integrating STEM elements in the co-academic activities, the uniform body, and the sports and games provide the pupils with non-formal STEM learning experiences. The non-formal learning can enhance and complement formal integrative STEM learning by injecting fun elements into activities to create interest in STEM. In addition, the pupils are given more flexibility in content (not strictly tied to the Curriculum and Assessment Standards Document) and time for integrative STEM learning activities that foster pupils' leadership, confidence, moral values, ethics, and self-esteem.

Lastly, the fifth domain is increasing parental and community involvement in integrated STEM education to help the school attain the resources and support for implementing STEM education and the informal STEM learning that occurs away from a structured, formal classroom environment. Three elements are referred to in this domain: the acquisition of resources for the Implementation of the STEM Program, the resource management for STEM strategy implementation, and the construction of networks and networking related to STEM education.

3.4 The Result of the Pilot STEM Project

As discussed above, the efficiency of school improvement for this project is measured with the STEMEC instrument. The pilot STEMEC project's result is presented below to give some information towards the applicable and measurable of the integrated STEM education framework.

The 16 primary schools start the project with the Beginning level (mean = 2.43). By the end of 2019, they showed good improvement and achieved a mean = of 3.37 with the Developing level. Although MCO was implemented during the COVID-19 pandemic, schools still showed improvement in their STEM Education implementation, with a mean = of 4.24 and a mean = of 4.49, respectively, in the years 2020 and 2021, which brought them to the Applying level. The 16 secondary schools start the project at the Developing level (mean = 2.75). Throughout the three years, they showed improvement in implementing STEM Education with a mean = of 3.66 in the year 2019, a mean = of 4.11 in the year 2020 and a mean = of 4.33 in the year 2021, which are in Applying level. The results for both types of schools indicated that the level of implementation of STEM education is progressive development and the primary schools showed better progress than the secondary schools (Fig. 9).

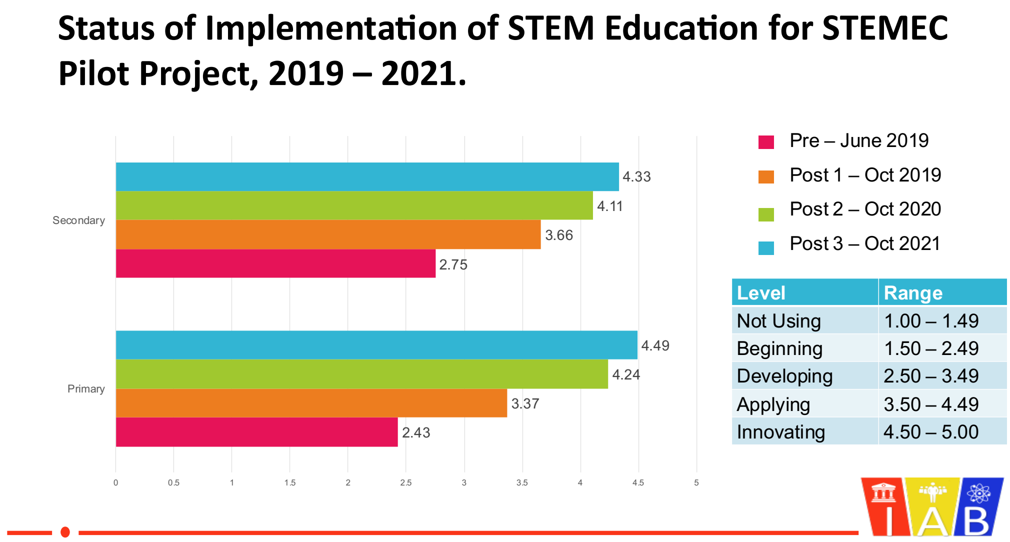

Fig. 9. The Result of the Pilot STEM Project (IAB-MoE- Speech of Closing Ceremony for The Excellent Leaders of Educational Institutions Colloquium, 2021)

3.5 Macro Professional Learning Community to Foster Continuous Improvement

Based on the result from the STEMEC project, formulating the Macro Professional Learning Community (PLC) for the school leaders as their professional development is the suggestion to foster and/or enact the continuous improvement of implementing integrated STEM education in school with the organisation development approach. The concept of Macro PLC is modified from teachers' PLC [38] by encouraging the school leaders to collectively inquire and share their practices in leading the school with a focus on system improvement of the integrated STEM education holistically. The collaborative inquiry allows the school leaders to enquire their practices and learn new and better strategies to enhance educational change at micro and macro levels. The school leaders support and work with each other, finding ways inside and outside their immediate community to enquire about their leadership practices. The Macro PLC employs the between-school improvement structure that promotes system-wide change [8] by taking advantage of the entire system's collaboration and networking [11]. The community provides opportunities for school leaders to exercise self- and collective reflection on practices to advance more interactive and richer professional learning. Besides, school leaders can mobilise a broader range of resources and expertise through networking that created by Macro PLC. Most importantly, this collaborative inquiry promotes bottom-up decision making versus autocratic top-down by putting forward the local contexts and highlighting the school leaders as prime movers to bring the STEM educational reform.

4. Conclusion

The world is getting VUCA, and technological advances have dominated our everyday lives. This rapid development of science and technology has changed the job landscape. Automation emerging from the development of IR4.0, artificial intelligence (AI), Internet of Things (IoT), machine learning, and robotics has taken over many of the routine manual jobs. Subsequently, the job sectors and employment are becoming fluid and different to keep up with change. As a result, the gap between the skills demanded the future jobs and the knowledge generated from the current education system is widening. Therefore, the need for a paradigm shift is obvious to focus on STEM that emphasises complex problem-solving skills in a real-life context, such as in-process and technical skills.

On top of that, other 21st-century skills, such as critical thinking, creativity, cultural awareness, and collaboration, are needed for future career advances. Thus, pupils with 21st-century skills who are competitive, knowledgeable, creative, and possess positive ethics can compete and generate economic growth with current work demands. For example, it is predicted that future workers will spend more than twice as much time on tasks requiring science, mathematics, and critical thinking than today. In addition, they must collaboratively solve complex problems in real-life situations and work with interdisciplinary teams. Therefore, integrative STEM education that nurtures 21st-century skills is crucial and relevant in preparing our pupils with sufficient learning experiences to allow them to become a STEM-literate workforce for nation-building.

The need to educate the school principals and all levels of teachers about integrative STEM education is clearly shown in the findings of this report. The Integrated STEM Education Framework is a workable program that allows schools to achieve progressive improvement in the implementation of STEM education. Therefore, the study needs to be replicated and expanded with a larger sample size that either examines multiple cohorts that teach the same integrative STEM education principles or incorporates more years of a single program's cohort evaluations. The researchers may then find different implementation success rates from different types of schools and leadership championing across organisations with various discipline specialisations and geography zones (rural and urban settings). The results of these studies could benefit OD planning teams as varied and more extensive audiences are their key targets.

In sum, Malaysian schools need to gear up this paradigm shift of the implementation of Integrated STEM education by integrating multidisciplinary and blending learning environments and showing pupils how the scientific method can be applied to everyday life. It teaches pupils to think and focus on the real-world applications of problem-solving. Integrative STEM learning experiences should be introduced to pupils gradually in early childhood. The application in education is also a step toward answering the challenges in the 21st century. Then, pupils have an immense capability to engage in STEM learning because of their curiosity and exploring the nature of the world. School principals and teachers are to promote pupils learning in STEM by providing more significant T&L experiential opportunities to exercise their curiosity, predict and experiment with ideas through hands-on, collaboration and open-ended play experiences in formal and non-formal settings. Parents and the community can extend the pupils' STEM explorations as they play and have fun in quality family time.

References

[1] Aldarmahi, Ahmed. "The impact of problem based learning versus conventional education on students in the aspect of clinical reasoning and problem solving." *Education in Medicine Journal* 8, no. 3 (2016).

[2] Bahrum, Suraya, Norsalawati Wahid, and Nasir Ibrahim. "Integration of STEM education in Malaysia and why to STEAM." *International Journal of Academic Research in Business and Social Sciences* 7, no. 6 (2017): 645-654.

[3] Cook, Kristen, and Sarah Bush. "Step Into STEAM: Your Standards-Based Action Plan for Deepening Mathematics and Science Learning, Grades K-5." (2019).

[4] Brown, Donald R., and Don Harvey. *An experiential approach to organization development*. Pearson Education, 2021.

[5] Dahle, L. O., Jan Brynhildsen, M. Behrbohm Fallsberg, Ingemar Rundquist, and Mats Hammar. "Pros and cons of vertical integration between clinical medicine and basic science within a problem-based undergraduate medical curriculum: examples and experiences from Linköping, Sweden." *Medical teacher* 24, no. 3 (2002): 280-285.

[6] Dewey, J., & Authentic, I. E. L. (1938). Experiential learning. New Jersey: Prentice Hall.

[7] Eckman, Ellen W., Mary Allison Williams, and M. Barbara Silver-Thorn. "An integrated model for STEM teacher preparation: The value of a teaching cooperative educational experience." *Journal of STEM Teacher Education* 51, no. 1 (2016): 8.
[8] Fullan, Michael. "System thinkers in action." *Innovation. UK. London: DfES with NCSL* (2004).
[9] Gemmell, Hugh A. "Comparison of teaching orthopaedics using an integrated case-based curriculum and a conventional curriculum: A preliminary study." *Clinical Chiropractic* 10, no. 1 (2007): 36-42.
[10] Goh, Pauline Swee-choo, and Bobbie Matthews. "Listening to the concerns of student teachers in Malaysia during teaching practice." *Australian Journal of Teacher Education* 36, no. 3 (2011): 92-103.
[11] Harris, Alma, and Michelle Jones. "Professional learning communities and system improvement." *Improving schools* 13, no. 2 (2010): 172-181.
[12] Havice, William, Pamela Havice, Chelsea Waugaman, and Kristin Walker. "Evaluating the effectiveness of integrative STEM education: Teacher and administrator professional development." *Journal of Technology Education* 29, no. 2 (2018): 73-90.
[13] Veza, Ibham, Mohd Farid Muhamad Said, Tri Widodo Besar Riyadi, Mohd Azman Abas, and Zulkarnain Abdul Latiff. "Issues in the Science and Engineering Education in Indonesia: How to Improve Competitiveness Through STEM Mastery." *International Journal of Advanced Research in Future Ready Learning and Education* 24, no. 1 (2021): 1-6.
[14] Institut Aminuddin Baki. (2021). *Speech of Closing Ceremony for The Excellent Leaders of Educational Institutions Colloquium, 2021.* Bandar Enstek: MoE.
[15] Institut Aminuddin Baki. (2022). *IAB Micro-Learning eModule: Fundamental STEM Education Leadership.* Bandar Enstek: MoE
[16] Institut Aminuddin Baki. (2022). *Proceeding of National Science, Technology, Engineering, and Mathematics (STEM) Education Leadership Colloquium in* 2022. Bandar Enstek, MoE.
[17] Ismail, Mohamad Hisyam, Muhamad Furkan Mat Salleh, and Nurul Akmal Md Nasir. "The issues and challenges in empowering STEM on science teachers in Malaysian secondary schools." *International Journal of Academic Research in Business and Social Sciences* 9, no. 13 (2019): 430-444.
[18] Israel, Maya, Kathie Maynard, and Pamela Williamson. "Promoting literacy-embedded, authentic STEM instruction for students with disabilities and other struggling learners." *Teaching Exceptional Children* 45, no. 4 (2013): 18-25.
[19] Jackson, Christa, Margaret J. Mohr-Schroeder, Sarah B. Bush, Cathrine Maiorca, Thomas Roberts, Caitlyn Yost, and Abigail Fowler. "Equity-oriented conceptual framework for K-12 STEM literacy." *International Journal of STEM Education* 8 (2021): 1-16.
[20] Jensenius A. (2012). Discpilinarities: intra, cross, multi, inter, trans. Available at: www.arj.no/.2012/03/12/disciplinarities-2 (Accessed 23 March 2022).
[21] Jones, Casey. "Interdisciplinary approach-advantages, disadvantages, and the future benefits of interdisciplinary studies." *Essai* 7, no. 1 (2010): 26.
[22] Kelley, Todd R., and J. Geoff Knowles. "A conceptual framework for integrated STEM education." *International Journal of STEM education* 3 (2016): 1-11.
[23] Krajcik, Joseph S., and Charlene M. Czerniak. *Teaching science in elementary and middle school: A project-based learning approach*. Routledge, 2018.
[24] FOI, LIEW YON, NAZERI MOHAMMAD, TEOH HONG KEAN, AZIYAH MOHD YUSOFF, and DAYANG HIRONI AWANG KIPLI. "EXPLORATORY FACTOR ANALYSIS (EFA) OF CONTROL BELIEF INSTRUMENT FOR SCHOOL LEADERS IN SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) SCHOOLS." *Global Journal of Educational Research and Management* 1, no. 2 (2021): 77-87.
[25] Ministry of Education Malaysia, (2013). *Malaysia Education Blueprint 2013-2025*. Putrajaya: MoE.
[26] Ministry of Education Malaysia, (2016). *Guide to the Implementation of Science, Technology, Engineering, and Mathematics in Teaching and Learning (Panduan Pelaksanaan Sains, Teknologi, Kejuruteraan & Matematik Dalam Pengajaran dan Pembelajaran).* Putrajaya: Division of Curriculum Development, MoE.
[27] Ministry of Education Malaysia. (2017). *Implementation Guide for Science, Technology, Engineering, and Mathematics (STEM) in Teaching and Learning*. Putrajaya: MoE.
[28] Ministry of Education Malaysia, (2018) *Report of Initiative MEB #49: Strengthen STEM Education 2017*. Putrajaya: MoE.
[29] Minister of Energy, Science, Technology, Environment and Climate Change, (2018). *The STEM Nasional Strategic Action Plan 2018-2025*. Putrajaya, Minister of Energy, Science, Technology, Environment and Climate Change.
[30] Palpanadan, Sarala Thulasi, and Venosha Ravana. "Future Trajectories in Teaching-Learning Practices for STEM Education in Malaysian Secondary Schools: A Scoping Review." *Asia Proceedings of Social Sciences* 9, no. 1 (2022): 169-170.

[31] Rozi, F., & Hanum, C. B. (2019). Pembelajaran IPA SD erbasis HOTS (Higher Order Thinking Skills) menjawab tuntutuan pembelajaran di abad 21 in Seminar Nasional Pendidikan Dasar Universitas Negeri Medan.
[32] Sanders, M. E. (2008). STEM, STEM education, STEMmania. *The Technology Teacher,* 68(4), 20-26. https://vtechworks.lib.vt.edu/handle/10919/51616
[33] Sanders, Mark E. "Integrative STEM education defined." (2013).
[34] Sanders, Mark E. "Integrative STEM education as “best practice”." Griffith Institute for Educational Research, Queensland, Australia, 2012.
[35] Shahali, Edy Hafizan Mohd, Ihsan Ismail, and Lilia Halim. "STEM education in Malaysia: Policy, trajectories and initiatives." *Asian Research Policy* 8, no. 2 (2017): 122-133.
[36] Simionescu, Timeea-Alexandra. "Management of Change in the Context of the School Organization, Development and Adaptability." *LUMEN Proceedings* 8 (2019): 131-140.
[37] Smith, Harold C. "A course director's perspectives on problem-based learning curricula in biochemistry." *Academic Medicine*77, no. 12 Part 1 (2002): 1189-1198.
[38] Stoll, Louise, Ray Bolam, Agnes McMahon, Mike Wallace, and Sally Thomas. "Professional learning communities: A review of the literature." *Journal of educational change* 7, no. 4 (2006): 221-258.
[39] Subotnik, Rena F., Robert H. Tai, Rochelle Rickoff, and John Almarode. "Specialized public high schools of science, mathematics, and technology and the STEM pipeline: What do we know now and what will we know in 5 years?." *Roeper Review* 32, no. 1 (2009): 7-16.
[40] Thibaut, Lieve, Stijn Ceuppens, Haydée De Loof, Jolien De Meester, Leen Goovaerts, Annemie Struyf, Jelle Boeve-de Pauw et al. "Integrated STEM education: A systematic review of instructional practices in secondary education." *European Journal of STEM Education* 3, no. 1 (2018): 2.
[41] Wan Husin, Wan Nor Fadzilah, Nurazidawati Mohamad Arsad, Oziah Othman, Lilia Halim, Mohamad Sattar Rasul, Kamisah Osman, and Zanaton Iksan. "Fostering students' 21st century skills through Project Oriented Problem Based Learning (POPBL) in integrated STEM education program." In *Asia-Pacific Forum on Science Learning & Teaching*, vol. 17, no. 1. 2016.
[42] Youngblood, Dawn. "Interdisciplinary Studies and the Bridging Discipline: A Matter of Process." *Journal of Research Practice*3, no. 2 (2007): 1-8.