An Overview of Strategies to Induce Higher Order Thinking Skills and Factors Hindering it in Science Teaching

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Abstract

There was a high concern to produce higher order thinking individuals in Malaysia. This could be seen in the report of National Education Blueprint 2013-2015 that focused on the Higher Order Thinking Skills (HOTs) development. However, the regress in achievement in TIMMS since 2003 had shown that students are not equipped with HOTs. The HOTs development claimed to be highly connected to the ability of the teacher to integrate aspects of pedagogy, teaching strategy and technology. This paper focused on overview of the literature review of strategies used to enhance higher order thinking skills in science subject and critical analysis on the factors hindering HOTs in classroom.

Keywords: Higher Order Thinking, Science subject, Instructional strategies

1.0 Introduction

Upon realising Malaysia vision 2020, the revolution of the education system demonstrates the effort taken so as to meet the current and future demands. The ultimate goal for Malaysia is to establish a progressive industrialised society towards science and technology. The driving force has led a new reformation across the curriculum to foster individuals with science literacy. The science literacy empowers students to appreciate, evaluate and apply scientific knowledge and processes (Impey et al., 2011). Thus, it serves as an important factor to ensure nation's future development and national competitiveness.

Kamisah et al., (2009) listed the three phases of science education in Malaysia started from the 3R's basic skills to the modern science programmes where different paradigmatic approaches are applied in teaching and learning process. The third phase shifted the conventional instruction into constructivist framework of learning style. Certainly, science education is now focusing on the development of cognitive process. The intention is to nurture students with the ability to judge, analyse, solve problems and make decisions in daily life (Ministry of Education, 2005).

As the 21st century dawned, the outcome of education is expected to produce higher order thinking individuals. Zoller and Pushkin (2007) state that Higher Order Thinking Skills (HOTs) such as critical thinking and problem solving is highly related in learning science, and often demonstrated by question asking and decision-making. The students with HOTs call for greater engagement to apply the knowledge and skills in daily life. Therefore, promoting HOTs in instructional process is very crucial as it is able to enhance students' ability to solve problem in real life situation.

However, Osborne (2013) urged that the science education in school is still producing lower level thinking students. This is supported by National Science Foundation & National Center for Science and Engineering Statistic (2010) with the statement that students are unable to think critically to solve real-world problems due to inadequate science literacy. In Malaysia, thinking skills have been indicated in Integrated Curriculum for Secondary School in 1988 and has been highlighted ever since (Curriculum Development Center, 1993). However, the achievements of science in both Trends International Mathematics and Science Study (TIMMS) and Programme for International Student Assessment (PISA) are still under average score.

The failure of producing effective thinkers and quality learners shows a crisis in Malaysian education. Ministry of Education and authority parties should pay attention to solve this critical issue. This paper overviews the literature of strategies used to arouse HOTs in teaching science and the factors that hinder HOTs in classroom.

2.0 Literature Review

According to the Ministry of Education (2005), all students encounter with science learning since primary school level. Biology, physics, chemistry and additional science will offer as effective subjects to upper secondary students who are literate in science. Students are required to possess considerable HOTs in order to master the nature of these subjects. Yet, the achievements in TIMMS and PISA assessments demonstrated the ineffective science education to foster HOTs students.

TIMMS is the assessment that aims to improve the teaching and learning in science and mathematics by examining the content to learn and expected cognitive skills to develop (Gonzales, *et al*., 2008). Knowing, applying and reasoning are the three domain of cognitive in TIMMS. Gonzales *et al*. (2008) and Mullis *et al*. (2009) reported that about sixty-five percent of the assessment is devoted by applying and reasoning. Hence, lower level thinking students are unable to solve the complex tasks.

Moreover, PISA assesses and evaluates the ability of 15-year-old students to apply the science literacy to solve the problems in complex life situation (OECD, 2013). It measures the competency of the students to determine the scientific issues, explain the phenomena scientifically and use the scientific evidence to make judgement. However, OECD (2013) stated the mean score of science obtained in 2012 was 420 which is below the OECD average. Students did not reach the standard of identifying, explaining and applying scientific knowledge in a variety of complicated life problems. Therefore, it is a need to improve the science education by stressing on HOTs in teaching and learning process.

2.1 Strategies to Improve HOTs

There are many studies highlighted that HOTs are essential in science curriculum (Corliss and Linn, 2011; Fitzpatrick and Schulz, 2015; Gil-Perez and Vilches, 2005; Zohar, 2004). The outcome of HOTs is likely to occur only if the students are engaged in activities that intentionally promote this kind of thinking. This is because learning environment engages students involve in investigation of information and application of knowledge will stimulate students' critical thinking skills (Snyder and Snyder, 2008). An review of literature has done regarding to the strategies to improve HOTs. This paper overviewed the emerging studies and pointed out three strategies to improve the HOTs in science. The three strategies are using constructivist learing approach in classroom, using assessment as a tool to increase students' higher level thinking and integrating technology in teaching and learning process.

2.1.1 Constructivist Learning Approaches to Improve HOTs

Bae (2006) revealed the statement that teacher-centered teaching is the weakness of the current pedagogies used in school curriculum. Teachers who focus on delivering lectures and rigorous examinations are showing a negative outcome to produce HOTS students (Siti Noridah, 2012). Dierick and Dochy (2001) asserted that traditional teacher centered practices are unable to generate meaningful learning and HOTs. This is because teacher becomes the center of knowledge and students receive the information passively. This will only produce lower order thinking skills with only remember and understand the facts. Thus, it is important for a teacher to practice constructivist learning in order to produce active thinkers and effective problem solver.

Cognitive activation teaching strategies can be used in order to foster students' HOTs. The learning outcome should not just lean on knowledge acquisition but aid generate students' engagement to think critically, make decision and solve the complex task (OECD, 2013). Constructivist learning environment can be built via student centered learning activities. The example of student centered activities includes individual and group project, presentation, problem solving exercises and written assignment (Phelan, 2012). Teachers take a role as a facilitator to encourage and guide the students to think critically.

For instance, education in Finland emphasises on HOTs by conducting student-centered teaching approaches that uphold the principles behind the constructivist theory (Sahlberg, 2009). The students are required to transfer and apply their knowledge in new real life situation. The students are fostered with the ability to make judgement, analyse, solve problem and make decision in daily life. This is the reason why students in Finland are able to consistently achieve high performance over all the assessed subjects in five PISA survey cycles since 2000 (OECD, 2001; 2004; 2007; 2010; 2013).

Many scholar and academicians have attached a great importance to foster HOTs via learning activities. They are many methods to create active learning environment such as Socratic questioning (Yengin & Karahoca, 2012), alternate assessment (Elder, 2004; Gronlund and Waugh, 2009), argumentation (Bailin and Siegel, 2003), concept mapping (Bramwell-Lalor & Rainford, 2014), technology rich classroom (Siti Noridah, 2012; Bae, 2006) and collaborative learning (Johnson et al., 2010; Dierick and Dochy, 2001). Ministry of Education (2005) urged that teaching science through inquiry and problem solving activities could promote students' HOTs. Teachers need to develop their ability to plan, execute, and improve the instruction with the purpose of generating HOTs in classroom. Teachers should engage students to seek for better understanding instead of becoming source and center of knowledge transmission.

2.1.2 Assessment as a Tool to Improve HOTs

Phelan (2012) critique that the purpose of lecturing is to guide the students to perform well in tests. Therefore, students spent ample of time to study the questions that will be asked in tests. They regarded the score of the result is determinant of their competency. This phenomenon has obstructed students to connect and transfer the knowledge to the real world context. There is a concern regarding to the teaching for understanding and teaching for examination at upper secondary physics education

(Geelan et al., 2004). However, they found in their study that teaching for understanding and teaching for assessment are highly related. It can create better learning outcome if teachers conduct both these things.

Bramwell-Lalor & Rainford (2014) agreed the statement by revealing that the assessment is a link between teaching and learning. A claim made by FitzPatrick and Schulz (2015) revealed that there was a strong alignment between the learning outcome and classroom assessment to foster HOTs students. Van der Berg (2004) clarified that assessment provided the information for teachers to identify the progress of the students and the outcome of the instruction.

There are five types of assessment, which are baseline assessment, formative assessment, summative assessment, portfolio assessment, and systemic assessment (Van der Berg,2004). The classroom assessment should focus on deep understanding and critical thinking (McMillian, 2010). Rote learning and low cognitive assessment will only produce lower level thinker. Questions must be able to assess the extent of thinking such as explanation, application and evaluation. Lower level thinking questions should be avoided. Thus, many studies have highlighted the importance of HOTs assessment that emphasised more on scientific reasoning and applications.

Teachers can utilise the taxonomy suggested by Anderson and Krathwohl (2001) to formulate learning material and assessment. Moseley el at. (2005), Aksela (2005) and Fitzpatrick and Schulz (2015) suppoted the taxonomy as it provides a good approach to analyse curriculum outcome and categorize the instructional goal. The higher cognitive level in the taxanomy claimed to be apply, analyse, evaluate and create. Therefore, the assessment created by the taxonomy can be used as a good tool to identify students' HOTs.

The report of National Education Blueprint 2013-2015 also revamped the national examination and school-based assessment toward the development of HOTs (Norzie, 2013). Certainly, Ministry of Education is taken the effort to reform the current curriculum in order to produce more HOTs students. Teachers have to change their conventional teaching routine to more student cognitive active learning environment. However, it is important to aware that the result of the assessment is not the criterion to identify students' competency, it indeed carries a developmental role.

2.1.3 Using Technology-enriched Environment to Improve HOTs

Upholding the National Science Education Philosophy, science education aims to produce individuals with the competency of science and technology (Ministry of Education, 2005). Instruction process that integrated with technology arouses students' interest and develops their learning potential in science literacy. Moreover, studies done by Hajar & Halimah (2007), Norzie (2013) and Siti Noridah (2012) urged that technology used in education can enhance students' HOTs. Rakes, Fields, and Cox (2006) affirmed that technology which blended within constructivist approach could provide a meaningful instrument to foster students' HOTs. The integration of technology and constructivist approach enables students to generate deep learning and to construct their own knowledge which will lead to the enhancement of learning performance.

Technological advancement in education has brought a change from conventional instruction to constructivist framework of learning style. This transformation can meet the current and future needs in this era (Dede, 2007). Phelan (2012) indicated that educational curriculum which integrates with information and communication Technologies (ICT) has positive impact in enhancing the learning potential and thus developing students' HOTs. For instance, Aksela (2005) studied using computer assisted inquiry to support secondary chemistry students meaningful learning and HOTs. This is because the approach stimulates the learning atmosphere and engage collaborative learning and inquiry learning (Green, 2001). The students are keen to transfer their knowledge acquiration to knowledge application while dealing with the tasks using instructional technology (Alkeaid, 2007). Hence, ICT can be the instructional technologies to enrich students with HOTs.

2.2 Factors of Hindering HOTs in Classroom

Based on the result in TIMMS 2011, Martin *et al.*, (2012) declared that the science education in school is still focusing on knowledge acquisition instead of instilling HOTs. This is because most of the students scored well in lower level of thinking skills rather than applying and reasoning. Osborne (2013) specified the lower thinking level is in recalling domain. He claimed that the failure to meet the current and future needs is caused by the lack of a good model of scientific reasoning and a body of expertise about the way to assess HOTs. A contrary claim made by Zohar (2013) that there are many research supporting models and theories to teach thinking skills in science during the past 30 years. He asserted that the good models are effective in arousing HOTs.

The important objective in teaching science is to foster HOTs. Ministry of Education has offered many programmes that infuse teachers new strategies and pedagogies to teach HOTs in class (Rajendran, 2001). He stated that there was no significantly influencing them to teach HOTs. Barak and Shakhman (2008) presented that not many teachers aware the issue of enhancing HOTs in school. Education Reform in Malaysia Report (2012) also stated that teachers are paying less concern to teach students HOTs. Therefore, it is prevalent to probe deeply to discuss the reason hindering the execution of HOTs in classroom.

It is evident that teacher who carries out the instruction in classroom plays a vital role in generating HOTs learning environment. The way how a teacher teaches is the key factor to generate HOTs students, not the content taught in the classroom. The transition from knowledge transmission to the knowledge construction required a huge change in daily teaching practices. Zohar (2013) suggested the types of knowledge of a teacher possess to conduct HOTs are subject matter knowledge, pedagogical content knowledge, metacognition (metacognitive knowledge and metacognitive skills) and knowledge of pertaining to constructivist approach. This definitely challenges teacher's capability in teaching process. They need to put extra efforts in order to adapt the HOTs teaching strategies.

There are some studies exposed the reasons why the teachers do not teach HOTs. Levinson (2006) stated that teachers are busying on daily teaching routine and have no time to reflect deeper on HOTs. There are contextual factors such as lack of time, large classes or mandatory exam (Barak and Shakhman, 2008). Hajar & Halimah (2007) explained that the teachers have heavy teaching commitment as they are required to finish the syllabus within a short period. Hence, it is difficult for them to directly practice the research-based ideal in the classroom.

Lastly, Barak and Shakhman (2008) also identified some of the teachers are lacking of knowledge and experience either in subject matter or in a certain instructional approach. This has impeded the teacher to create cognitive activation learning environment. Apart of that, teachers need further clarification regarding to the nature of thinking strategies. This is because these thinking strategies are tightly upholding to the backbone theories which are different with the conventional teaching practices. There is one example of the lack of clarification about the nature of inquiry

(Abraham & Millar, 2008; and Abraham & Reiss, 2012) Teachers offer more hands-on experiences than minds on during the learning process. It eventually showed the undesirable outcome of inducing HOTs.

7.0 Conclusion

In conclusion, the importance of fostering HOTs in science education is well recognized. It definitely can be a good support for students' content knowledge development (Beyer and Davis, 2008). This paper overviewed the literature regarding to the strategies used to foster HOTs in science curriculum. Based on the emerging studies, using constructivist learing approach in classroom, using assessment as a tool to increase students' higher level thinking and integrating technology in teaching and learning process are three way to induce HOTs. Moreover, the factors hindering HOTs in classroom are probed deeply in this paper too. All in all, the effectiveness to nurture HOTs in teaching and learning process is highly connected to the ability of the teacher to integrate aspects of pedagogy, teaching strategy, assessment and technology. It is indispensable to raise the teachers' understanding both theoretically and practically in teaching science with HOTs (Schulz & FitzPatrick, 2013). Teachers need to change the traditional view of teaching and embrace the new design of approaches with the intention to successfully embed the HOTs into the existing Malaysian science curriculum. Thus, teachers should reflect on and enhance their professional development in order to align the outcome with the curriculum goal.

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