MALAYSIAN ONLINE JOURNAL OF EDUCATIONAL MANAGEMENT (MOJEM)

OCTOBER 2023, VOLUME 11, ISSUE 4, 63 - 91
E-ISSN NO: 2289 – 4489

SUSTAINABILITY EDUCATIONAL LEADERSHIP AND MANAGEMENT FOR STEM-BASED APPROACH: AN EXPERT QUALITATIVE FORMULIZATION

Mohd Razip Bajuri[1]*, Nor Syazwani Mohd Rasid[1], Roslizam Hassan[2] & Sabariah Aman[3]

[1]
Department of Mathematics and Science Education,
Faculty of Education,
Universiti Malaya
Kuala Lumpur

[2]
School of Education,
Faculty of Social Sciences and Humanities,
Universiti Teknologi Malaysia
Johor Bahru

[3]
Institut Pendidikan Guru
Kampus Pendidikan Islam
Bangi

Corresponding Author:
Department of Mathematics and Science Education,
Faculty of Education,
Universiti Malaya
Kuala Lumpur

E-mail:

razip.bajuri@um.edu.my

ABSTRACT

The success of STEM-based teaching in a school is a continuous effort requiring full support and commitment of all teachers regardless of the school's leaders. Teachers' role as instructional leaders is essential in providing a meaningful learning experience to the students. This objective of this study is to formulate a STEM-based educational leadership and management concept to direct schools to support STEM education goals. A qualitative research approach was employed, specifically a case study involving the expertise of seven researchers from various disciplines within the educational STEM fields. There are four themes with several elements respectively identified to sustain leadership and management of STEM-based teaching using logic-ontology, resulting in the Cohen Kappa coefficient index at 0.86. The four themes are Motivational Leadership in STEM-based Approach (STEM-ML), STEM-based Academic Leadership (STEM-AL), STEM-Thinking Leadership (STEM-TL), and Technological Changing Leadership (STEM TCL). These themes are pivotal in influencing the sustainability of interdisciplinary research to foster national and societal development as per the formulated framework. Consequently, the concept of STEM sustainability leadership and management holds utmost significance, as it ensures the development's sustainability on social, emotional, economic, and environmental fronts. However, this formulization is developed by limited participants. Thus, it is recommended to validate this framework using a wide range of samples. Moreover, this study holds broad implications for STEM leadership and management on STEM-based practice for specific field expertise. The concept aims to provide a significant contribution to the growth of comprehensive, holistic, and sustainable development and to extend the current literature on STEM-based research leadership and management.

Keywords: **STEM Leadership, STEM Management, STEM Sustainability Leadership, STEM-Based Research**

INTRODUCTION

The Malaysian Ministry of Education has revised the country's education system and developed a long-term planning strategy with a primary focus on STEM education due to Malaysia's lagging performance in TIMSS and PISA in 2011. Hence, the Ministry of Education Malaysia has taken immediate initiatives by developing the Malaysian Education Blueprint (MEB) 2013-2025 to address this decline issue (Ministry of Education, 2013a). The latest percentage of students' enrolment in STEM stream in higher institution also decreasing from 33.5% in 2018 to 31.8% in 2021 (Kementerian Pendidikan, 2021). It shown that the target of 60% STEM students by 2030 still far to achieve. At the meantime, Science, Technology, Engineering, and Mathematics (STEM) education is seen as an essential element in equipping students to meet future needs and is often considered a way to enhance a nation's global competitiveness (ITEA, 2009). The STEM education reform movement is driven by various research findings indicating a shortage of adequately prepared workforce in technology-related fields in various developing and advanced countries, including Malaysia. STEM was initially introduced in the United States due to a decline in results in mathematics and science in 2001. Previously, the goals of emphasizing STEM education in United States initially are to increase the talent pool through improving K-12 science and mathematics education; to sustain and increase long-term basic research related to the economy, security, and quality of life; to increase the attractiveness of the United States to recruit and retain the best and brightest scientists and engineers in the world; and to increase incentives for innovation (Committee on Science Engineering and Public Policy, 2007). According to Reeve (2015), STEM education could provide a country like Malaysia with three kinds of intellectual capital, which nurturing scientists and engineers who drive ongoing research and development as the core to the economic growth of a country, equipping technologically proficient workers who are capable of dealing with the demands of a science-based, high-technology workforce, and fostering scientific literacy among citizens who make intelligent decisions about public policy and who understand the world around them.

The above goals of STEM education are still reflected in the current objectives of STEM enhancement in MEB, which is to prepare students with knowledge, skills, and values in the STEM fields to increase the number of experts in STEM and drive the country's economic growth. Thus, Malaysia needs a diverse and skilled workforce from all genders and races who excel in science and engineering and are interested in pursuing STEM careers to remain globally competitive (Curriculum Development Division (CDC), 2016). Implementing integrated STEM education within the curriculum represents persistent efforts to achieve the objectives (Kementerian Pendidikan Malaysia, 2016). It is widely acknowledged that the quality leadership and management could make a significant difference to school and students' outcomes (Bush, 2007). It is shown that influential leaders and managers are recognized to provide the best possible education for their learners. Besides that, Bolman & Deal (2021) highlight the significance of according to equal importance to both leadership and management in developing and maintaining successful education systems and achieving their objectives.

Consequently, effective leadership and management are imperative in sustaining excellence in STEM-based teaching, thus facilitating to achieve the STEM education objectives, and there are three main narratives to be adopted as educational practice by students, teachers, and educational leadership. The content of the educational leadership narrative highlights a bottom-up leadership style that needs to replace the traditional top-down leadership approach. Subsequently, leadership practices have transitioned into a distributive leadership style that is now due to be implemented. This leadership pattern can enhance teachers' motivation levels, thereby transforming and improving teacher performance by providing opportunities for teachers to collaborate and contribute to decision-making within the organization (Kementerian Pendidikan Malaysia, 2018), especially in STEM education.

The enhancement of STEM education as emphasizes in MEB is being pursued through three distinct phases: Wave 1 (2013-2015): This phase involved in enhancing the quality of STEM education, Wave 2 (2016-2020): The second phase to create interest and awareness of STEM within community, and Wave 3 (2021-2025): The current phase is to elevate STEM education to a state of excellence by introducing operational flexibility improvements. The practice

of distributive leadership has begun to take root among teachers and school leaders, serving as a primary focus in the second wave implementation of STEM enhancement (Ministry of Education, 2013b). During this phase, leadership and management, including teachers and school administrators, are responsible with engaging the community and collaborating with relevant organizations to promote STEM education.

As academic experts and practitioner communities are still comprehending what STEM entails, individuals and groups have assumed various leadership and management roles to successfully implement STEM in schools. (Natarajan, Tan & Teo, 2021) found some key foundational enablers from leadership and management to ensure teaching and learning function smoothly. Among the keys are school leaders' facilitation of staff development, opportunities for collaboration, leaders' modelling practice, autonomy, support for risk-taking, participatory decision-making, STEM instructional leaders' support, and a culture of trust and respect.

Furthermore, Adam (2019) underlined that as teachers act, educational leadership and management should prioritize meaningful teaching approaches. The meaningful teaching approaches to implement integrated STEM education should involve higher-order thinking, creativity aspects, critical thinking, reasoning, and thinking skills. Hence, teaching approaches such as inquiry-based, problem-based, project-based, and collaborative teaching could sustain STEM education in Malaysia (Bahagian Pembangunan Kurikulum, 2016). Since STEM-based teaching has its characteristics to implement, leaders must understand each discipline's unique characteristics and apply them to build a synergistic platform to magnify the similarities and harness the differences for learning. Therefore, sustainable leadership and management specifically in STEM-based teaching are critical to ensure the agenda's continuity and success.

PROBLEM STATEMENT

The purpose of integrated STEM education is to provide students with a meaningful learning experience through formal or informal learning. Subsequently, the deep learning experience should be provided by teachers though the curriculum and co-curriculum activities. This comprehensive approach requires the full participation of teachers and students which driven by school leaders who embrace the STEM educational leadership and set the change vision of the school as a STEM Sustainable School. Nevertheless, teachers often find it challenging to implement STEM-based teaching due to different understanding of integrated STEM, whether monodisciplinary or integrated (Natarajan et al., 2021), as they must ensure that students' performance in assessments remains uncompromised. While some studies have examined student learning outcomes and STEM lessons (Han et al., 2015; Hansen & Gonzalez, 2014), there have been limited direct measures of specific STEM knowledge and skill sets. Although STEM leadership may provide department heads and teachers with permission and top-down support for STEM implementation, they may lack the necessary resources, such as materials and expertise, to implement their intended version of STEM fully, often compromising with a simplified version and hindering the assessment of STEM implementation outcomes.

In addition, teachers need to collaborate with colleagues across different disciplines when conducting STEM-based teaching. However, teachers face constraints in working collaboratively with colleagues (Le et al., 2021), lack of time (Adam & Halim, 2019; Jekri & Han, 2020; Le et al., 2021), and structural scheduling barriers (Adam & Halim, 2019). STEM-based teaching demands adjustment of the current school organization, including timetabling, professional development, collaboration, and fostering a culture of continuous learning. This refers to school and teachers' leadership and management in planning and directing their curriculum and instruction through teamwork. Teachers should collaborate and teach in teams to overcome school's structural limitations (Tan et al., 2019). This collaboration needs school leaders to grant time and space for the teaching team to discuss, participate in professional dialogue, exchange knowledge, and share ideas.

Besides that, STEM-based teaching involves decision-making among teachers and students (Sutaphan & Yuenyong, 2019). Teachers are observed actively involved in decision-making processes in schools, to contribute to professional

development of others, share their expertise with their peers, and are autonomous in making decisions in their works called as teacher leadership (Leithwood & Jantzi, 2000; Mokhlis et al., 2019). Meanwhile, the decision-making stage for students is during engineering design process incorporated into STEM-based teaching. During this stage, students can designate what they think it is an importance, and among them in the group must make the decision together. Additionally, students will apply all relevant knowledge and carefully consider factors to choose appropriate solutions.

Instructional reforms education like the enhancement of STEM-based teaching especially depends on teacher leaders' capacity, and teacher themselves to implement any new approach and help colleagues to understand how it fits with their values, skills, and expertise. In practice, however, when teachers are recruited into leadership roles, they often find the work to be fraught with ambiguities and tensions (Leithwood & Jantzi, 2000). The school's principal or headmaster and teachers shared and led the change vision to the organisation community by enacting a STEM ambassador towards the whole school community. Leadership and management from school leaders and teachers plays a vital role to enable the implementation of integrated STEM education coherently and holistically, as organisational development is supported by individual development (Yon Foi & Hong Kean, 2022).

Previous studies related to the leadership and management's roles in achieving education goals are focused on school leaders (principal or headmasters) and its administration (Al Rosid & Mukarromah, 2020; Hamzah et al., 2020; Shafee & Ismail, 2020; Wan Othman & Salim, 2020). This situation illustrates that the school's leadership role can only be seen by superiors to their subordinates. Nonetheless many teachers perform various leadership tasks, like school leaders in school administration. Given the limited research on principal and teacher leadership specifically for integrated STEM, current ideas of leadership and management form the basis of our best thinking about what leadership and management for STEM might look like. Therefore, there is a question about whether teacher leadership in teaching and facilitation can influence the achievement of a school's goals, successful STEM-based teaching particularly. This paper attempts to develop a conception of leadership and management to sustain STEM-based teaching.

Aims and Objectives of Study

This article aims to develop an expert qualitative formulation for sustainability educational leadership and management in STEM-based approach. Specifically, the research objectives of this article are:

1. to investigate the themes of leadership and management to sustain STEM-based teaching.
2. to identify the linked elements in the theme of leadership and management to sustain STEM-based teaching.

In line with the research objectives, the research questions are:

- What are the themes of leadership and management to sustain STEM-based teaching?
- What are the elements associated within the themes of leadership and management to sustain STEM-based teaching?

METHODOLOGY

Research Design

This study employed a qualitative case study to formulate the sustainability educational leadership and management for STEM-based approach. A methodological arrangement was design to frame a single case (Yin, 2016) in one faculty with different departments to portray narrative of educational leadership among participants using a qualitative data collection protocol which consists of: a. set of semi-structured interview question; b. document analysis checklist; and c. observation checklist. The formulization was rooted on the main data (interview transcript) and support by other two types of data (participants STEM activities and supported document in the form of article and

report). Data saturation point by assuming that there were no new emerging elements emerges amongst the boundaries was perform on the number of selected participants (7 participants) (Creswell & Poth, 2018).

Sampling Technique

The samples of this study were seven researchers from various STEM fields selected based on their experience, practitioners, and contributions in high impact research and articles related to leadership and management of STEM-based teaching. The participants are labelled as P1, P2, P3, P4, P5, P6, and P7. The selection of P2 to P7 according to the recommendations of two participants from previous participant. For example, recommended the next two participants (P2 and P3). This technique was repeated by the following participants recommendations as shown in Figure 1. The seven participants undergone a depth-interview session (verbal data collection) and sharing their STEM-based teaching documents for further analysis (concrete evidence).

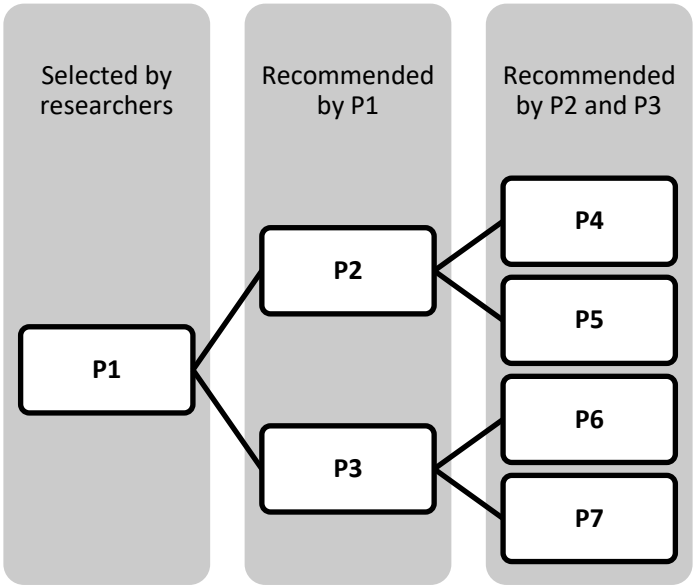

Figure 1. *Participants Selection*

Data Analysis

A depth-interview was conducted with each of the seven participants. A digital device was used to record audio during the interviews, and then each recorded file was copied into a computer. Each interview takes from 90 minutes to 120 minutes. After the interview, each section was named with a specific code for the information on the Excel sheet. Qualitative categorization from data was carried out to formalize where thematic analysis is used to analyse the data. Participant's verbal data were transcribed and the ideas about driving factors on sustainability STEM-based leadership and management, respected elements for all themes were formulated from the interview transcript based on word interpretation into an abstract phrase. Abstract words will represent and demonstrate the situation or phenomena. These abstract phrases are used as a starting point from which other statements can logically be categorized as elements. Based on this rule, the interpretations that construct the STEM-based leadership and management formulation with their elements were cross-checked amongst participants to avoid individual misinterpretations or over interpretation.

All themes with their elements were triangulated with a secondary source data which is the participant's documents record. This process was carried out by cross-checking all the emerging themes and elements

with respective participant's document. Formulization of the themes and the relationship with their elements were carried out by applying a logical ontological relationship to link all themes to their respected elements.

Then, the Cohen Kappa is utilized to evaluate the level of agreement of the themes based on the following formula:

$$K = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)}$$

Where Pr(a) is the actual observed agreement, and Pr(e) is the chance agreement (McHugh, 2012). Table 1 shows the interpretation of Cohen's Kappa.

Table 1: *Interpretation of Cohen's Kappa (McHugh, 2012)*

Value of Kappa	Level of Agreement	% of Data that are Reliable
0-.20	None	0-4%
.21-.39	Minimal	4-15%
.40-.59	Weak	15-35%
.60-.79	Moderate	35-63%
.80-.90	Strong	64-81%
Above .90	Almost Perfect	82-100%

FINDINGS

Demographic Profile

The findings are formulized to four themes: STEM-Thinking Leadership (STEM-TK), STEM-Motivational Leadership (STEM-ML), STEM-Academic Leadership (STEM-AL), and STEM-Technological Management Leadership (STEM-TCL). Each theme has its own two to five elements as shown in Figure 2.

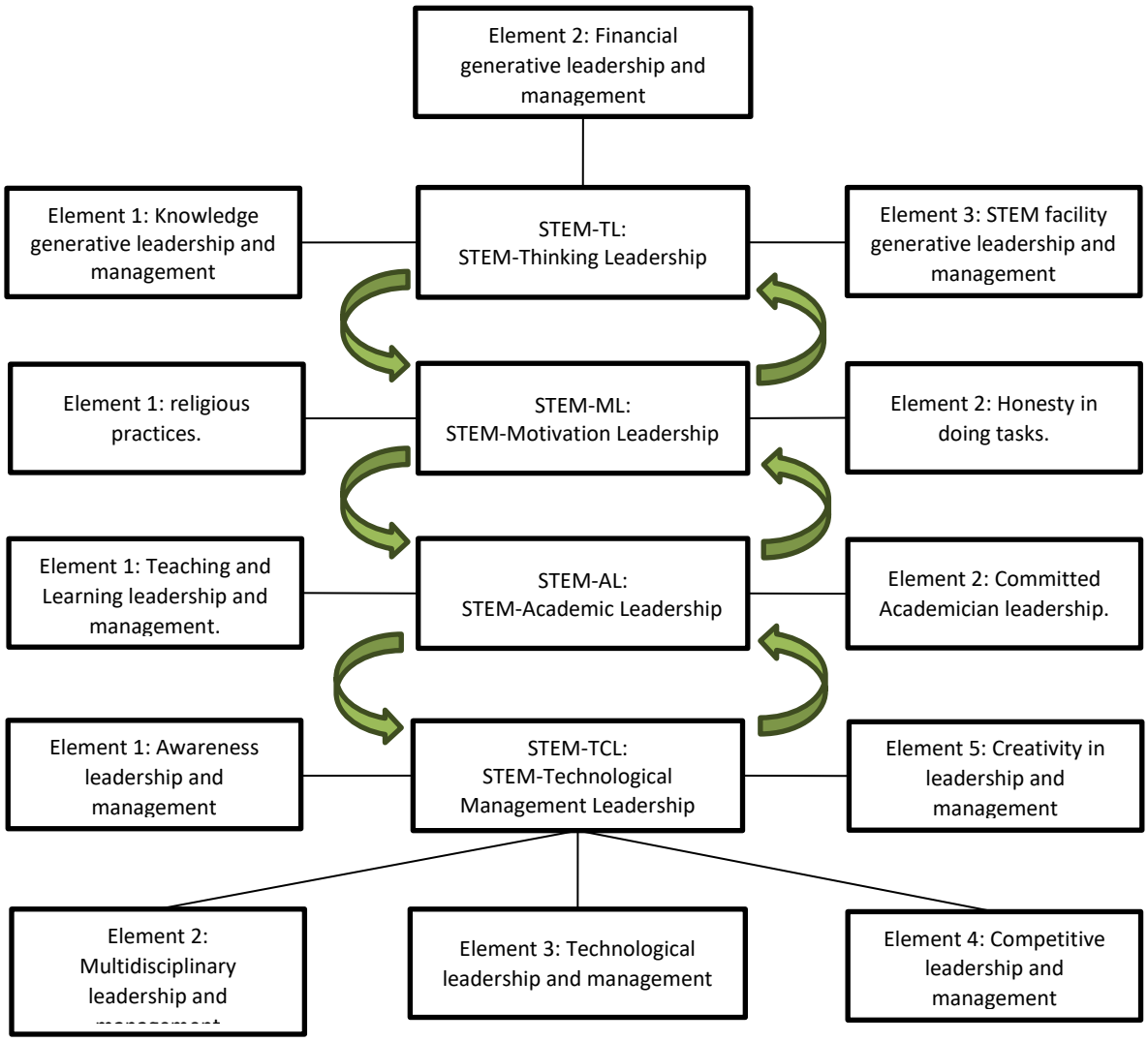

Figure 2. *Formulation of Sustainability Educational Leadership and Management for STEM-based Approaches*

The flow of sustainability leadership and management for an educational institution is formulated based on the data obtained from interview transcription. The findings show that to manage and lead in STEM based educational institution successfully is by enhancing the ability to of colleagues on school's STEM program for the benefit of students and promote development of new technology. Each four themes with its elements will be explained as follows:

5.1 Theme 1: STEM-Thinking Leadership

STEM teachers should have STEM-Thinking leadership to conduct STEM-based education. There are three elements in STEM-TL, namely: Knowledge generative, Financial, and STEM facility leadership and management.

5.1.1 Element 1: Knowledge Leadership

Successful STEM-based education leaders should have a mindset toward creating and overseeing the generation of new knowledge. These elements emerge from P1 (1-140) in the context of producing new mathematical model in new methods and understanding of problem solving for mathematical model:

"...there is a method...I know that method...people don't use that method, they only solve one equation...but I'm in the field of fluid...I have an equation, maybe two or three equations...but he has a couple...can't solve one to one... he had to solve three times...no one has ever done that..." 8:50
"...we get a new equation...after that we model it...if we remove certain terms that we added...we can get the model as the first person who we refer..." 8:63
"...mathematician is always over thinks... I want to find an expression that X is equal to...what is the mathematical expression...we can't find because we always turn back..." 8:65

P1 describes STME-TL as having the characteristics of giving good examples to colleagues and students to explore new knowledge in many aspects. In addition, P1 and P2 stated that a STEM-educational leader should always encourage colleagues and students to overcome teaching and learning difficulties. Leading and managing an institution to start STEM-based knowledge activities should emphasize the high ability of scientific theory and high problem-solving (1-068). The participants use mathematical modeler as an example the needs to know the basic theory on solving complex systems (excerpt 2:106) (excerpt 8:49):

"The best is...my friend who work on bio-medical engineering in UM... they don't develop models, they only do experiments, put the experiments into the software, they just analyze use software, get results, then he just discusses his results, but for me, I'm a mathematician…and I always need to look on what is the theory behind that….I always tell my students, we..."2:106

"...he's the one who first made this basic...he no need to so many input...it was very simple...and he manage to publish it in a famous journal...everyone read it...and let other people do their job to continue...the basic idea is there..." 8:49

5.1.2 Element 2: Financial Leadership and management

Financial leadership and management element can be shown when participants explain how they find external financial support institution for their project (12:17; 3:14, 8:44; and 11:13). These quotations indicate clear involvment of external institution on supporting financial on conduting STEM based activities. For P4 and P5, they share expertise with others on the knowledge they have to solve real situation, and these is an advantage to seek external financial support to do STEM-based activity. Figure 3 shows a collaboration on STEM-based activity using external financial support.

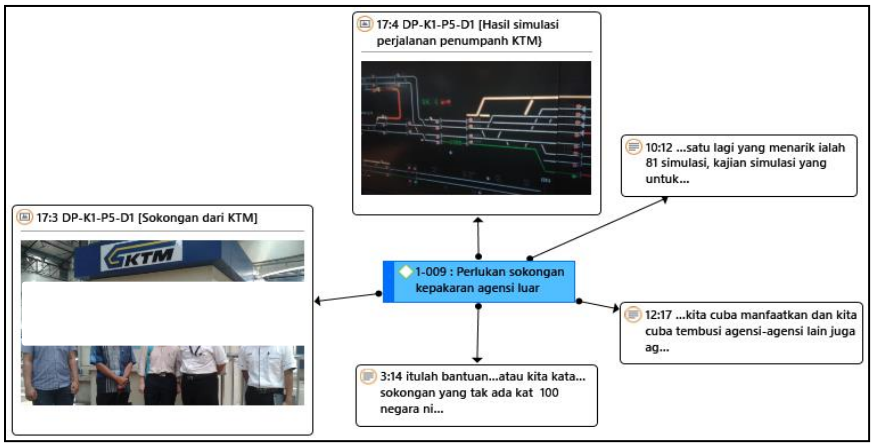

Figure 3. *Collaboration of STEM-based activity from Atlas.ti analysis*

"...we try to make use our output…and we try to penetrate other agencies as well, so that we can use it...we share our knowledge and expertise…and this is the remark that I enjoy the most…we got support from KTMB and MITI..." 12:17

Besides financial support they are also receive others technical and expertise and facilities support to make sure development process of the STEM-based activities can be sustain:

"...we need support...especially expertise and facilities that is not available in our country...because based on my experience in oversea...we can easily get customized part for a special purpose of our project…it not happened here…we quite difficult to get any company to fabricate a special used part or prototype…3:14

Support in the form of financial from agencies interested in STEM-based education and activities for developing for a project is also a main method of collaboration that normally being done. This was stated by almost all participants:

"...we need research grant...mathematics is hard to get...when I came back in 2000...as far as I know, there were no lecturers here get any grant, it was after 2000 that they got grants...from the government...it used to be called IRPA...but they didn't accept...because we are mathematicians and for them math is just kind of basic..." 8:44

Equipment is a basic element to support developing STEM-based activities and teaching approaches. The equipment can be in the form of a computer system for data processing and database system access facility that can provide important and useful data for a real and authentic activities:

"In terms of equipment...from the grant we can get...I'm more into algorithms...so more on full power machine...computer. If we need a lab, we will work with biologists, or like PM10, we will get data from certain parties... that's how it is." 11:13

1.1.1 Element 3: STEM Facility Management and Leadership

Managing and leading schools for STEM-based education cannot be escaped from the elements of providing facility. These elements are interpreted from excerpts 7:83, 8:75, 9:50, 10:43 and 11:12. The necessary facilities can be types of financial for activities and task development, technological equipment such as computer systems that can accommodate a lot of data processing capabilities, collaboration with various government and private institution, and parents such as illustrated in passage 7:83, 8:75, 9:50,10:43 and 11:12:

"...started doing my project in solar energy...the first stage is indeed is a insiders challenge for...even asking for grants people don't want to give...people refuse...I used to present not even single question...he has friends who are professors who evaluate him, right...I asked him if he had any questions...he said no...I was inside too...he asked all kinds of questions...when he came out he could get but not me...but for solar energy I sit on the panel..." 7:83

"Emm...basically that's the thing...first of all the ability...that's the main thing...our thinking ability...the others are the equipment...the administration is the second thing...the challenge I think is the grant...research grant ...mathematics is hard to get..." 8:75
"...we have external institution who gave us finance support...if they didn't give us finance, wouldn't run our project...the current situation every STEM based project actually needs money..." 9:50
"Preparation if we get funds, of course...sometimes students face financial problems, so we too, if we have seen a study, there is a student, we can let him know that we can apply for funds, that is another thing apart from training write to get research funds, students also know...oh these are apparently the conditions." 10:43

"...now it's hard to work alone…we need students...we also need to control our own emotion...and then financial support...that's the first thing to look that give influence...we need financial support...that is it which we must first find." 11:12

1.2 Theme 2: STEM-Motivational Leadership

Second theme called as STEM-ML. Teachers should have two important elements, which are religious practices and honesty in completing the tasks.

1.2.1 Element 1: Religious practices

The concept of sustainability educational leadership and management in STEM-Based approaches can be formulated to element of providing strength and encouragement for teacher and students to face challenges and barrier in conducting STEM-based challenges. These must be done by cultivating religious practices in everyday life and can be seen from participants when they are highlighting on the responsibility to fulfilments of religious ordered such as performing five times daily prayers (1-112), being honest in duties (1-076), building inner strength (1-117) and setting the goals of our everyday work to gain God's blessed. Elements 1-112 interpreted from passage 3:92 from participant K1 indicate these situations where prioritizing five times prayer as the important daily task to be carried out to overcoming and handling difficulties. This religious practice can build a strength to face and manage other task difficulties in their career:

"...so, I'm trying to hold on that concept...when I have...we need Allah...it's a long time...when we have a meeting...I said...you want you to be happy, don't you?...okay we go for pray...can stop and we leave the meeting room for pray...why can't we leave meeting for prayer...so I just say that..." 3:92

1.2.2 Element 2: Honesty in doing tasks

The element of honesty in carrying out duties is also an element that is demanded in religion and it is also the important element for enhance self and organization management. For participant K1, applying the element of honesty to students can be considered as an aspect that needs to be prioritized in carrying out a learning activity related to science and mathematics. This is interpreted from the passage 3:50 in a situation where he instructs students to carry out an assignment:

"...I've already given you instructions that if you open the internet, you're not being honest with yourself...I will not know...but you're not being honest, it's not the best, isn't it..." 3:50

From these case, caltuvating of inner strength for educational leadership and management to face a challenge can be done by following a religious way of life. These elements should be practise for schools leaders in their management to leads teachers and students when enforcing to carrying out of challange task such as implementation of STEM-based approach. For participants K1, building strength in teachers and students can be done in everyday teachers proffesion such as to keep punctuality and performing religious orders. This should be done to obtain god blassed for smoothness in doing all matters in all aspects in carrying out every work task as stated in excerpts 3:90 and 3:91:

"...one more thing from the Islamic point of view...try to pray on time in congregation...that's it...God willing everything else will be clear...we take care of what God tells us...God takes care of us..." 3:90
"...so far I feel...I feel those values if we delay...what is...his concept is easy for me to say like this...if we want to defecate...don't we delay?..." 3:91

1.3 Theme 3: STEM Academic Leadership (STEM-AL)

Manage and lead his team to try and doing new things as early as they can in doing a task indicate that participants were a leader who always want to the fiest. The character of earnestly doing the task (2-46) is interpreted from excerpt 8:42 from participants P1. These can be seen from this quote when he recounts that he can usually complete a certain task quickly and:

"...ohh I made it quickly...then I just gave it to the student...that's why I told the student to make it...right...I was satisfied I thought one night...I used to be unmarried again...bring it back home...I'll bring it back to my work house..." 8: 42

1.3.1 Element 1 : Commited Leadership

Manage to be commited leadership according to P5 is the element of being focus in career and it should be realizing in every task to promote interest in what we do, for example P5 these is an important elemet in he always carrying out when compleating modeling task involving multidisciplines as interpreted from the passage 10:52 as below:

"...some people are committed...if they are committed, it's good...what i mean is if he or she no interest, it could be change their interest...interest can be nurtured later, these type of person sucesses, but my style, i ask, if he said I'm like that...it will be ok. For me do things first...at first I don't know...but soon I will be interested..." 10:52

From passage 10:52, comitmen in doing tasks can be shown by focusing behavior in doing tasks. The focus can also foster interest in a certain field which can be interpreated from the statement 4-08. Relating with STEM based integration it will also involving the element of coordination of various expertise which can be interpreted from the passage 9:54 and 9:55:

"The main obstical is limited time for a task...some times we look it as unfair situation...but I assume it as challange... because beside teaching we have a lot of other work... many other tasks... we teach, we do research, writing, supervision students...all we have to do..." 9:54

"we have lectures work...we have a publication work...we have to write...at the same time we have to do a project sosial project...so that was the main obstacle...we have an involvement with the community...go out there and enter rural schools..." 9: 55

1.3.2 Element 2: Teaching and Learning Management and Leadership

Teaching and learning management and leadership in STEM based approach is the element where others lecturer or teachers could follow the technique and steps. For example, they are encouraged to teach their students to follow the right principles and procedures in science, mathematics, and technology when they are performing STEM based activities. These can be indicated from passage 1:74 and passage 1:76. The quote states that mathematical modelling for example needs to be built according to certain steps and cannot skip steps. Among the steps is sketching and giving a definition from a free-body diagram of a phenomenon to be studied:
"...have to do that first...some people keep jumping...do the PhD right...do the complicated one...after that you're stuck...that's the problem...not following the steps right...we walk before we run, right..." 1:74
"Haa...he has steps...because in modeling we see wather you good at modeling or not...we look at some model first...what does the models tell us...then need to draw what are the things you want to model...you can't jump...later you will stuck...because you didn't do the basics first...don't keep doing the real stuff..." 1:76

Managing a modeling task using element of sketching idea on a solution (1-161) is interpreted from quotes 1:100 and 8:22. The quote shows the importance of sketching an idea to publish a mathematical equation for a

phenomenon:

"...in modelling we need to describe what is the phenomena we want to study…from this step you need to figure out the idea of the phenomenon...in a sketch diagram. We need to consider some assumptions...sometimes people don't know..." 1:100

"I always ask my student…what have you sketched; did you get the idea...what are the boundaries line...horizontal...fluid on top...you need to draw...it cannot suddenly an equation...you can't say…oh Navier-Stokes equation. This is the boundary condition...where is the diagram? I said...it must come from a diagram...in our brains there is a picture, right...not directly an equation..." 8:22

Management and Leadership in teaching and learning using STEM based approach cannot be escaped from the elements of real situation task problems (1-029). These indicators were interpreted from the quote's participants P2, P4 and P1. From excerpt 4:69, participants P4 said real situational problems can be used as modelling problems that can integrate STEM disciplines, for example the meaning of financial management and so on:

"Ha...start with everyday real-world problems...for example like sometimes how we manage our funds...money right...we try to do it in the form of programming...ha like that...and then only simple things...just let our students think... programming is not just for solving math problems...that's just steps is it..." 4:69

According to K3-P1 participants, normally students are good in programming, but they are still not good in using that knowledge to solve problems in real situations.

"...these students are good at programming...but they don't know where to use it... when I want to introduce technology, there is the issue...they need a lot of exposure...so my technique is…which is a real problem outside... so we will look for real issues that happen outside...real problem..." 9:22

For P2 participants, the ability to solve problems in real situations is important especially to facing the work environment. Therefore, it is important to manage and lead to train students to be able to solve daily problems well:

"Ha...start with daily problems...like sometimes how he manages funds to money...money right...we try to do it in the form of programming...ha like that...and then only simple things really...just want him to think... programming is not just for solving math problems...that's the way it is...for example..." 4:69

According to K3-P1, students are usually skilled in programming and so on, but they are still not skilled in using that knowledge to solve problems in real situations:

"...so these students are good at programming...but they don't know where to use it...so this technology, when I want to introduce technology, there is an issue...for him to have programming, he needs a lot of exposure...so I have technique, which is a real problem outside... so we will look for real issues that happen outside...real problem..." 9:22

For P2 participants, the ability to solve problems in real situations is important especially for facing the work environment. Therefore, it is important to train students to be able to solve daily problems well:
"... I always talk to my students... when I give you the equation you must solve, there is indeed a solution... but if you work later... you have a real problem, you I don't know what the solution is..." 2:11

Management and Leadership in teaching and learning using STEM based approach also need to train teachers and students to be a good decision-maker (8-24). This is interpreted from quotes 3:38 and 3:81 from participants K1. Based on these quotes, there are some characteristics of decision-making in the context of applying in STEM-based approach in teaching and learning task conducting by participants:

"...in medical, we need to know how many scapula's to use...how long... that's deep math right...then he needs to know blood pressure...we need to decide" 3:38

"...when we give you exercise, it is not given to you whether you do or not...but it is for you to look...yes, that means you know what to do...right...and how to do it...right..." 3:81

Encouraging the ability to correct the findings of previous study is an important element (1-238) to manage and lead in teaching using STEM based approach. It was found from participants P1. Through passage 8:58, participant recounted an incident in which he was able to detect an error in a study that had been conducted through an article that had been published. Through this ability, he re-corrects the mathematical model that has been produced before developing it into a new model:

"...sometimes he does the skill out...I have found...the researcher I found an unexpected result...when I was doing the PhD...so my supervisor said we cover the result...okay...first recover the result...we already have the basis...after that I changed the technique...and I manage to publish a paper…the problem was previous researcher use wrong sign…I use a negative sign...so I use the method, I can get results when I correcting the sign...so my supervisor satisfied with me...i use two different methods I have the same result...the person has it if he uses what is in his paper...he got the result...we have checked and checked there is indeed a mistake... " 8:58 and 8:59

"...the other said his research is over...but he's not even sure who's right...a researcher is always like that...being defensive when people say he's wrong...but I think westerners aren't not like that..." 8:60

"Okay...we usually look at key papers, study properly, we have to recalculate, all the sign…can it be be reproducible with other method...it's like we do an experiment...the results must be able to be repeated...if other people copy it, what set of data does he have? Is all do the same?" 8:62

Management and leadership in teaching and learning using STEM based approach need to be a focus in discipline focus (2-28), and this element is interpreted from quotes 4:88, 9:34 and 10:50. The quotes show that there is an element of focus in our own field expertise, but we need to know a bit others discipline. Both focus points are important in the process of disciplinary integration. In the context of focusing on our fields discipline, quote 4:88 from participant P4 for example says that he only focuses on her field of programming even though integration involves various fields:

" I give you example, like programming...I used to have an intelligent system course...it's true that I'm interested in that...I focus more on that...and then I'm more...that's like there's no limitation...it's like I asked more-more...I want to know more...compare the ordinary ones...but my focus is only in machine learning…it is two different things "4:88

"...I weak in chemistary...I don't know a single thing about chemistary..." 9:34

In the context of focusing on what is being done, participants P5 stated that focusing on what is being done is by training and train our patient to be directed to what is to be done:

"...sometimes we don't even understand what we read, we will experience that situation...because we are thinking about other things...actually the brain goes to other things, you can't concentrate on what are you doing if you keep thinking others' problems..."10:50

Management and leadership in teaching and learning using STEM based approach also will involve the element of design knowledge (1-022). This element exists from participants K3-P1 through passage 9:37. The quote talks about his experience working as an engineer designing Air-Cond systems. It illustrates that design knowledge is essential in various contexts, whether in conducting STEM learning tasks or in STEM-related task fields. It serves as a tool to realize an idea generation:

"...after finishing ITM I worked in a consultancy company, at that time I was appointed an engineer straight

away...designing Air-Cond systems with fire prevention systems...for buildings...so I worked there for a year and eight months there...so I feel that design thinking is an important thing when we involve STEM-based career " 9:37

Finally, Management and leadership in teaching and learning using STEM based approach should be able to create work environment that could support (1-001) STEM-based activities. This element was interpreted from P2 through passage 3:89 and P5 in passage 10:49. Work environmental support could come from colleagues, students and parants. They can give their support by mentoring in carrying out STEM-based activities:

"...then another support from colleagues, people we respect...they support us, or even our wife's children are happy...he gives support...then with that...aaa...we have strength..." 3:89

"...but you have to remember, parents play important roles..." 10:49

Mentoring (1-035) is interpreted from the passage 8:17, which is to explain and provide encouragement to know the STEM field to the outside community:

"...for the school I'll show them more examples...I'll show them pictures...picture of fluid dynamics..." 8:71
Based on elements discussed, sustainability in management and leadership in teaching and learning using STEM based approach covers all aspects to support STEM-based activities to be successfully implemented. The categorized elements are then tabulated Table 4.10.

1.4 Theme 4: Technological Leadership (STEM-TL)

1.4.1 Element 1: Lead and manage for Technology Development Awareness

Being an aware on technological development person (1-038) is the element a leader should have to conducting STEM base approach. This element is interpreted from excerpt 2:119 from participants P2. According to P2 a leader should be trained to be alert on observing a technological phenomenal change and should have a principle to faced problem using and developing for new technology. These elements were delegated to the teacher and students especially when handling STEM activity. For example, solving the equation that needs to be solved by assist of computer software, errors in doing observations of a phenomena can cause a mathematical model to be programmed incorrectly. This will cause the result obtained to be incorrect or inaccurate. This is told in the passage 2:119:

"...the danger is for a student who wants to take shortcut, he uses the software, but he doesn't know what he wants, what he knows is keeps getting graded...but he doesn't know what it is, right...for example, orientation...if he doesn't know the orientation, he just plays in... the result will be reversed... for example, the person walks backwards but he just keeps entering the value... because he has a very weak theory, right, he doesn't know the result..." 2:119

1.4.2 Element 2: Multidisciplinary Management and Leadership

Multidiciplinary management and leadership in these case study emerge by the indicator of participant's involvement to manage and guide multidisciplinary research (1-247) using mathematical modelling. Most of the participants states that using STEM integration, one can improve multidisciplinary abilities. This can be interpreted in from quotes 10:15 and 10:16 from P5:

"Besides that, there is also a study on forensics, in forensic study involves community and police, there is modeling, indeed each study has its mathematics and its model, because this is statistics, it involves statistics..." 10:15

"...for example in the recognition of firearm patterns, yes, we have done a study on the recognition of firearms, so

how do we translate that image into mathematics, into numbers, yes, we can actually translate the image, for example, on the casing of the bullet..."10: 16

In this case study, mathematical modelling is a solving tool to solve other decipline problems such as Physics, Engineering and forensics. The element of the ability to integrate all dicipline together require multidicipline management and leadership (1-126) in order for a project to sucessesfull. This element is interpreted from the passage 4:28 explaining that mathematical model can be produced through observing the changes in a system. The ability to write equations of change is important. These things allow a correct picture to be given of a phenomenon. A good mathematical model can produce something useful for example in the form of artificial intelligence:

"...based on the previous data, we can generate a mathematical model based on the change...according to the pattern...that's the simplest...what's a little complicated, we include other factors...economic factors to price factors..." 4:28

1.4.3 Element 3: Technological Management and Leadership

Technological management and leadership elements from this study emerge when exist indicator of the ability to produce new technology in terms of models that can be commercialized or patented (1-138). From the interviews conducted, there is data that can be interpreted to show the ability to produce an innovation that can be commercialized which also has the potential to be patented. The quotes are 9:68, 9:69, 9:70 and 10:21:

"...Ortho-knee is ready, Ortho-Hip is being made...Ortho-Knee is being patented...and is being trademarked...it has to be used at Hospital University B... now Hospital University B will use it for two years...if two years Hospital University B says okay, we will announce it to other hospitals..." 9:68

"...so, this time it's a suggestion from him...we make it, we build it and then we sell it to people...when people ask us, we say we've been using it for two years...ha, right...people are convinced, right...we make it, we use it...we don't make it we tell others to use..." 9:69

"...but now I thank God I already have five patterns...but if other people have dozens...I only have a few...five patterns..."9:70

"We were informed that it is possible to make a patent, but we haven't done it yet, we haven't got that patent yet, we are moving towards the pattern because it is enough to meet the features to get a patent, our product is only limited to software." 10:21

A STEM-based leader should manage an institution to encourage for produce products or idea of product. Based on the interview there is an element for product development using STEM-based approach. Participant P1 who produced a software to facilitates medical students learning has design a product using Computers Aided Design (CAD) for imaging purpose that can be used for surgical in hospitals:

"...simple Computer Aided Design, we made our own program, for high school students to draw, this high school is in the first, second, third grade at the time, we want them to feel drawing using a mouse, this in the subject of creative design...so create this...we actually managed to send this to all technical schools in the Selangor area..." 9:3
"...another is in the processes for IP...intellectual properties...but I this item is not to be sold in the market...it's small item that can be used in hospital…" 9:71

"...the result is very good; it can be accepted in the ISI journal…it has attracted many people in conference…so many people are also interested about moment in gunfire…we have produced a program to identify identical gunfire for forensic used…" 10:25

A STEM-based leader should manage and lead on the development of production ideas which can be transfer to consumer products such as stating by K1 in 10:36:

"The important thing of course is that we want to understand what we want to do, right? If the idea comes from us, then it's okay, because we already understand, because sometimes students don't understand what they want then they give-up...so we must guide how they can get the result…but in forensic, student knows what the goal is they can develop…may be a database for ink identification in Malaysia…" 10:36

1.4.4 Element 4: Competative Management and Leadership

Management and Lead to be competitive (2-21) are also among the elements that can be categorized in sustainability for STEM implementation. From these case study the competitive characteristic is the result that can be interpreated from P1 and K1. In excerpt 3:30, participants K1 stated that they would try to compete in various contexts, from self-management contexts to contexts involving research:

"...I really don't like other people to come first...haha...haha...you can understand that...I must be the first to open the fence or turn on the lights...haha, I want to do that...haha...but now I can't fight...Prof . Isaac is early..." 3:30

P1 also have the same principles in carrying out a task. Through the passage 8:34 he explains that he is competing in publishing an article about research on mathematical models of fluid mechanics:
"... because I once submitted a paper... This professor is just that... because I don't think he is a fluid person... he is a numerical person... when I send it, I can get him as a referee, right... after that my paper He reviewed it for a long time... maybe he kept it... he is a method expert... so when he sees that I have that equation..." 8:34

1.4.5 Element 5: Leadership and Management in Creativity

From the perspective of educational leadership, creativity (1-018) is one of the important elements that can motivate someone to implement STEM based approach in schools. There are several characteristics of creativity that can be interpreted from various data sources. One of the aspects that represent these elements is the teacher's ability to produce creative method dan technique in presenting new finding and teach to students such as stated by P1. From the quote 5:48 practicing creative teaching representation can be a unique way to attract students to learn and explore new knowledge:

"We found that the effects of the controller are more pronounced, especially at the subcritical values of R = 24.9 (R < Rc2 = 27.78) and R = 63 (R < Rc2 = 65.01) which can be used to restrain chaotic behavior in a thermal convection loop and sustain unidirectional flow"5:48

Based on the collected data, there are also elements of leadership and management that encourage students to articles writing. From this case, leaders have promoted their subordinates to write books. This element was taken from P1 when he tells his career experience as an academic. A book can be written from the result their involvement in STEM-based field. For example, the books write by P1 are books that illustrate how he sees the existence of science, technology, engineering, and mathematics and how humans should interact with such knowledge:

"...in the end I wrote a lot of these books...for example like this...Science Thauhidic...and this book tries to put science in the position of knowledge...and this is my experience of how we interact with the Al-Quran...the touch of the Al-Quran to scientists...how Al-Quran touches us..." 7:28 (P1)

"Just a paper... just to be able to get out... for PhD students... God willing... but we don't want to stop at the self-book... right... if we can we want to do it... make it... my student alhamdulillah... he not only produced a thesis, but

he produced a book from his thesis..." 12:24 (P3)

The production elements of article P2 are also interpreted from quotes 9:59, 9:61, 10:69 and 11:27. These elements can be said to exist in all participants. This is because it is a criterion that must be met as an academic:

"...the journal is for people who are in our field, right...journals, conferences really have to be done...if I am the KPI, he must have five journals a year...the ISI journal..." 9:59

"My first article...I sent it to the Straits Times...News Straits Times...my first one is a story frame...an article like this...I bought a frame at my house...so I can say...for the children...this is the first article..." 9:61.

"Then we also wrote an article, in the newspaper not yet, some friends also asked us to write, in the University B magazine we explained the impact, which like KTM was sent in the IMPAK magazine, which means that KTM is working..." 10:69.

"Okay...if among scholars we present at a conference, or publish a paper...only academics will read it, and only academics will attend the conference, right...that's the way we convey it..." 11:27

All emerging themes under the concepts of sustainability STEM educational leadership and management with the respective elements and sources of data triangulation are presented in Table 2. The consistency of data triangulation from different sources (interview responses, observations, and documents) shows consistency and reliability of some of the elements.

1.4.6 Element 3: STEM Facility Management and Leadership

Managing and leading schools for STEM-based education cannot be escaped from the elements of providing facility. These elements are interpreted from excerpts 7:83, 8:75, 9:50, 10:43 and 11:12. The necessary facilities can be types of financial for activities and task development, technological equipment such as computer systems that can accommodate a lot of data processing capabilities, collaboration with various government and private institution, and parents such as illustrated in passage 7:83, 8:75, 9:50,10:43 and 11:12:

"...started doing my project in solar energy...the first stage is indeed is a insiders challenge for...even asking for grants people don't want to give...people refuse...I used to present not even single question...he has friends who are professors who evaluate him, right...I asked him if he had any questions...he said no...I was inside too...he asked all kinds of questions...when he came out he could get but not me...but for solar energy I sit on the panel..." 7:83

"Emm...basically that's the thing...first of all the ability...that's the main thing...our thinking ability...the others are the equipment...the administration is the second thing...the challenge I think is the grant...research grant ...mathematics is hard to get..." 8:75
"...we have external institution who gave us finance support...if they didn't give us finance, wouldn't run our project...the current situation every STEM based project actually needs money..." 9:50
"Preparation if we get funds, of course...sometimes students face financial problems, so we too, if we have seen a study, there is a student, we can let him know that we can apply for funds, that is another thing apart from training write to get research funds, students also know...oh these are apparently the conditions." 10:43
"...now it's hard to work alone…we need students...we also need to control our own emotion...and then financial support...that's the first thing to look that give influence...we need financial support...that is it which we must first find." 11:12

1.5 Theme 2: STEM-Motivational Leadership

Second theme called as STEM-ML. Teachers should have two important elements, which are religious practices and honesty in completing the tasks.

1.5.1 Element 1: Religious practices

The concept of sustainability educational leadership and management in STEM-Based approaches can be formulated to element of providing strength and encouragement for teacher and students to face challenges and barrier in conducting STEM-based challenges. These must be done by cultivating religious practices in everyday life and can be seen from participants when they are highlighting on the responsibility to fulfilments of religious ordered such as performing five times daily prayers (1-112), being honest in duties (1-076), building inner strength (1-117) and setting the goals of our everyday work to gain God's blessed. Elements 1-112 interpreted from passage 3:92 from participant K1 indicate these situations where prioritizing five times prayer as the important daily task to be carried out to overcoming and handling difficulties. This religious practice can build a strength to face and manage other task difficulties in their career:

"...so, I'm trying to hold on that concept...when I have...we need Allah...it's a long time...when we have a meeting...I said...you want you to be happy, don't you?...okay we go for pray...can stop and we leave the meeting room for pray...why can't we leave meeting for prayer...so I just say that..." 3:92

1.5.2 Element 2: Honesty in doing tasks

The element of honesty in carrying out duties is also an element that is demanded in religion and it is also the important element for enhance self and organization management. For participant K1, applying the element of honesty to students can be considered as an aspect that needs to be prioritized in carrying out a learning activity related to science and mathematics. This is interpreted from the passage 3:50 in a situation where he instructs students to carry out an assignment:

"...I've already given you instructions that if you open the internet, you're not being honest with yourself...I will not know...but you're not being honest, it's not the best, isn't it..." 3:50

From these case, caltuvating of inner strength for educational leadership and management to face a challenge can be done by following a religious way of life. These elements should be practise for schools leaders in their management to leads teachers and students when enforcing to carrying out of challange task such as implementation of STEM-based approach. For participants K1, building strength in teachers and students can be done in everyday teachers proffesion such as to keep punctuality and performing religious orders. This should be done to obtain god blassed for smoothness in doing all matters in all aspects in carrying out every work task as stated in excerpts 3:90 and 3:91:

"...one more thing from the Islamic point of view...try to pray on time in congregation...that's it...God willing everything else will be clear...we take care of what God tells us...God takes care of us..." 3:90
"...so far I feel...I feel those values if we delay...what is...his concept is easy for me to say like this...if we want to defecate...don't we delay?..." 3:91

1.6 Theme 3: STEM Academic Leadership (STEM-AL)

Manage and lead his team to try and doing new things as early as they can in doing a task indicate that participants were a leader who always want to the fiest. The character of earnestly doing the task (2-46) is interpreted from excerpt 8:42 from participants P1. These can be seen from this quote when he recounts that he can usually complete

a certain task quickly and:

"...ohh I made it quickly...then I just gave it to the student...that's why I told the student to make it...right...I was satisfied I thought one night...I used to be unmarried again...bring it back home...I'll bring it back to my work house..." 8: 42

1.6.1 Element 1 : Commited Leadership

Manage to be commited leadership according to P5 is the element of being focus in career and it should be realizing in every task to promote interest in what we do, for example P5 these is an important elemet in he always carrying out when compleating modeling task involving multidisciplines as interpreted from the passage 10:52 as below:

"...some people are committed...if they are committed, it's good...what i mean is if he or she no interest, it could be change their interest...interest can be nurtured later, these type of person sucesses, but my style, i ask, if he said I'm like that...it will be ok. For me do things first...at first I don't know...but soon I will be interested..." 10:52

From passage 10:52, comitmen in doing tasks can be shown by focusing behavior in doing tasks. The focus can also foster interest in a certain field which can be interpreated from the statement 4-08. Relating with STEM based integration it will also involving the element of coordination of various expertise which can be interpreted from the passage 9:54 and 9:55:

"The main obstical is limited time for a task...some times we look it as unfair situation...but I assume it as challange... because beside teaching we have a lot of other work... many other tasks... we teach, we do research, writing, supervision students...all we have to do..." 9:54

"we have lectures work...we have a publication work...we have to write...at the same time we have to do a project sosial project...so that was the main obstacle...we have an involvement with the community...go out there and enter rural schools..." 9: 55

1.6.2 Element 2: Teaching and Learning Management and Leadership

Teaching and learning management and leadership in STEM based approach is the element where others lecturer or teachers could follow the technique and steps. For example, they are encouraged to teach their students to follow the right principles and procedures in science, mathematics, and technology when they are performing STEM based activities. These can be indicated from passage 1:74 and passage 1:76. The quote states that mathematical modelling for example needs to be built according to certain steps and cannot skip steps. Among the steps is sketching and giving a definition from a free-body diagram of a phenomenon to be studied:
"...have to do that first...some people keep jumping...do the PhD right...do the complicated one...after that you're stuck...that's the problem...not following the steps right...we walk before we run, right..." 1:74
"Haa...he has steps...because in modeling we see wather you good at modeling or not...we look at some model first...what does the models tell us...then need to draw what are the things you want to model...you can't jump...later you will stuck...because you didn't do the basics first...don't keep doing the real stuff..." 1:76

Managing a modeling task using element of sketching idea on a solution (1-161) is interpreted from quotes 1:100 and 8:22. The quote shows the importance of sketching an idea to publish a mathematical equation for a phenomenon:

"...in modelling we need to describe what is the phenomena we want to study…from this step you need to figure out the idea of the phenomenon...in a sketch diagram. We need to consider some assumptions...sometimes people don't know..." 1:100

"I always ask my student…what have you sketched; did you get the idea...what are the boundaries line...horizontal...fluid on top...you need to draw...it cannot suddenly an equation...you can't say…oh Navier-Stokes equation. This is the boundary condition...where is the diagram? I said...it must come from a diagram...in our brains there is a picture, right...not directly an equation..." 8:22

Management and Leadership in teaching and learning using STEM based approach cannot be escaped from the elements of real situation task problems (1-029). These indicators were interpreted from the quote's participants P2, P4 and P1. From excerpt 4:69, participants P4 said real situational problems can be used as modelling problems that can integrate STEM disciplines, for example the meaning of financial management and so on:

"Ha...start with everyday real-world problems...for example like sometimes how we manage our funds...money right...we try to do it in the form of programming...ha like that...and then only simple things...just let our students think... programming is not just for solving math problems...that's just steps is it..." 4:69

According to K3-P1 participants, normally students are good in programming, but they are still not good in using that knowledge to solve problems in real situations.

"...these students are good at programming...but they don't know where to use it... when I want to introduce technology, there is the issue...they need a lot of exposure...so my technique is…which is a real problem outside... so we will look for real issues that happen outside...real problem..." 9:22

For P2 participants, the ability to solve problems in real situations is important especially to facing the work environment. Therefore, it is important to manage and lead to train students to be able to solve daily problems well:

"Ha...start with daily problems...like sometimes how he manages funds to money...money right...we try to do it in the form of programming...ha like that...and then only simple things really...just want him to think... programming is not just for solving math problems...that's the way it is...for example..." 4:69

According to K3-P1, students are usually skilled in programming and so on, but they are still not skilled in using that knowledge to solve problems in real situations:

"...so these students are good at programming...but they don't know where to use it...so this technology, when I want to introduce technology, there is an issue...for him to have programming, he needs a lot of exposure...so I have technique, which is a real problem outside... so we will look for real issues that happen outside...real problem..." 9:22

For P2 participants, the ability to solve problems in real situations is important especially for facing the work environment. Therefore, it is important to train students to be able to solve daily problems well:
"... I always talk to my students... when I give you the equation you must solve, there is indeed a solution... but if you work later... you have a real problem, you I don't know what the solution is..." 2:11

Management and Leadership in teaching and learning using STEM based approach also need to train teachers and students to be a good decision-maker (8-24). This is interpreted from quotes 3:38 and 3:81 from participants K1. Based on these quotes, there are some characteristics of decision-making in the context of applying in STEM-based approach in teaching and learning task conducting by participants:

"...in medical, we need to know how many scapula's to use...how long... that's deep math right...then he needs to know blood pressure...we need to decide" 3:38

"...when we give you exercise, it is not given to you whether you do or not...but it is for you to look...yes, that means

you know what to do...right...and how to do it...right..." 3:81

Encouraging the ability to correct the findings of previous study is an important element (1-238) to manage and lead in teaching using STEM based approach. It was found from participants P1. Through passage 8:58, participant recounted an incident in which he was able to detect an error in a study that had been conducted through an article that had been published. Through this ability, he re-corrects the mathematical model that has been produced before developing it into a new model:

"...sometimes he does the skill out...I have found...the researcher I found an unexpected result...when I was doing the PhD...so my supervisor said we cover the result...okay...first recover the result...we already have the basis...after that I changed the technique...and I manage to publish a paper…the problem was previous researcher use wrong sign…I use a negative sign...so I use the method, I can get results when I correcting the sign...so my supervisor satisfied with me...i use two different methods I have the same result...the person has it if he uses what is in his paper...he got the result...we have checked and checked there is indeed a mistake... " 8:58 and 8:59

"...the other said his research is over...but he's not even sure who's right...a researcher is always like that...being defensive when people say he's wrong...but I think westerners aren't not like that..." 8:60

"Okay...we usually look at key papers, study properly, we have to recalculate, all the sign…can it be be reproducible with other method...it's like we do an experiment...the results must be able to be repeated...if other people copy it, what set of data does he have? Is all do the same?" 8:62

Management and leadership in teaching and learning using STEM based approach need to be a focus in discipline focus (2-28), and this element is interpreted from quotes 4:88, 9:34 and 10:50. The quotes show that there is an element of focus in our own field expertise, but we need to know a bit others discipline. Both focus points are important in the process of disciplinary integration. In the context of focusing on our fields discipline, quote 4:88 from participant P4 for example says that he only focuses on her field of programming even though integration involves various fields:

" I give you example, like programming...I used to have an intelligent system course...it's true that I'm interested in that...I focus more on that...and then I'm more...that's like there's no limitation...it's like I asked more-more...I want to know more...compare the ordinary ones...but my focus is only in machine learning…it is two different things "4:88

"...I weak in chemistary...I don't know a single thing about chemistary..." 9:34

In the context of focusing on what is being done, participants P5 stated that focusing on what is being done is by training and train our patient to be directed to what is to be done:

"...sometimes we don't even understand what we read, we will experience that situation...because we are thinking about other things...actually the brain goes to other things, you can't concentrate on what are you doing if you keep thinking others' problems..."10:50

Management and leadership in teaching and learning using STEM based approach also will involve the element of design knowledge (1-022). This element exists from participants K3-P1 through passage 9:37. The quote talks about his experience working as an engineer designing Air-Cond systems. It illustrates that design knowledge is essential in various contexts, whether in conducting STEM learning tasks or in STEM-related task fields. It serves as a tool to realize an idea generation:

"...after finishing ITM I worked in a consultancy company, at that time I was appointed an engineer straight away...designing Air-Cond systems with fire prevention systems...for buildings...so I worked there for a year and eight months there...so I feel that design thinking is an important thing when we involve STEM-based career " 9:37

Finally, Management and leadership in teaching and learning using STEM based approach should be able to create work environment that could support (1-001) STEM-based activities. This element was interpreted from P2 through

passage 3:89 and P5 in passage 10:49. Work environmental support could come from colleagues, students and parants. They can give their support by mentoring in carrying out STEM-based activities:

"...then another support from colleagues, people we respect...they support us, or even our wife's children are happy...he gives support...then with that...aaa...we have strength..." 3:89

"...but you have to remember, parents play important roles..." 10:49

Mentoring (1-035) is interpreted from the passage 8:17, which is to explain and provide encouragement to know the STEM field to the outside community:

"...for the school I'll show them more examples...I'll show them pictures...picture of fluid dynamics..." 8:71
Based on elements discussed, sustainability in management and leadership in teaching and learning using STEM based approach covers all aspects to support STEM-based activities to be successfully implemented. The categorized elements are then tabulated Table 4.10.

1.7 Theme 4: Technological Leadership (STEM-TL)

1.7.1 Element 1: Lead and manage for Technology Development Awareness

Being an aware on technological development person (1-038) is the element a leader should have to conducting STEM base approach. This element is interpreted from excerpt 2:119 from participants P2. According to P2 a leader should be trained to be alert on observing a technological phenomenal change and should have a principle to faced problem using and developing for new technology. These elements were delegated to the teacher and students especially when handling STEM activity. For example, solving the equation that needs to be solved by assist of computer software, errors in doing observations of a phenomena can cause a mathematical model to be programmed incorrectly. This will cause the result obtained to be incorrect or inaccurate. This is told in the passage 2:119:

"...the danger is for a student who wants to take shortcut, he uses the software, but he doesn't know what he wants, what he knows is keeps getting graded...but he doesn't know what it is, right...for example, orientation...if he doesn't know the orientation, he just plays in... the result will be reversed... for example, the person walks backwards but he just keeps entering the value... because he has a very weak theory, right, he doesn't know the result..." 2:119

1.7.2 Element 2: Multidisciplinary Management and Leadership

Multidiciplinary management and leadership in these case study emerge by the indicator of participant's involvement to manage and guide multidisciplinary research (1-247) using mathematical modelling. Most of the participants states that using STEM integration, one can improve multidisciplinary abilities. This can be interpreted in from quotes 10:15 and 10:16 from P5:

"Besides that, there is also a study on forensics, in forensic study involves community and police, there is modeling, indeed each study has its mathematics and its model, because this is statistics, it involves statistics..." 10:15

"...for example in the recognition of firearm patterns, yes, we have done a study on the recognition of firearms, so how do we translate that image into mathematics, into numbers, yes, we can actually translate the image, for example, on the casing of the bullet..."10: 16

In this case study, mathematical modelling is a solving tool to solve other decipline problems such as Physics, Engineering and forensics. The element of the ability to integrate all dicipline together require multidicipline

management and leadership (1-126) in order for a project to sucessesfull. This element is interpreted from the passage 4:28 explaining that mathematical model can be produced through observing the changes in a system. The ability to write equations of change is important. These things allow a correct picture to be given of a phenomenon. A good mathematical model can produce something useful for example in the form of artificial intelligence:

"...based on the previous data, we can generate a mathematical model based on the change...according to the pattern...that's the simplest...what's a little complicated, we include other factors...economic factors to price factors..." 4:28

1.7.3 Element 3: Technological Management and Leadership

Technological management and leadership elements from this study emerge when exist indicator of the ability to produce new technology in terms of models that can be commercialized or patented (1-138). From the interviews conducted, there is data that can be interpreted to show the ability to produce an innovation that can be commercialized which also has the potential to be patented. The quotes are 9:68, 9:69, 9:70 and 10:21:

"...Ortho-knee is ready, Ortho-Hip is being made...Ortho-Knee is being patented...and is being trademarked...it has to be used at Hospital University B... now Hospital University B will use it for two years...if two years Hospital University B says okay, we will announce it to other hospitals..." 9:68

"...so, this time it's a suggestion from him...we make it, we build it and then we sell it to people...when people ask us, we say we've been using it for two years...ha, right...people are convinced, right...we make it, we use it...we don't make it we tell others to use..." 9:69

"...but now I thank God I already have five patterns...but if other people have dozens...I only have a few...five patterns..."9:70

"We were informed that it is possible to make a patent, but we haven't done it yet, we haven't got that patent yet, we are moving towards the pattern because it is enough to meet the features to get a patent, our product is only limited to software." 10:21

A STEM-based leader should manage an institution to encourage for produce products or idea of product. Based on the interview there is an element for product development using STEM-based approach. Participant P1 who produced a software to facilitates medical students learning has design a product using Computers Aided Design (CAD) for imaging purpose that can be used for surgical in hospitals:

"...simple Computer Aided Design, we made our own program, for high school students to draw, this high school is in the first, second, third grade at the time, we want them to feel drawing using a mouse, this in the subject of creative design...so create this...we actually managed to send this to all technical schools in the Selangor area..." 9:3
"...another is in the processes for IP...intellectual properties...but I this item is not to be sold in the market...it's small item that can be used in hospital…" 9:71

"...the result is very good; it can be accepted in the ISI journal…it has attracted many people in conference…so many people are also interested about moment in gunfire…we have produced a program to identify identical gunfire for forensic used…" 10:25

A STEM-based leader should manage and lead on the development of production ideas which can be transfer to consumer products such as stating by K1 in 10:36:

"The important thing of course is that we want to understand what we want to do, right? If the idea comes from us,

then it's okay, because we already understand, because sometimes students don't understand what they want then they give-up...so we must guide how they can get the result…but in forensic, student knows what the goal is they can develop…may be a database for ink identification in Malaysia…" 10:36

1.7.4 Element 4: Competative Management and Leadership

Management and Lead to be competitive (2-21) are also among the elements that can be categorized in sustainability for STEM implementation. From these case study the competitive characteristic is the result that can be interpreated from P1 and K1. In excerpt 3:30, participants K1 stated that they would try to compete in various contexts, from self-management contexts to contexts involving research:

"...I really don't like other people to come first...haha...haha...you can understand that...I must be the first to open the fence or turn on the lights...haha, I want to do that...haha...but now I can't fight...Prof . Isaac is early..." 3:30

P1 also have the same principles in carrying out a task. Through the passage 8:34 he explains that he is competing in publishing an article about research on mathematical models of fluid mechanics:
"... because I once submitted a paper... This professor is just that... because I don't think he is a fluid person... he is a numerical person... when I send it, I can get him as a referee, right... after that my paper He reviewed it for a long time... maybe he kept it... he is a method expert... so when he sees that I have that equation..." 8:34

1.7.5 Element 5: Leadership and Management in Creativity

From the perspective of educational leadership, creativity (1-018) is one of the important elements that can motivate someone to implement STEM based approach in schools. There are several characteristics of creativity that can be interpreted from various data sources. One of the aspects that represent these elements is the teacher's ability to produce creative method dan technique in presenting new finding and teach to students such as stated by P1. From the quote 5:48 practicing creative teaching representation can be a unique way to attract students to learn and explore new knowledge:

"We found that the effects of the controller are more pronounced, especially at the subcritical values of R = 24.9 (R < Rc2 = 27.78) and R = 63 (R < Rc2 = 65.01) which can be used to restrain chaotic behavior in a thermal convection loop and sustain unidirectional flow"5:48

Based on the collected data, there are also elements of leadership and management that encourage students to articles writing. From this case, leaders have promoted their subordinates to write books. This element was taken from P1 when he tells his career experience as an academic. A book can be written from the result their involvement in STEM-based field. For example, the books write by P1 are books that illustrate how he sees the existence of science, technology, engineering, and mathematics and how humans should interact with such knowledge:

"...in the end I wrote a lot of these books...for example like this...Science Thauhidic...and this book tries to put science in the position of knowledge...and this is my experience of how we interact with the Al-Quran...the touch of the Al-Quran to scientists...how Al-Quran touches us..." 7:28 (P1)

"Just a paper... just to be able to get out... for PhD students... God willing... but we don't want to stop at the self-book... right... if we can we want to do it... make it... my student alhamdulillah... he not only produced a thesis, but he produced a book from his thesis..." 12:24 (P3)

The production elements of article P2 are also interpreted from quotes 9:59, 9:61, 10:69 and 11:27. These elements can be said to exist in all participants. This is because it is a criterion that must be met as an academic:

"...the journal is for people who are in our field, right...journals, conferences really have to be done...if I am the KPI, he must have five journals a year...the ISI journal..." 9:59

"My first article...I sent it to the Straits Times...News Straits Times...my first one is a story frame...an article like this...I bought a frame at my house...so I can say...for the children...this is the first article..." 9:61.

"Then we also wrote an article, in the newspaper not yet, some friends also asked us to write, in the University B magazine we explained the impact, which like KTM was sent in the IMPAK magazine, which means that KTM is working..." 10:69.

"Okay...if among scholars we present at a conference, or publish a paper...only academics will read it, and only academics will attend the conference, right...that's the way we convey it..." 11:27

All emerging themes under the concepts of sustainability STEM educational leadership and management with the respective elements and sources of data triangulation are presented in Table 2. The consistency of data triangulation from different sources (interview responses, observations, and documents) shows consistency and reliability of some of the elements.

Table 2: Emerging Themes of Sustainability STEM Educational Leadership and Management list

Concept	Themes	Elements	Source of data (P1 to P7)			
			Interview	Observation	Document	Cohen's K Coefficient
Sustainability STEM Educational Leadership and Management	STEM-Thinking Leadership (STEM-TL)	STEM Knowledge Leadership	All	P1, P2, P5	all	0.82
		Financial leadership	All	-		0.90
		STEM Facility management	All	-	P1, P2, P5	0.85
	Motivational Leadership (STEM-ML)	Religious practice	All	P1. P4, P5	P5	0.78
		Honesty	All	-	-	0.92
	STEM Academic Leadership (STEM-AL)	Committed	All	All	P1, P5, P6	0.89
		T&L management	All	All	All	0.96
	Technological Management leadership (STEM-TML)	Awareness Leadership and Management	All	-	All	0.93
		Multidiciplinary Management and Leadership	All	All	All	0.78

Technological Management and	All	P2, P3, P5, P7	P2, P3, P5, P7	0.85
Competitive Management and	All	-	All	0.78
Leadership and Management in Creativity	All	All	All	0.89
Average Kappa Value:				0.86

DISCUSSION

The formulization concept of sustainability educational leadership and management for STEM-based approaches from seven experts' perspective can be understood as an educational leadership and management paradigm to enhance excellence by performing and cultivating STEM-based career. Constant comparative analysis performed, formulate four main themes of sustainability educational leadership and management in STEM-based education approaches. All themes were linked and rearranged in hierarchy to show the development and processes.

The first theme is STEM-TL emphasizes the role of teachers' cognitive in the leadership and management in STEM-based. STEM teachers should have the innovative mindset to develop new idea teaching strategies by strengthening their content knowledge and pedagogical content knowledge (Wieselmann, Roehrig, Ring-Whalen & Meagher, 2021). Besides that, teachers are responsible for elevating the quality of national education to a global level. Thus, to achieve this level, teachers must challenge themselves to ensure that creative and innovative thinking, critical thinking, reasoning, and learning ability are successfully enhanced by teachers to students as they prepare to face the tide of globalization. This finding is parallel with (Wieselmann et al., 2021) claimed that teachers should open to innovation and continual learning to support effective STEM education. This can be done by having good financial management so that all the facilities for STEM-based education can be provided to suit complete the innovation of teaching strategies. It means a leader should constantly keep analysing what transformation can bring good consequences for the organization.

The second theme is STEM-Motivational leadership. Motivation is critical in influencing teacher's performance in achieving educational objectives. The two elements lie under this theme, religious practices and honesty. These elements should be shown through the leader's ethical value performance their religious belief and honesty in completing tasks (for example, setting organization objectives is to fulfil religious and belief obligations). Religious practices are necessary to building the inner strength of a person to address challenges especially in STEM-based education. Besides that, teacher's religious beliefs in education have identified connections with their teaching practices. Hartwick (2015) stated that teachers' hold with their religious tend to adopt teaching practices that are most beneficial for their students. Moreover, these themes can be explained by two elements. The first element is moral and ethical values as a good leader and manager, which motivate a person to be responsible for sustainable educational development to achieve ability on producing new technology. Ulfathmi et al. (2021) revealed that highly motivated teachers will be encouraged and strive to improve their abilities in carrying out their tasks as educators to achieve the best outcomes.

Next is the third theme of STEM-academic leadership, consists of two elements. The elements are teaching and learning and committed academician leadership and management. Committed academic leadership is the important

teacher leadership character to consistently implementing STEM-based education even though they are facing challenges and problems related STEM-based education. Teachers are more likely to remain in the teaching profession when they experience a sense of belonging and perceive their contributions as significant to the achievements of their school and students (Mulford, 2003). Leadership and management should provide a commitment committee to find solutions to reduce the teaching and learning challenges, as mentioned by P5. This theme will develop responsibilities and commitments among members in an institution to improve their STEM-based education.

The fourth theme of sustainability STEM-based educational leadership and management is technological leadership and management which constructed by five elements: i) Awareness, ii) Multidisciplinary, iii) Technological, iv) Competitive, and v) Creativity leadership and management. This theme is the concept of innovation for new technology ideas to develop students' interest. Strong technological leadership and expertise in specific knowledge domains are the two important factors could contribute to this theme. The combination of these two factors might inspire their colleagues and students to engage with new technologies. For example, a leader with in-depth knowledge of heat transfer topic and theoretical underpinning of technology can develop new STEM-based activities, driven by the creation of technology concept. Besides that, awareness of new technologies can be achieved by the leaders who actively embrace to technological changes every day. One of the seven roles of modern teacher is to act as a leader who can support student learning empowerment teaching and learning. The highlighted leadership characteristics of modern teacher by ISTE are actively shaping, advancing, and accelerating a common vision of empowering learning with technology in collaboration with stakeholders, advocating for equal access to technology to meet students' diversity needs, serving as an exemplar in identifying, investigating, evaluating, creating, and adopting new digital resources and tool for learning among colleagues (ISTE, 2017). Multidisciplinary management can be conducted by determining the introduction of advantages across the STEM fields. Most participants realized that collaboration from different STEM fields is suitable for multidisciplinary in technological leadership and management. Multidisciplinary collaboration is usually conducted for a specific project (i.e. P1 to P7). For example, P5 collaborated with PDRM and KTM to manage and share their specialty for a STEM project.

Implementing a STEM-based approach in schools is the process of social influence from superiors to subordinates, the ability to exert influence over others is crucial. As the significant driving force, a leader should have a solid STEM-based learning planning to ensure continuous recognition of performance can be done. From this study's perspective, STEM-based leadership has a dynamic relationship which is based on mutual influence between leaders and members. Consequently, it results in higher self-motivation and technical development as it promotes changes in teaching and learning styles.

CONCLUSION

Incorporating the leadership and management concept in STEM-based approaches for current STEM-based education undeniably brings a new educational leadership perspective. This concept adapts educational leadership transformation in new technology development generation. It must start with STEM-TL. For this level, the elements of STEM knowledge play an important role, so an organization to run STEM teaching and learning could be initiated. Thinking will encourage a leader to have the ability to manage an organization's finances and facility for STEM-based activities so that it can be implemented as a priority. Furthermore, to break barriers and face challenges, the concept of STEM-ML for sustainable STEM-based approach is closely linked with the continuation of the dimensions related to religion, belief, value, and spirituality to face STEM-based education. Sustainability STEM-based educational leadership and management need to be developed through social development, difficulties and challenges faced by the practices and encouragement of religious and spiritual belief elements. Leaders and educators who are engaged with the connection of the STEM approach with religion and spirituality represent the possibility of motivating new implementation of STEM-based approaches. These can impact social well-being and development among society. STEM academic leadership then plays a vital role with committed and ability to manage the implementation of STEM-

based teaching and learning. Finally, technological leadership is the big concept in STEM-based leadership, encompassing of five elements. A leader must be able to lead and manage technology awareness for new ideas of technology developments. Thus, one needs to adapt flexibility to multidisciplinary to solve a specific field problem. Awareness of STEM-leader or educators of the impact of the concerns on their commitment can be a new formula to implement STEM-based practice of this study.

Since this formulization is not being tested on the real sample, it is suggested for further recommendation to make a generalization. Moreover, replication of this study in other institutions with other research-based careers is crucial. Exploring the experiences of other institution-based programs, such as schools, could help determine any similar STEM-based leadership elements. Possible generalization of the identified elements and themes to all situations in their academic and career management can be conducted through a quantitative study. Other populations could also be investigated to explore multiple perspectives. This study revealed that the concept of sustainability STEM-based leadership and management for STEM-based education as a guideline for social sustainability. All these elements complement each other in developing new STEM-based teaching approach that environmental and economic sustainability, which is demonstrated by educational leadership. Practicing the elements of STEM for educational competency in specific fields provides clear objectives for the implantation of the STEM approach in society. Consequently, innovative ideas among STEM practitioners can be developed. Therefore, individuals must build their inner strength (including moral and ethical values) not only for a scientific career but generally for everyday life.

REFERENCES

Adam, A. (2019). Faktor Keberkesanan Guru Cemerlang Sains Dalam Proses Pengajaran dan Pemudahcaraan. https://www.researchgate.net/publication/335909143

Adam, N. A., & Halim, L. (2019). Cabaran Pengintegrasian Pendidikan STEM dalam Kurikulum Malaysia. Seminar Wacana Pendidikan, 252–260.

Al Rosid, Moh. H., & Mukarromah, M. (2020). Korelasi Gaya Kepimpinan Kepala Sekolah Dengan Motivasi Kerja Guru. Jurnal Tarbiyatuna, 1(2).

Bahagian Pembangunan Kurikulum. (2016). Panduan Pelaksanaan STEM dalam Pengajaran dan Pembelajaran.

Bolman, L. G., & Deal, T. E. (2021). Reframing Organizations: Artistry, Choice, and Leadership (7th ed.). John Wiley & Sons, Inc.

Bush, T. (2007). Educational Leadership and Management: Theory, Policy, and Practice. South African Journal of Education Copyright © 2007 EASA, 27(3), 391–406.

Committee on Science Engineering and Public Policy. (2007). Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. In Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. National Academies Press. https://doi.org/10.17226/11463

Creswell, J. W., & Poth, C. N. (2018). Qualitative Inquiry & Research Design: Choosing Among Five Approaches (4th ed.). Sage Publication.

Curriculum Development Division (CDC), M. of E. (2016). Sharing Malaysian Experience in Participation of Girls in STEM Education.

Hamzah, N., Abd Halim, M. T., & Baseri, M. (2020). Gaya Kepimpinan Pemimpin Sekolah dalam Pengurusan dan Penyelesaian Masalah Program Pendidikan Khas. Wacana Pengurusan Dan Kepimpinan Pendidikan, 38–58.

Han, S., Capraro, R., & Capraro, M. M. (2015). How Science, Technology, Engineering, and Mathematics (STEM) Project-Based Learning (PBL) Affects High, Middle, and Low Achievers Differently: The Impact of Student Factors on Achievement. International Journal of Science and Mathematics Education, 13(5), 1089–1113. https://doi.org/10.1007/s10763-014-9526-0

Hansen, M., & Gonzalez, T. (2014). Investigating the Relationship between STEM Learning Principles and Student Achievement in Math and Science. American Journal of Education , 120(2), 139–171.

Hartwick, J. M. M. (2015). Public School Teachers' Beliefs in and Conceptions of God: What Teachers Believe, and

Why it Matters. Religion and Education, 42(2), 122–146. https://doi.org/10.1080/15507394.2014.944065
ISTE. (2017). ISTE Standards for Educators. A Guide for Teachers and other Professionals. In International Society for Technology in Education.
ITEA, I. T. E. A. (2009). The Overlooked STEM Imperatives: Technology and Engineering K-12 Education.
Jekri, A., & Han, C. G. K. (2020). The Challenges in Implementing Stem Teaching and Learning in Secondary Schools. International Journal of Education, Psychology and Counseling, 5(34), 80–90. https://doi.org/10.35631/ijepc.534006
Kementerian Pendidikan, M. (2021). Statistik Pendidikan Tinggi 2021.
Kementerian Pendidikan Malaysia. (2018). Laporan Tahunan Pelan Pembangunan Pendidikan Malaysia 2013-2025.
Le, L. T. B., Tran, T. T., & Tran, N. H. (2021). Challenges to STEM education in Vietnamese high school contexts. Heliyon, 7(12). https://doi.org/10.1016/j.heliyon.2021.e08649
Leithwood, K., & Jantzi, D. (2000). Principal and Teacher Leadership Effects: A replication. School Leadership and Management, 20(4), 415–434. https://doi.org/10.1080/713696963
McHugh, M. L. (2012). Interrater Reliability: The Kappa Statistic. Biochemia Medica, 22(3), 279–282.
Ministry of Education, M. (2013a). Executive Summary Malaysia Education Blueprint.
Ministry of Education, M. (2013b). Malaysia Education Blueprint 2013-2025. www.moe.gov.my
Mokhlis, S., Perniagaan, F., Dan, E., & Sosial, P. (2019). Headmasters' Leadership in the Implementation of 21st Century Education: A Preliminary Study. In Malaysian Online Journal of Education (Vol. 3, Issue 2).
Mulford, B. (2003). School Leaders: Challenging Roles and Impact on Teacher and School Effectiveness.
Natarajan, U., Tan, A. L., & Teo, T. W. (2021). Theorizing STEM Leadership: Agency, Identity and Community. Asia-Pacific Science Education, 7(1), 173–196. https://doi.org/10.1163/23641177-bja10021
Reeve, E. M. (2015). STEM Thinking! Technology and Engineering Teacher. Technology and Engineering Teacher, 75(4), 8–16.
Shafee, S., & Ismail, F. (2020). Komunikasi Berkesan dalam Pengurusan dan Kepimpinan Sekolah. Wacana Pengurusan Dan Kepimpinan Pendidikan, 59–75.
Sutaphan, S., & Yuenyong, C. (2019). STEM Education Teaching Approach: Inquiry from the Context Based. Journal of Physics: Conference Series, 1340(1). https://doi.org/10.1088/1742-6596/1340/1/012003
Tan, A.-L., Teo, T. W., Choy, B. H., & Ong, Y. S. (2019). The S-T-E-M Quartet. Innovation and Education, 1(1). https://doi.org/10.1186/s42862-019-0005-x
Ulfathmi, Arafat, Y., & Setiawan, A. A. (2021). The Influence of Principal Leadership and Work Motivation on Teacher Performance. Journal of Social Work and Science Education, 2(2), 160–168.
Wan Othman, W. Z., & Salim, S. N. (2020). Peranan PGB Sebagai Pemimpin Instruksional yang Berkesan dalam Mengurus Perubahan. Wacana Pengurusan Dan Kepimpinan Pendidikan, 1–13.
Wieselmann, J. R., Roehrig, G. H., Ring-Whalen, E. A., & Meagher, T. (2021). Becoming a STEM-focused School District: Administrators' Roles and Experiences. Education Sciences, 11(12). https://doi.org/10.3390/educsci11120805
Yin, R. K. (2016). Qualitative Research from Start to Finish (2nd ed.). A Division of Guilford Publications, Inc.
Yon Foi, L., & Hong Kean, T. (2022). STEM Education in Malaysia: An Organisational Development Approach? International Journal of Advanced Research in Future Ready Learning and Education, 29, 1–19.