A META-A Meta-Analysis on Developing Effective Hots Questioning Skills for Stem Teachers in Malaysia

Nor'Aida Khairuddin, Rohaya Talib, Haiza Atmareni Harmeni and Muhammad Radzali

October 24, 2019

A META-ANALYSIS ON DEVELOPING EFFECTIVE HOTS QUESTIONING SKILLS FOR STEM TEACHERS IN MALAYSIA

Nor'Aida Khairuddin[1]*, Rohaya Talib [1], Haiza Atmareni Harmeni[2] & Muhammad Radzali[3]

[1]PhD Student, School of Education, Universiti Teknologi Malaysia, Malaysia*
[1]Senior Lecturer, School of Education, Universiti Teknologi Malaysia, Malaysia
[2]PhD Student, School of Education, Universiti Teknologi Malaysia, Malaysia
[3]PhD Student, School of Education, Universiti Teknologi Malaysia, Malaysia

Corresponding Author: Nor'Aida Khairuddin, School of Education, Universiti Teknologi Malaysia, Malaysia
Email: aidakhairuddin@gmail.com

Abstract

In developing 21st-century skills, improvement of STEM education is in demand in most countries for solving complex global issues and global economic development. Effective questioning skills by STEM teachers could help to engage and scaffold students in learning and higher-level thinking process. However, most STEM teachers in Malaysia still applied lower-order and closed-ended questions in teaching and learning session because of their lack of knowledge and skills in HOTS questioning. This paper provided an overview of effective strategies to develop HOTS questioning skills. The research methodology was based on literature review search strategy through ERIC, online database and journals such as EBSCOhost, ScienceDirect, Scopus, Springer Link, Web of Science (WoS), SAGE, Taylor and Francis Online, and Wiley Online Library. The keywords used for this research were STEM education, questioning skills, higher-order thinking skills (HOTS) and STEM pedagogical development. From the meta-analysis, the results showed that promote inquiry approach, proper wait-time, pedagogical content knowledge and recognition were the dominant strategies in questioning, which helped to develop students' cognitive and HOTS abilities. Findings from this review will guide the STEM teachers to enhance their pedagogical skills, especially in HOTS questioning and strengthen the quality of STEM education in future.

Keywords: STEM Education; Questioning Skills; Higher-order Thinking Skills (HOTS); STEM Pedagogical Development.

1. INTRODUCTION

STEM education development is essential for most countries in the world and become focus of innovation and social impacts of 21st century. The improvement of STEM education is in demand nation-wide for solving complex global issues and global economic development.

More than 1.3 million jobs are required in STEM disciplines to support Malaysian government initiatives in New Economic Model (NEM) by 2020 (Hafizan, Shahali, Ismail, & Halim, 2020). The 21st century skills in STEM disciplines require workforce to be more critical and creative in their thinking and actions (Chapoo, 2019). Holistic approaches in an authentic context are fundamental to develop these STEM skills (Bahrum, Wahid, & Ibrahim, 2017). The best and suitable instructional strategies are required to engage students in high quality of STEM education (Kelley & Knowles, 2016).

In 2017, Standard Curriculum for Secondary School (Kurrikulum Standard Sekolah Menengah, KSSM) started to implement higher-order thinking skills (HOTS) in most instructional activities based on 21st century learning (PADU Annual Report, 2017). At the same year, in 2017, Educational Planning and Research Division, MOE started to improve STEM teachers' pedagogical skills and capabilities for developing HOTS in teaching and learning sessions (PADU Annual Report, 2017). HOTS including critical thinking, creative thinking, problem-solving and decision making are the components of 21st century skills that must be developed by STEM teachers to the students (Yager, 2015). One of the instructional methods for STEM teachers to measure and access 21st century skills of STEM students is by developing good higher-order thinking questioning skills in the classroom and laboratory (Dean & Dean, 2002; Wilen, 2012).

Questioning of a part of learning process method that could stimulate student s thinking towards further information and deeper their understandings (Merisier, Larue, & Boyer, 2018, p. 109; Napp, 2017; Tofade, Elsner, & Haines, 2013; Wang, 2016; Wilen, 2012). Low cognitive level questions is based on low convergent thinking for example, recall the knowledge while the high cognitive level questions is based on divergent thinking that require the learners to think critically (Liu, 2019; Wilen, 2012). Closed-ended questions or convergent questions only require one specific answer while open-ended questions could encourage students' participation session and could access thinking strength from the responses answers (Gunderson, 2017; Liu, 2019). Open-ended or divergent questions could stimulate higher-order thinking such as application, analysis, synthesis and evaluate according to Bloom's taxonomy cognitive domain (Gunderson, 2017; Wilen, 2012). Higher-order cognitive questioning could enhance student's achievement (Rajendran, 2013). As a result, it is essential to analyse questioning skills among teachers based on the holistic view and approach (Agarwal, 2019; Döş et al., 2016). From the good questioning skills, STEM teachers could organise their students' thinking systematically to achieve educational objectives through teaching and learning sessions (Napp, 2017; Shahrill, 2013).

Additionally, in STEM education, inquiry-based questioning is an essential form of scaffolding to develop HOTS among students (Chapoo, 2019).Scaffolding in inquiry teaching give opportunities for STEM teachers to develop complex higher order questions. This will encourage students to deepen their concepts, procedures and understanding of STEM subjects through thoughtful, purposeful, clear and open-ended questions (Olusegun, 2015; Tajudin, Puteh, & Adnan, 2017) . Based on the constructivism theory by Vygotsky, students' understanding on the concepts of STEM subjects depends on their previous knowledge and experienced from their real-life situations (Hendry, 1996; Olusegun, 2015). Effective inquiry learning environments have positive impact for teachers to facilitate their students onto higher-level thinking and could expand more students' idea by encouraging students with different cognitive levels of questions (Yenmez, Erbas, Cakiroglu, & Alacaci, 2017). Only four types of inquiry-based questions which involve HOTS such as clarifying, focusing, probing and prompting (Chapoo, 2019). In probing questions, students have to think deeper, clarify, justify and explain their responses from the answers given (Cumhur & Matteson, 2017; Yenmez et al., 2017).

In Malaysia, a few studies on instructional strategies have been conducted to improve teachers' pedagogical skills in delivering HOTS questions to the students(Arase, Kamarudin, & Hassan, 2016; Saido, Siraj, Bakar, Nordin, & Saadallah, 2015; Sulaiman et al., 2017; Yusoff & Seman, 2018). From the observation in inquiry teaching, they found that majority of chemistry teachers could generate convergent questions based on factual memorisation and less higher-level science process skills questions such as interpreting data (Sim & Arshar, 2010). In inquiry-based pedagogies, to enhance teachers' questioning skills, teachers must plan and determine the type and levels of questions based on students' cognitive level before lesson session begins in the classroom (Arase et al., 2016). The teachers had to prepare a list of questions based on student's achievement so the students will be aware of upcoming strategy to gain further information and new knowledge (Arase et al., 2016). Based on a qualitative study on teachers' perspective of HOTS, teachers need to improve their knowledge and pedagogical skills of HOTS questioning in the classroom to strengthen students' science concepts (Sulaiman et al., 2017). Large size of class causes the majority of the students with different cognitive levels and academic achievement challenging to understand science concepts deeply (Sulaiman et al., 2017). The majority of primary schools' teachers in Terengganu only have basic knowledge and skills in HOTS questioning because of poor understanding in the concept of the thinking process (Yusoff & Seman, 2018). Most teachers could not differentiate between the core and subskills of creative and critical thinking (Yusoff & Seman, 2018).

However, the majority of STEM teachers struggled to apply and enhance their HOTS due to time constraints and other limitation (Lee, Kamarudin, Talib, & Hassan, 2017). They found that most STEM teachers have difficulties in mastering their content knowledge, curriculum and pedagogical skills effectively based on the latest MOE curriculum concept (Lee et al., 2017). These STEM teachers poor in delivering HOTS questions effectively to the students because their lack of knowledge and understanding in HOTS (Lee et al., 2017; Yusoff & Seman, 2018). The concept and understanding of HOTS were still new to the teachers and students (Arase et al., 2016). Lack of high quality in questions model and questioning skills practice during teachers' training from majority of the higher institutions lead to this problem (Cumhur & Matteson, 2017). Moreover, lack of time, resources, tools, professional support, professional training and laboratory infrastructure are the factors that influenced these poor questioning skills among these STEM teachers (Hafizan et al., 2020). Some teachers did not have an opportunity to practice scientific language when generating open-ended questions in the classroom (Eliasson, Karlsson, & Sørensen, 2017). Additionally, some teachers were resisted to pursue learning outcomes of HOTS but more interested in achieving learning content-specific goals in most of their lesson sessions (Yen & Halili, 2015).

2.RESEARCH QUESTIONS

This meta-analysis was a structure of methodology to synthesis the results of several or more existed studies for future improvement of instructional methods and pedagogical skills especially in developing effective HOTS questioning skills among STEM teachers in Malaysia. The purpose of this study is to identify several dominants effective strategies for STEM teachers to develop HOTS for the students from their questioning skills. Besides, this study investigated various impacts of these effective strategies towards student's development in

HOTS and complex thinking strategies to solve problems in real-life situations. This paper aimed to answer the research questions as stated below:

i. What are the dominant effective strategies of questioning skills by STEM teachers to develop HOTS among students in STEM lesson sessions?

ii. What are the impact of an effective questioning skills to student's development in HOTS and complex thinking strategies to solve problems in real-life situations?

3. METHODOLOGY

Data collection and analysis

For searching the resources for this study, online database strategy through ERIC which was known as online digital library of educational research and information was used to search the related pertinent published journal articles and conference papers. Others online database such as EBSCOhost, ScienceDirect, Scopus, Springer Link, Web of Science (WoS), SAGE, Taylor and Francis Online, Wiley Online Library and Google Scholar also used for searching the related topic on this study. This study also refer to the latest Malaysian Ministry of Education reports as the references.

However, due to the limited resources of this study, only four keywords were used to search such as STEM education, questioning skills, higher-order thinking skills (HOTS) and STEM pedagogical development. At the first stage, all types of articles from all field such as peer review journals including concept papers, research papers, systematic review papers, meta-analysis papers and conference papers were selected based on the selected four keywords from January 2013 to August 2019. Some of the selected articles did not mention or elaborate more specific term of questioning skills. During the second stage, only journals (research papers) and review papers were set as the primary sources. At the third stage, the selected articles according to these four keywords from stage two were screened and analysed qualitatively which focus only on important facts of pedagogical and instructional strategies especially in questioning skills.

4. RESULTS

This section will elaborate the findings descriptively based on the research questions from the previous literature reviews. The main aim of this study is to identify and determine the effective dominant strategies of questioning skills among STEM teachers that could give positive impacts on HOTS and complex thinking achievement among the students. The findings for this study were analysed qualitatively and divided into four parts such as promote HOTS questioning, complex thinking, teacher's content expertise especially in subject content knowledge and pedagogical content knowledge and questioning principles. Table 1 presented the summary of the findings according to the research questions.

	HOTS			Thinking strategies		Content Expertise		Questioning principles			
	CT	CrT	RT	PS	MD	SCK	PCK	PI	WT	R	L
(Sim & Arshar, 2014)	√	√				√	√	√	√		
(Lee et al., 2017)	√	√	√	√	√			√			
(Saido et al., 2015)	√	√						√			
(Hähkiöniemi & Hähkiöniemi, 2017)		√		√	√			√			
(Rutten, van der Veen, & van Joolingen, 2015)	√	√		√		√	√	√		√	
(Wang, 2016)	√	√	√		√		√	√		√	
(Booven, 2015)	√	√	√				√	√		√	
(Nichols, Burgh, & Kennedy, 2017)				√	√	√	√	√			
(Shahrill, 2013)	√	√		√			√		√	√	
(Yenmez et al., 2017)	√	√			√		√	√	√	√	
(Tofade et al., 2013)	√	√	√					√	√		
(Döş et al., 2016)	√	√		√		√	√	√	√	√	
(Bywater, Chiu, Hong, & Sankaranarayanan, 2019)	√	√	√	√			√	√	√	√	√
(Gaspard & Gainsburg, 2019)		√	√	√				√			
(Sulaiman et al., 2017)	√	√	√	√	√		√	√	√	√	
(Pedrosa-de-jesus, Moreira, & Lopes, 2014)		√		√	√	√	√	√			
(Magas, Gruppen, Barrett, & Dedhia, 2017)		√	√	√					√		
(Zeegers & Elliott, 2019)	√	√	√	√	√		√	√	√	√	
(Festo, 2016)	√	√	√			√	√	√	√	√	
(Kastberg, Lischka, & Hillman, 2018)			√	√		√	√	√		√	
(Keong, Ong, Hart, & Chen, 2016)	√	√	√	√		√		√	√	√	
(Ernst-slavit & Pratt, 2017)	√	√	√				√	√			√
(Yusoff & Seman, 2018)	√	√		√	√	√	√	√	√	√	
(Aziza, 2018)	√	√						√	√		
(Cumhur & Matteson, 2017)	√	√				√	√	√	√	√	
(Dohrn & Dohn, 2018)	√	√	√	√				√	√	√	
(Tajudin et al., 2017)	√	√				√	√	√			

HOTS	Thinking Strategies	Content Expertise	Questioning Principles
CT = Creative Thinking CrT = Critical Thinking RT = Reflective Thinking	PS = Problem Solving MD = Making decision	SCK = Subject content knowledge PCK = Pedagogical content knowledge	PI = Promote inquiry WT = Wait-time R = Recognition L = Language

Table 1

4.1 Higher-Order Thinking Skills (HOTS)

A total of 26 out of 27 studies focused on generating HOTS questions which could develop by the excellent questioning skills among STEM teachers. All of the studies involved in STEM disciplines such as mathematics, science, physics, chemistry, biology from primary and secondary schools level, and some of the studies were from engineering and medical field in undergraduate level at the universities.

In this study, HOTS questioning was divided into three categories such as creative thinking, critical thinking and reflective thinking. HOTS questioning referred to the questions which could promote HOTS among the students. In Bloom's revised taxonomy, analysing, evaluating and creating were determined as higher-order thinking (Anderson & Krathwohl, 2001). In learning the STEM subjects, HOTS could be developed by performing scientific investigation through laboratory activities and solving complex solutions in mathematics (Arase et al., 2016). HOTS questions could help students bridged their previous learning experienced and new experienced from real-life situations.

In instructional context, applying excellent questioning skills is required to enhance students' HOTS in learning session(Halim, Yusrizal, Mazlina, Melvina, & Zainaton, 2018; Wang, 2016). In developing creative thinking skills for the students, STEM teachers would construct questions for students to generate ideas, relating, making inferences, predict, making a hypothesis, synthesis, mental picture, reasoning and creating in learning activities (Arase et al., 2016). The students could generate ideas and new solutions to the problems by improving their creative thinking skills (Chabeli, 2006). In critical thinking skills, STEM teachers could enhance their students' ability in applying, analysing, evaluating and making conclusions (Napp, 2017). Reflective thinking involved an exploration of issues or experiences in order to lead to new understandings (Chabeli, 2006). Reflective thinking for students could be developed from knowledge acquisition by HOTS questioning (Shukla & Dungsungnoen, 2016). It will also allow students to refine their ideas and reflect their thinking (Keong et al., 2016). Appropriate questions could improve students' learning achievement and higher thinking skills (Hill & Hill, 2016).

4.2 Thinking strategies

A total of 16 studies from 27 studies could promote problem-solving skills for students from effective HOTS questioning skills. Problem-solving is a process on identifying and clarifying a problem, hypothesizing solutions, testing alternative solutions, choosing and applying the appropriate solutions (Gough, 1991; Lee et al., 2017). From effective HOT questioning skills, STEM teachers could generate higher-order questions to encourage students to solve problems in authentic and real-life situations (Chabeli, 2006). Open-ended questions could develop numerous new ideas and multiple answers from the students from the STEM teachers (Aziza, 2018). In STEM laboratory activities, students could generate and test the hypothesis through experimental inquiry (Chabeli, 2006). In mathematics, problem-solving skills are essential for the students to solve mathematical solutions in order to search an accurate and precise answer (Kastberg et al., 2018). Problem-solving skills give opportunities for students to think about various solutions and encourage them to develop their reasoning abilities in choosing the best solutions (Shahrill, 2013). Only 9 over 27 studies which represented making decision skills among students could develop through HOTS questioning skills. Students have to provide substantial justification from scientific reasoning based on the evidence to select the best alternatives either from learning session or real-life situations (Keong et al., 2016).

4.3 Content expertise

A total of 11 out of 27 studies could relate excellent HOTS questioning skills with higher subject content knowledge. Before generating HOTS questions to the students, STEM teachers' must have better knowledge and understanding of the STEM subjects they teach (Van Driel & Berry, 2010). Previous studies had an interest in the conceptualisation of teacher's subject content knowledge to enhance instructional method (Van Driel & Berry, 2010). STEM teachers must have the ability to offer knowledge affirmation for students and enhance students' understanding of subject matter (Keong et al., 2016). High quality of instructional method especially in HOTS questioning need teachers to understand clearly the STEM subject facts, concepts, laws and principles before the plan and conduct questioning in learning session (Stronge, Grant, & Xu, 2015). STEM teachers' competence in subject content knowledge influenced their pedagogical thinking and decision making (Stronge et al., 2015).

For pedagogical content knowledge, a total of 18 out of 27 studies reported from the developing STEM HOTS questioning studies. Questioning skills and strategies depends on STEM teachers pedagogical content knowledge (Yenmez et al., 2017; Zeegers & Elliott, 2019). Pedagogical content knowledge is a bridge between subject content knowledge and practice of teaching (Chick & Beswick, 2018; Van Driel & Berry, 2010). In pedagogical content knowledge, there were three categories from Shulman's (1986) such as Knowledge of Content and Students (KCS), Knowledge of Content and Teaching (KCT) and Knowledge of Curriculum (Van Driel & Berry, 2010). STEM teachers must know student's understanding of the STEM subject area, instructional strategies including knowledge and understanding of the learning objectives based on latest STEM curriculum, to generate excellent HOTS questioning skills (Ab Kadir, 2017; Stronge et al., 2015).

4.4 Questioning principles

A total of 26 from 27 studies reported about promote inquiry as part of questioning principle to produce better HOTS questioning skills. STEM teachers must generate a series of questions to enhance cognitive development and thinking skills for the students. Inquiry-based questions were categorised into four types such as clarifying questions, focusing questions, probing questions and prompting questions (Chapoo, 2019). Open inquiry questions from the STEM teachers could develop students' higher-order thinking, including problem-solving skills, making decision skills and creating skills in learning session (Lee et al., 2017). As a result, students' justification and reasoning skills improved continuously (Yusoff & Seman, 2018). STEM teachers could also create open questions to improve students' higher-order scientific understandings in STEM subjects which could promote inquiry in learning session (Booven, 2015). More purposeful, clear and thought-provoking questions affected students' achievement in HOTS.

Besides, applying wait-time from STEM teachers in questioning session in the classroom or laboratory gave opportunities for students to process information and constructed new knowledge (Hill & Hill, 2016). A total of 15 from 27 studies discussed wait-time in HOTS questioning applications for STEM subjects. Increasing the wait-time by the STEM teachers could encourage students at various levels of cognitive development to participate and response the HOTS questions in learning session (Aziza, 2018; Hill & Hill, 2016; Shahrill, 2013; Tofade et al., 2013). Wait-time between three to five seconds was the suitable time for teachers to wait for student response in answering the HOTS questions (Hill & Hill, 2016; Keong et al., 2016; Shahrill, 2013).

According to Oxford Advanced Learner's Dictionary 9th edition (2015), recognition means the act of accepting any responses from others. A total of 15 from 27 studies showed that recognition from STEM teachers was important in questioning session in the classroom. STEM teachers were responsible for creating a positive environment by accepting any responses from the students without any bias in teaching and learning session (Cumhur & Matteson, 2017; Gough, 1991).

5. DISCUSSIONS

Based on the results from this meta-analysis, pedagogical content knowledge, promote inquiry in questioning, wait-time and recognition were the dominant effective strategies of questioning skills from the STEM teachers which could promote HOTS to the students. From the pedagogical content knowledge, STEM teachers should have an ability to construct HOTS questions based on their student's cognitive levels and understanding of STEM concepts (Shahrill, 2013).

Besides, preparing a lesson plan, teaching strategies, classroom management, assessment and STEM teacher's attitude towards the curriculum are parts of pedagogical content knowledge which leads towards effective questioning skills in the classroom. STEM teachers must able to arrange their lesson plan according to the latest curriculum, school culture, classroom situations, curriculum materials, students' cognitive abilities and learning resources (Jo & Bednarz, 2014; Triyanto, 2019). In teaching strategies, open-ended questions are suggested to encourage more response from the students. Proper classroom management will make sure instructional goals by applying HOTS questions is achieved during the given teaching period (Festo, 2016). Assessment knowledge and understanding of these STEM teachers using Revised Bloom's taxonomy is essential for them to define the categories of questions, suitable types of questions and future students' outcome to evaluate students in the classroom (Festo, 2016). STEM teachers' positive attitude towards the latest curriculum will encourage these teachers to develop and practice their HOTS questioning skills in teaching session effectively with passion.

Inquiry-based questioning leads to higher-order thinking for the students in learning STEM. Well-formed questions from STEM teachers encouraged student's inquiry continuously (Liu, 2019). Inquiry-based higher-order cognitive questioning increased students' achievement, deepen student's STEM concept, the ability for students' to formulate a hypothesis in experimental activities and identify evidence to conclude (Eliasson et al., 2017). Questioning sequences from lower-order to higher-order from STEM teachers based on thinking process level is required to access and evaluate students' performance in the classroom (Hamblen, 2015; Napp, 2017).

Firstly, clarifying questions based on inquiry-based questioning from STEM teachers could help students to give more evidence to support their answer when they could not provide reasonable explanations. Clarify questioning could stimulate the students' critical thinking by articulating their understanding of important STEM concepts. Students could elaborate on their idea or statement and constructed new conceptual knowledge from the learning session (Festo, 2016; Yip, 1999). Formulating the questions by phrasing and clarify words affect the effectiveness of the questions (Tofade et al., 2013). Secondly, in focusing questions, STEM teachers could generate more details and specific answers from the students by narrowing and limiting the student's scope (Chapoo, 2019; Elder, Paul, Elder, & Paul, 2010; Napp, 2017). In learning STEM, which involved scientific facts, mathematical formulas, principles and laws, STEM teachers are suggested to deliver more factual recall questions to strengthen the students' cognitive recall skills before asking HOTS questions. Thirdly, probing questions from STEM teachers encourage the students to provide more concrete evidence from their explanation after responding to the questions (Chapoo, 2019). Probing questions will develop students' logical thinking from inductive and deductive reasoning skills in experimental activities and solving problems in mathematical questions (Druva & Anderson, 1983). Students' deep and analytical thinking skills in STEM will develop by justifying, supporting and analysing their explanations or statements when answering HOTS questions. STEM teachers could guide the students to conclude by giving the accepted hypothesis after conducting STEM lab experiment by prompting questions (Chapoo, 2019).

Additionally, wait-time give opportunities for students at various levels of cognitive development to process information after listening to the HOTS questions. Based on the previous studies, STEM teachers were suggested to give the students time to response the HOTS question between 3 to 5 seconds (Gough, 1991; Hill & Hill, 2016; Keong et al., 2016; Wilen, 2012). If more complex mental operations are involved in a learning session, STEM teachers are advised to extend wait-time more than 5 seconds to give opportunities for the student to response the HOTS questions (Keong et al., 2016).

Finally, recognition from STEM teachers creates a positive environment in the learning session. The conducive learning environment in school climate could promote better social interaction between STEM teachers' and students. STEM teacher's personality and relationship with the students give a positive impact on the learning environment (Cumhur & Matteson, 2017). If the teachers are not keen to make the learning environment comfortable, it will restrict students' learning (Shahrill, 2013). STEM teachers have to listen to all student's response carefully without any bias and first judgement to create a positive atmosphere in the classroom (Gough, 1991). Positive feedback from these STEM teachers to the students after responding to the proposed HOTS questions are required. These STEM teachers must encourage students' participation in responding to the questions by balancing the volunteers and non-volunteers' in the learning session. In the learning session, STEM teachers are suggested to apply open-ended questions based on student's past experienced so that the students' will give opinions, reasons, identify implications, formulate a hypothesis and making decisions from their values and standards (Festo, 2016).

6. CONCLUSIONS

Therefore, well trained and continuous professional development in instructional strategies and pedagogical skills could contribute to the high quality of STEM teachers who could improve student's performance in STEM (Devangi, Perera, Asadullah, & Asia, 2018). Questioning skills which promote HOTS to students will be developed through intensive teaching training and professional development organised by the Malaysian Ministry of Education. Policymakers, school administrators and STEM teachers will refer to these outcomes of this study to enhance their instructional strategies and organise better STEM teaching training in future. As a result, STEM teachers questioning skills for developing HOTS to the students in the classroom will improve. If the STEM teachers have low competence in developing their questioning skills, the Malaysian students will unable to understand the STEM concepts profoundly and apply HOTS to solve in real-life situations.

ACKNOWLEDGEMENT

The authors would like to thank Universiti Teknologi Malaysia and Malaysian Ministry of Education for providing full sponsor scholarship, *Hadiah Latihan Persekutuan* that enables this study to be carried out.

REFERENCES

Ab Kadir, M. A. (2017). What Teacher Knowledge Matters in Effectively Developing Critical Thinkers in the 21 st Century Curriculum? *Thinking Skills and Creativity*, *23*, 79–90.

Agarwal, P. K. (2019). Retrieval practice & bloom's taxonomy: Do students need fact knowledge before higher order learning? *Journal of Educational Psychology*, *111*(2), 189–209.

Anderson, L.W and Krathwohl, D.R. *A Taxonomy For Learning, Teaching and Assessing*. *Complete Edition*. New York: Addison Wesley Longman. 2001

Arase, A., Kamarudin, N., & Hassan, A. (2016). The Development of Students' Capabalities in Higher Order Thinking Skill (HOTS) Through Science Education. *Jurnal Pemikir Pendidikan*, *7*, 1–18.

Aziza, M. (2018). An Analysis of A Teacher ' s Questioning Related to Students ' Responses and Mathematical Creativity in An Elementary School in The UK, *10*(4), 475–487.

Bahrum, S., Wahid, N., & Ibrahim, N. (2017). Integration of STEM Education in Malaysia and Why to STEAM, *7*(6), 645–654.

Booven, C. D. Van. (2015). International Journal of Science Revisiting the Authoritative – Dialogic Tension in Inquiry-Based Elementary Science Teacher Questioning, (May), 37–41.

Bywater, J. P., Chiu, J. L., Hong, J., & Sankaranarayanan, V. (2019). The Teacher Responding Tool: Scaffolding the teacher practice of responding to student ideas in mathematics classrooms. *Computers and Education*, *139*(May), 16–30.

Chabeli, M. M. (2006). Higher order thinking skills competencies required by outcomes-based education from learners. *Curationis*, *29*(3), 78–86.

Chapoo, S. (2019). Enhancement of 9th grader students' 21st century skills through inquiry-based questions in integrated STEM activity. *AIP Conference Proceedings*,*2081*(March).

Chick, H., & Beswick, K. (2018). Teaching teachers to teach Boris: a framework for mathematics teacher educator pedagogical content knowledge. *Journal of Mathematics Teacher Education*, *21*(5), 475–499.

Cumhur, F., & Matteson, S. M. (2017). Mathematics and Science Teacher Candidates ' Beliefs of Developing Questioning Skills in, *6*(December), 297–318.

Dean, A., & Dean, A. (2002). Preceptor Questioning and Student Critical Thinking, *18*(3), 176–181.

Devangi, L., Perera, H., Asadullah, M. N., & Asia, E. (2018). International Journal of Educational Development Mind the gap : What explains Malaysia ' s underperformance in Pisa ? ☆. *International Journal of Educational Development*, (August), 0–1.

Dohrn, S. W., & Dohn, N. B. (2018). The role of teacher questions in the chemistry classroom. *Chemistry Education Research and Practice*, *19*(1), 352–363.

Döş, B., Bay, E., Aslansoy, C., Tiryaki, B., Çetin, N., & Duman, C. (2016). An analysis of teachers ' questioning strategies, *11*(22), 2065–2078.

Druva, C. A., & Anderson, R. D. (1983). Science teacher characteristics by teacher behavior and by student outcome: A meta-analysis of research. *Journal of Research in Science Teaching*, *20*(5), 467–479.

Elder, L., Paul, R., Elder, L., & Paul, R. (2010). The Role of Socratic Questioning in Thinking , Teaching , and Learning, (November 2014), 37–41.

Eliasson, N., Karlsson, K. G., & Sørensen, H. (2017). The role of questions in the science classroom–how girls and boys respond to teachers' questions*. *International Journal of Science Education*, *39*(4), 433–452.

Ernst-slavit, G., & Pratt, K. L. (2017). Teacher questions : Learning the discourse of science in a linguistically diverse elementary classroom. *Linguistics and Education*, *40*, 1–10.

Festo, K. (2016). Question Classification Taxonomies as Guides to Formulating Questions for Use in Chemistry Classrooms. *European Journal of Science and Mathematics Education*, *4*(3), 353–364.

Gaspard, C., & Gainsburg, J. (2019). Abandoning questions with unpredictable answers. *Journal of Mathematics Teacher Education*.

Gunderson,A. (2017) The Well-Crafted Question Inspiring Students To Connect, Create and Think Critically. *American Music Teacher*, April/May 2017, 14-18

Gough, D. (1991). Thinking About Thinking.*National Association of Elementary School Principals.7(2),* 3-6

Hafizan, E., Shahali, M., Ismail, I., & Halim, L. (2020). Policy Trajectories and Initiatives in STEM Education STEM Education in Malaysia : Policy , Trajectories and Initiatives, 122–133.

Hähkiöniemi, M., & Hähkiöniemi, M. (2017). International Journal of Mathematical Education in Student teachers ' types of probing questions in inquiry-based mathematics teaching with and without GeoGebra mathematics teaching with and without GeoGebra. *International Journal of Mathematical Education in Science and Technology*, *0*(0), 1–15.

Halim, A., Yusrizal, Mazlina, H., Melvina, & Zainaton. (2018). Questioning skill of science teacher from the students perscpective in senior high school. *Journal of Physics: Conference Series*, *1088*.

Hamblen, K. A. (2015). An Art Criticism Questioning Strategy Within the Framework of Bloom ' s Taxonomy, *26*(1), 41–50.

Hendry, G. D. (1996). Constructivism and educational practice, *40*(I), 19–45.

Hill, J. B., & Hill, J. B. (2016). Questioning Techniques : A Study of Instructional Practice Questioning Techniques : A Study of Instructional Practice, *7930*(November).

Jo, I., & Bednarz, S. W. (2014). Developing pre-service teachers' pedagogical content knowledge for teaching spatial thinking through geography. *Journal of Geography in Higher Education*, *38*(2), 301–313

Kastberg, S. E., Lischka, A. E., & Hillman, S. L. (2018). Exploring Mathematics Teacher Educator Questioning as a Relational Practice : Acknowledging Imbalances Exploring Mathematics Teacher Educator Questioning as a Relational Practice : Acknowledging Imbalances. *Studying Teacher Education*, *00*(00), 1–15.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*.

Keong, K., Ong, A., Hart, C. E., & Chen, P. K. (2016). Promoting Higher-Order Thinking Through Teacher Questioning: a Case Study of a Singapore Science Classroom. *New Waves Educational Research & Development*, *19*(1), 1–19.

Lee, T. J., Kamarudin, N., Talib, O., & Hassan, A. (2017). How Does Inquiry-Based Instruction Affect Learning in a Secondary School Science Class? In G. B. Teh & S. C. Choy (Eds.), *Empowering 21st Century Learners Through Holistic and Enterprising Learning* (pp. 103–113). Singapore: Springer Singapore.

Liu, Y. (2019). Using reflections and questioning to engage and challenge online graduate learners in education. *Research and Practice in Technology Enhanced Learning*, *14*(1).

Magas, C. P., Gruppen, L. D., Barrett, M., & Dedhia, P. H. (2017). The American Journal of Surgery Intraoperative questioning to advance higher-order thinking. *The American Journal of Surgery*, *213*(2), 222–226.

Merisier, S., Larue, C., & Boyer, L. (2018). Nurse Education Today How does questioning in fl uence nursing students ' clinical reasoning in problem-based learning ? A scoping review. *Nurse Education Today*, *65*(February), 108–115.

Napp, J. S. (2017). The Importance of Questioning in Developing Critical Thinking Skills. *International Journal for Professional Educators*, *84*(1), 30–41.

Nichols, K., Burgh, G., & Kennedy, C. (2017). Comparing Two Inquiry Professional Development Interventions in Science on Primary Students' Questioning and Other Inquiry Behaviours. *Research in Science Education*, *47*(1).

Olusegun, S. (2015). Constructivism Learning Theory : A Paradigm for Teaching and Learning, *5*(6), 66–70.

PADU- Annual Report. 2017. *Malaysia Education Blueprint 2013-2025.* Ministry of Education Malaysia 2018.

Pedrosa-de-jesus, H., Moreira, A., & Lopes, B. (2014). Research in Science & Technological Education So much more than just a list : exploring the nature of critical questioning in undergraduate sciences, (November), 37–41.

Rajendran, N.S. *Teaching & Acquiring Higher-Order Thinking Skills Theory & Practice*. 3th ed. UPSI Tanjung Malim: Penerbit UPSI. 2013

Rutten, N., van der Veen, J. T., & van Joolingen, W. R. (2015). Inquiry-Based Whole-Class Teaching with Computer Simulations in Physics. *International Journal of Science Education*, *37*(8), 1225–1245.

Saido, G. M., Siraj, S., Bakar, A., Nordin, B., & Saadallah, O. (2015). Higher Order Thinking Skills Among Secondary School Students in Science Learning, *3*(3), 13–20.

Shahrill, M. (2013). Review of effective teacher questioning in mathematics classrooms. *International Journal of Humanities and Social Science*, *3*(17), 224–231.

Shukla, D., & Dungsungnoen, P. (2016). Students Perceived Level and Teachers Teaching Strategies of Higher Order Thinking Skills; A Study on Higher Educational Institutions in Thailand. *Journal of Education and Practkice*, *7*(12), 211–219.

Sim, S. L. W., & Arshar, M. Y. (2014). A preliminary study of chemistry teachers' question in inquiry teaching. *Sains Humanika*, *2*(4), 217–224.

Stronge, J. H., Grant, L. W., & Xu, X. (2015). *Teacher Behaviours and Student Outcomes*. *International Encyclopedia of the Social & Behavioral Sciences: Second Edition* (Second Edi, Vol. 23).

Sulaiman, T., Muniyan, V., Madhvan, D., Ehsan, S. D., Persekutuan, W., & Lumpur, K. (2017). International Research Journal of Education and Sciences (IRJES), *1*(1).

Tajudin, N. M., Puteh, M., & Adnan, M. (2017). Developing Themes of Guiding Principles to Foster Higher Order Thinking Skills in Teaching and Learning of Mathematics. *International Journal of Academic Research in Progressive Education and Development*, *6*(4), 195–199.

Tofade, T., Elsner, J., & Haines, S. T. (2013). Best Practice Strategies for Effective Use of Questions as a Teaching Tool, *77*(7).

Triyanto, R.D.H. Adopting Lesson Study to Enhance Pre-Service Teachers' Pedagogical Knowledge. *The New Educational Review*,56(2), 244-254.

Van Driel, J. H., & Berry, A. (2010). Pedagogical content knowledge. *International Encyclopedia of Education*, (Figure 1), 656–661.

Wang, A. (2016). Exploring the impact of teacher experience on questioning techniques in a Knowledge Building classroom. *Journal of Computers in Education*.

Wilen, W. W. (2012). Review Effective Questions and Questioning : A Research Review, (April 2015), 37–41.

Yager, R. (2015). The Role of Exploration in the Classroom (STEM). *Society*, *52*(3), 210–218.

Yen, T. S., & Halili, S. H. (2015). Effective Teaching of Higher-Order Thinking (Hot) in Education. *The Online Journal of Distance Education and E-Learning (TOJDEL)*, *3*(2), 41–47.

Yenmez, A. A., Erbas, A. K., Cakiroglu, E., & Alacaci, C. (2017). Mathematics teachers ' knowledge and skills about questioning in the context of modeling activities. *Teacher Development*, *4530*(August), 1–22.

Yip, D.-Y. (1999). Implications of Students' Questions for Science Teaching. *School Science Review*, *81*(294), 49–53.

Yusoff, W. M. W., & Seman, S. C. (2018). Teachers ' Knowledge of Higher Order Thinking and Questioning Skills : A Case Study at a Primary School in Teachers ' Knowledge of Higher Order Thinking and Questioning Skills : A Case Study at a Primary School in Terengganu , Malaysia. *Journal of Academic Research in Progressive Education& Development*, *7*(2), 1–19.

Zeegers, Y., & Elliott, K. (2019). Who's asking the questions in classrooms? Exploring teacher practice and student engagement in generating engaging and intellectually challenging questions. *Pedagogies*, *14*(1), 17–32.