METACOGNITION AS TEACHING AND LEARNING APPROACH FOR SCIENCES, TECHNOLOGY, ENGINEERING AND MATHEMATICS TEACHING

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Abstract
Due to global challenges in term of social and economics, the world has given great attention to Science, Technology, Engineering and Mathematics (STEM) teaching not only in higher education but primary and secondary education. This innovation is to equip the young people to compete in the job market and economic development. STEM is an interdisciplinary approach which presents the academic concept couple with real-world problem. Thus, teachers need to prepare for such transformation, particularly the way to impact knowledge on STEM. This paper systematically describes how to strengthen the efforts of teaching STEM to achieve better learning through metacognitive approach.

Keywords: *Metacognition, Approach, Teaching, Instruction, Learning.*

Introduction

The world of the 21st century has dramatically changed as a result of technological transformation and rapid explosion of information which has led to the beginning of 4th Industrial Revolution, this combine physical, digital and biological system (Helmi et al., 2019). The challenges of this 21st century led to what is branded as Science, Tecghnology, Engineering and Mathematics (STEM) education (Isma'il et al., 2019). Olarinoye (2019) posited that no nation can develop without STEM in this era. Therefore, to be among the develop nation, teaching and learning of STEM education need to change. According to Zakariah et al. (2016), active teaching practice involving students-centered approach is the most effective teaching process to integrate STEM in teaching. This would enhance students' creativity, curiosity and life-long learning. Metacognition has seen as a way forward because it gives much concern to theory of learning which focuses on teaching students on how to think. Aliu et al. (2020) asserted that metacognition serve as mirror which give back the

reflection of what students have learnt and how they learnt it. For effective use of this approach in STEM teaching, teacher need (a) to have general theoretical knowledge of metacognition and (b) to have the personal ability to practice metacognitive thinking with respect to classroom activities (Zohar & Barzilai, 2013).

Metacognitive concept

The complexity and dynamic nature of metacognition indicates that it is multifaceted concept. This gives rise to its different definition from literatures. Many researchers stress that metacognition is best defined by recognizing that it is both knowledge about, and control over, thinking processes (Mai, 2015). Kohasan et al. (n.d.) defined metacognition as "cognition of cognition" which means an acts of thinking about one's own mental process. Gaylo and Dales (2017) defined it as the ability to control one's own thinking processes in problem solving and higher order thinking. Siddiqui and Dubey (2018) also defined it as the ability to evaluate one's own comprehension and understanding of subject matter and use that evaluation to predict how well one might perform on a task. Hence, metacognition is the higher level of process of knowing, understanding and learning something. Metacognition encompasses a set of mental processes which enable people to understand their cognitive behavior (Jain, Tiwari & Awasthi, 2017).

As far back when Flavell who happen to be the father of metacognition and other contributors started contributing to the concept, metacognition has two main components, that is metacognitive knowledge/awareness and metacognitive experience/regulation. Metacognitive knowledge is described as what we know (awareness) about our own cognitive process (Dike et al. 2017). Metacognitive knowledge refers to acquired knowledge about cognitive processes which can be used to control cognitive processes. Herlanti and Soekisno (2018) noted that awareness of this knowledge lead to the development of stronger cognitive skills deeper information processing. Metacognitive knowledge further divided into three categories: (i) person variables or knowledge about one's self and other's thinking (ii) task variables or knowledge that different types of tasks exert different types of cognitive demands and (iii) strategy variables or knowledge about cognitive and metacognitive strategies for enhancing learning and performance (Flavell, 1979, 1987 cited in Siddiqui & Dubey, 2018). These are further modified by Siddiqui and Dubey into three sub-components:

- Declarative knowledge: This includes knowledge about oneself and others as a learner and about what factors influence one's performance.
- Procedural knowledge: This refers to knowledge of processes and actions and knowledge about the execution of procedural skills.
- Conditional knowledge: Refers to knowing when and why to apply various cognitive actions (p. 484).

Metacognitive experience took place as a result of metacognitive regulation. Metacognitive regulations are the activities or processes use to control cognitive

activities to achieve desire goals. The activities include:

- Planning: It involves the selection of appropriate strategies and the allocation of resources that affect performance.
- Monitoring: It refers to one's on-line awareness of comprehension and task performance.
- Evaluation: Refers to appraising the products and a regulatory process of one's learning (Siddiqui & Dubey, 2018, P. 485).

Advantages of Metacognition in Education

Metacognition is important because it encourage student centre learning. Metacognitive activities could be used to determine the way the students can be taught to better apply their cognitive resources for successful learning through their metacognitive control. Some importances of metacognition were highlighted by Siddiqui and Dubey (2018) as follow:

- Metacognition for Conscious Engagement: The metacognitive process helps students dwell on and analyse the learning task. This makes the students mindful learners. Mindfulness can be thought of as creating an optimally receptive state for new learning and experience, increasing the likelihood that appropriate metacognitive skills will be selected and employed. Mindfulness practice requires the activation of metacognitive knowledge, monitoring, and control.
- Metacognition for Reflective Education: One of the roles of education is to develop reflective practitioners. Metacognition involves deep reflection on the cognitive processes and then regulation of those processes to maximize learning. Metacognitive skills help learners to reflect on the task at hand and also in action and on action. It also helps learners to reflect on their own reflections, thus leading to learning that is self-directed, goal oriented and self-evaluated.
- Metacognition for greater Experiential Learning: Experiential learning is a process that takes place when the learner gains insights from direct experiences encountered by him/her. To gain these insights the learner has to be conscious of the learning experiences at hand and the strategies that would help in the learning process. Therefore, greater the metacognitive awareness greater would be the benefits obtained by the learners from the experiential process.
- Metacognition for Enhanced Thinking: Besides helping in reflective thinking, metacognition also enhances analytical and critical thinking thus enabling the learners to gain an appropriate perspective of the learning task at hand.
- Metacognition for Deep Learning: Metacognition does away with surface learning and helps learners go through various loops of learning thereby leading to deeper understanding. The learners are able to know and thereby tap the relevant resources for gaining deep learning.
- Metacognition for Greater Accountability: Students used to

metacognitive thinking, assume greater responsibility for their own learning. They are aware of their own strategies and are open to modifications in their thought processes if the situation demands. Training in metacognitive skills would help students plan their tasks and activities more effectively.

- Metacognition for Lifelong Learning: Most students drop out or do not take up further studies, as they lack the skills that are required to be self-directed learners. A practice of metacognitive skills would help in lifelong learning as they get accustomed to goal setting and strategizing their learning. (pp. 485-486)

Metacognitive Approach for Teaching STEM

Metacognitive instruction is applied for improving students' metacognitive thinking, for improving students' skills (such as reading skills, problem-solving skills or higher-order thinking skills) or for improving students' knowledge and conceptual understanding (Zohar & Barzilai, 2013). The aspect of metacognition that most useful for teaching instruction is metacognitive prompts. Metacognitive prompts are questions, cues, or probes that introduce by teachers or student peers with the aim of fostering metacognitive thinking. The purpose of metacognitive prompting is to guide learners in the process of identifying the structure of problems, creating connections with prior knowledge, and selecting learning strategies (Mai, 2015). For effective implementation of metacognitive instruction, a metacognitive instruction framework was developed, as in figure 1 (Ozturk, 2016). Referring to figure 1, teacher teaching with metacognitive instruction needs to adhere with WWW&H rule (What to do, When, Why and How to do so). This is to initiate teaching with meta-discussion and guide students through metacognitive strategies. The application of WWW&H rule is for raising students metacognitive awareness, skill and self-questioning. Ozturk claimed that in challenging students through metacognitive questions, students are prompted to become conscious of their cognitive processes, to describe, and to evaluate it before, during and after an activity.

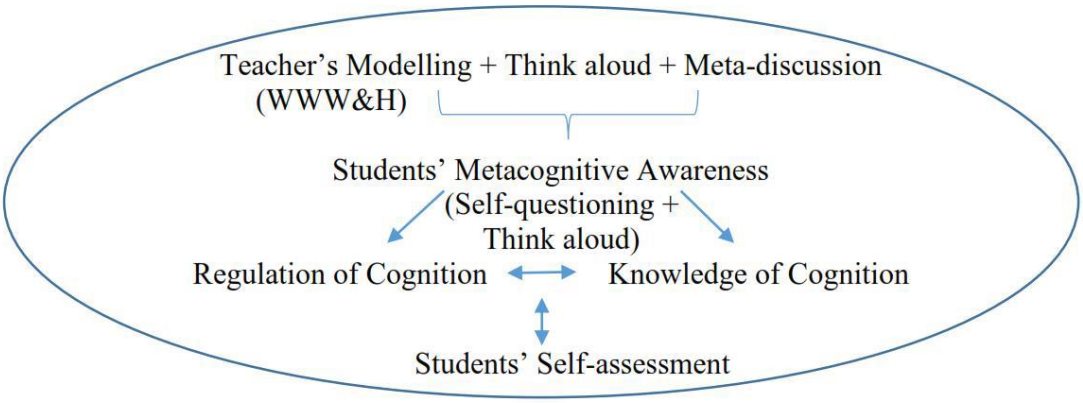

Figure 1: Metacognitive Instruction Framework (Ozturk, 2016)

The supportive learning strategies that are useful for the effective implementation of metacognitive instruction in STEM teaching includes: (1) Cooperative learning (Smith et al., 2009; Ozturk, 2016); (2) Problem-Based Learning (Smith et al., 2009; Gao & Schwartz, 2015); Zakariah, Kamarrudin, Tompang, Mohtar & Halim, 2016); (3) Project-Based Learning (Zakariah et al., 2016) and (4) Inquiry-Based Learning (Gao & Schwartz, 2015; Zakariah etal., 2016). Problem-based learning, project-based learning and inquiry-based learning are challenging learning strategies which encourage cooperative learning because students will share the problem and the information to provide solution to the problem.

Cooperative Learning

In cooperative learning, two or more students in a group work together to reach the goal of task given to them but teacher serve as instructor. Students are assigned into heterogeneous groups according different cultural backgrounds, abilities and gender (Huang et al., 2012). The smaller the group the more each member to talk, the less chance someone to be left out. Smaller groups also require less group management skills. Larger groups are good in a way that it provide more people for doing a big task, increase the variety of peoples' qualities such as skills, personalities, backgrounds etc., and reduce the number of group for teachers to monitor (Jacobs & Hall, 2002). For successful implementation, cooperative learning principles and techniques are essential tools to encourage mutual helpfulness in the groups and active participation of all members. Smith et al., (2009) identified five elements to be structured and established among the students in a group for successful implementation of cooperative learning: positive interdependence, face-face promotive interaction, individual accountability and personal responsibility, teamwork skill, and group processing. The effectiveness of cooperative learning is judge by group performance. So, each and every one of the group should be able to give explanation on the task given to their group. Hence, student need to help his/her group mate because any response given by any of the group belong to the whole group not for a particular person giving it.

Problem-Based Learning

Problem-Based learning is a student-centered method of teaching which involves learning through solving unclear but genuine problems (Etherington, 2011). The central ideas of this learning strategy are to activate prior knowledge and facilitate new learning. Students encountered by real-world problem or problem posed by teacher (through probing, questioning and challenging student thinking) that requires solution. Students analyze the problem to understand what they know about the problem, what they need to know about the problem, then apply inductive or deductive process to understand the problem and find its possible solution. This learning situation helps students to develop the skills and confidence for formulating problem they have never seen before (Smith et.al, 2009). The features that could lead to effective implementation of problem-based learning include:

- Engages students as stakeholders in a problem situation.
- Organizes curriculum around this holistic problem, enabling student learning in relevant and connected ways.
- Creates a learning environment in which teachers coach student thinking and guide student inquiry, facilitating deeper levels of understanding (Akcay, 2009, p. 28)

Project-Based Learning

Project-based learning is a teaching method in which students are directed to create an artifact (or artifacts) to present their gained knowledge (Planning & Teaching Strategies, n.d.). Artifacts here may include writings, art, drawings, three dimensional representations, videos, photography, or technology-based presentations. This instructional strategy encourage student to be actively participated in learning process to find solution to the problems. The effective activities of project-based learning give students the ability to develop the skills of 21st century such as cooperation, communication, critical thinking digital sufficiency while working in small groups to realize a common duty together (Gulmez, 2018). Some necessary steps are involve in the effective implementation of project-based learning (Aldabbus, 2018), this include:

1. Identification of the project - teacher identifies and chooses a project from a topic. This should meet the learners' needs and attract their attention.
2. Introduction of the topic - teacher should introduce the topic in an interesting way that will activate students' prior knowledge. This is to stimulate students and encourage their eagerness to know more about the topic.
3. Students' driving question – the question should be challenging, open ended and directly related to the core of the project. Driving question helps students to be focused on the area of the project and gives them a purpose behind conducting the project.
4. Students' voice and choice – students should be encourage to use their own ideas in designing the project, what materials to be used, source of information and to present the end product.
5. Feedback and revision - the teacher along with peers work together to provide constructive feedback to each other. Students usually learn from the process of conducting the project through which they revise and modify their work according to the feedback received from their teacher and peers.
6. Project exhibition - students should be encouraged as much as possible to display their projects and talk about them to other people and answer their questions. Presenting the end product to a public audience like students and teachers of other classes, parents, community members and friends is considered the main motive for students to work hard and feel proud of what they have done.

Inquiry-Base Learning

The terms inquiry generally signifies the process of acquiring or obtaining information by investigation, often personally and voluntarily carried out by

the person who is eager to know the phenomenon in question (Md Shamsudin et al., 2013). It is an instructional learner-centered approach that on the bases of inquiry, students develop knowledge and skills for a solution to a defined problem (Trna et al., 2012). Inquiry-based learning is influenced by problem-based learning in which students use an authentic problem as the context from in-depth investigation for what they have know and what to know (Akcay, 2009). This implies that the process of inquiry starts from question generated from scientific problem that require investigation through hand-on-activities or scientific experiments. The scientific experiments are required because inquiry is a process that required students understand the nature and properties of science (Khalik et al., 2018). Students involved in inquiry undergo the following five steps:

1. They engaged by scientifically oriented questions.
2. They are priority is to give evidence that give explanation to address scientifically oriented questions.
3. They formulate an explanation from the evidence.
4. They now investigate the explanation formulated from previous evidence.
5. Finally, they communicate and justify their proposed explanation.

Implication of Using Metacognitive Approach for STEM Teaching

Zohar and Barzilai (2013) posited that application of metacognition in the classroom is an extremely powerful mode of teaching. This means teaching STEM with metacognitive approach could accord many benefits for teachers, especially in making their teaching effectively to achieve STEM goals. The following are some likely benefit of using metacognitive approach for STEM teaching:

Setting and pursuing goals – this is an important in the area of metacognition. It is an high expectation of the teachers to support learners. It is what we give them the feedback after the whole process of teaching and learning.

Planning strategy – at the beginning of teaching activities, teachers would be aware of learning strategies, steps, time frame and goals to be considered. As a result, students will be actively participated. When teaching is well planned with metacognitive approach, it will be make learners become self-directed.

Generating questions – teachers would be able to ask themselves what students know, what they don't know and how students will understand what they don't know. Learners also will ask themselves these same questions during learning process. Questioning of given information will engage teachers in posing questions for themselves before and during teaching and learning process and pause regularly to determine whether students understand the concept and if they can link it with prior knowledge.

Choosing consciously – teacher would be able to explore the result of their choices before and during the decision process. Therefore, teachers will be able to establish the relationship between their decisions, their actions and the results of

their decisions. This will enable them to learn from their mistake.

Evaluating stuents' way of thinking and acting – one of the aspects that enhance evaluation of learning process accordingly is metacognition. Teachers can assess the learning activity by stating helpful and hindering aspects and their likes and dislikes of the learning activity. Metacognition give room for the evaluation on how students think and act during the process of solving problem.

Identifying the difficulty – proper identification of difficulty also shows the way we give importance to metacognition. Traditional ways of identifying students' difficulty such as "Do you understand? Any problem?" has to be discouraged. As a result, metacognition give teachers the opportunity to distinguish between students' current knowledge and the knowledge they need, this will convince the teachers the right strategy for solving the problem.

Record keeping – self-regulation is another important aspect of metacognition. For teachers to be self-regulated in their teaching process, they have to use their knowledge during planning, monitoring and information gathered or obtained through feedback from assessment. As a result teachers are required to keep all records during teaching and learning exercises.

Conclusion

The world priority on STEM education makes it necessary looking for the best way to implement it not only in the University but also in primary and secondary schools. STEM teaching requires teaching approach that supports student-centered learning and student higher order of thinking. In considering metacognitive approach for STEM teaching, teachers are required to planned well and choose a supportive learning strategy which is suitable for their own classes to fit the outcome they desire. Though, according to Mustafa et al. (2016) project-based learning was found as the most effective strategy to implement the integration of STEM education.

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