Effects of Computational Thinking Competencies on Scientific Argumentation Learning among Secondary School Students

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Abstract: Argumentation in science education has emphasised on the engagement of students in making scientific claims where they communicate with others. The argumentation is a problem-solving process that nurtures students' higher order thinking (HOT) by encouraging them to think critically and create solutions. Computational thinking (CT) is the competencies integral for successfully solving problems posed in a technology driven teaching and learning context. Teachers need to develop and scaffold the students' CT competencies to equip them to be future-ready learners. Accordingly, this study will design instructional strategies for teachers to embed CT-integrated instruction within argumentation teaching in the context of Biological science. Subsequently, the development of students' CT competencies and argumentation performance will be assessed. The five CT dimensions taken into account in this study are abstraction, decomposition, generalisation, algorithmic design and evaluation. As there is a growing trend of integrating CT across various disciplines, problem solving is no longer viewed as a final goal of learning in science. Instead, it is a competence that should be acquired by individuals to apply throughout the acquisition of scientific knowledge.

Keywords: Computational thinking, argumentation, problem solving, higher order thinking

1. Introduction

Argumentation have been advocated as the core practice in science education to develop higher-order thinking (HOT) (Eskin, & Berkiroglu, 2008). The mastery of scientific argumentation competencies nurture students' HOT such as reasoning abilities and thus facilitating their academic achievements (Heng, Surif, & Seng, 2015). The scientific argumentation is emphasised through the adoption of higher order thinking skills (HOTS), which is reasoning skills in the primary and secondary school curriculum in Malaysia. Reasoning skills is one of the HOTS required in problem solving activities. At this point, Malaysian school-based Science assessments focus more on problem-solving skills and creativity. In solving scientific problems, argumentation require problem solvers to identify different viewpoints, create a reasonable solution supported by data and evidence. Along this line, Computational thinking (CT) embraces HOT, as CT is a problem-solving approach that draws on fundamental Computer Science (CS) concepts to reformulate and solve the problems (Wing, 2006). CT has been integrated into Malaysian school curriculum in January 2017, starting with primary and secondary students. Research highlights that there is a growing need to integrate CT into academic subjects (Yadav, Hong, & Stephenson, 2016). However, there is lack of empirical findings about how CT can be used to improve the science instructions. Hence, this study focuses on developing students' CT competencies through scientific argumentation.

2. Literature Review

2.1 Higher Order Thinking in Scientific Argumentation

Argumentation is known as a fundamental aspect of science education and has become one of the major objectives in teaching and learning of science (Duschl, Schweingruber, & Shouse, 2007). Recently, the review on the future argumentation research suggested teaching HOT through argumentation (Henderson, McNeill, González-Howard, Close, & Evans 2018). The problem-solving process enhances individuals' HOTS, such as reasoning skills as they are required to apply and communicate relevant knowledge based on the context. The HOTS can be developed through scientific argumentative practices (Eskin & Berkiroglu, 2008). Nevertheless, very little attention is given to argumentative tasks in the teaching of science in Malaysia (Heng et al., 2015). From 2016 onwards, the primary and secondary school national assessments in Malaysia comprise at least 40% of HOT questions. However, despite the implementation of HOT development from primary to secondary school level, most Malaysian students are still facing difficulties in comprehending the science content (Academy of Sciences Malaysia, 2018). Thus, more efforts in polishing teachers' instructional practices is needed to improve students' scientific argumentation through enhancing HOTS (Ping, 2019). The teachers play a critical role in deciding the critical aspects of the learning and how to make learning visible for students (Voon, Wong, Looi and Chen, 2020).

2.2 Integration of Computational Thinking Competencies into Argumentation Learning

Past research has indicated that CT can be used as a means to improve problem solving skills (Wing, 2006). CT fits in the framework of competencies from the perspective of cognitive dispositions as described by Klieme, Hartig and Rauch (2008). Acquisition of CT can be accomplished by gaining experience from relevant context of demand, it may be affected by external interventions and can be enhanced by continuous practices to build the expertise in a particular domain. Based on the studies conducted by Korkmaz and colleagues (2017), the five CT competencies which were widely-accepted by the International Society for Technology in Education (ISTE), Computer Science Teachers Association (CSTA), and US National Science Foundation (NSF) are described in detailed as: (1) critical thinking is the ability to analyse and make assessment-oriented judgments that lead to decision making; (2) problem solving refers the ability to sustain in investigative processes by generating solutions; (3) algorithmic thinking means the ability to think in a detailed way by placing the proceedings in sequence to produce a solution; (4) creativity is the ability to develop genuine ideas with the combination of existing ideas and new ideas through critical thinking and problem-solving; (5) cooperativity refers to the ability to help each other in learning with different methods in accordance with a common purpose.

2.2.1 Computational Thinking Dimensions

Research shows that the integration of CT into science learning has the potential to help students learn science contents and science practices (Wing, 2008). In this study, CT will be integrated into the topic of Human Reproduction in the science curriculum as many misconceptions have been consistently identified globally (Sirovina, & Kovačević, 2019). Given the pervasiveness of CT in STEM, this new competence is a foundational competency for being successful in STEM work (Wing, 2010). However, CT is relatively new to the field of science education (Peel, Sadler, & Friedrichsen 2019). There were many interventions conducted in the programming context but limited empirical studies focusing on CT learning and science learning (Kalelioğlu, 2018). Hence, there is a clear need for empirical studies supporting the integration of CT and science, especially connecting to science learning outcomes (Peel et al., 2019). Therefore, this study intends to investigate the effects of CT competencies on students' argumentation performance. This study will design instructional practices to develop HOTS by integrating five CT dimensions into scientific argumentation: (1) abstraction requires individuals to identify the most important aspects of a problem; (2) problem decomposition is to break down problems into smaller and more manageable parts, then focusing on solving each part of problem; (3) algorithmic design focuses on creating step-by-step processes to complete a task or solve a problem; (4) evaluation refers to the identifying, judging the possible solutions and applying the best solution, improving the solution to be applied in other situations; (5) generalisation means taking a solution (or part of a solution) to a problem and generalising it so it can be applied to similar problems.

3. Research Objective

This study aims to investigate the effects of CT competencies on argumentation learning among secondary school students. It also proposes the integration of CT dimensions into instructional practices to improve students' scientific argumentation learning: first by integrating five CT dimensions into lesson plans to develop students' CT competencies; second by evaluating the effect of CT competencies on their scientific argumentation performance.

3.1 Theoretical Framework

This study will employ the interactive constructivism founded by Reich (2007) as the theoretical framework to examine the effects of CT in supporting teachers' instructional design of spoken and written argumentation. The interactive constructivism comprises the features of radical constructivism (Von Glasersfeld, 1989) and social constructivism (Vygotsky, 1978). The synthesis of radical and social constructivists stated that knowledge is self-constructed and socially mediated (Tobin & Tippins, 1993). The theoretical framework asserts that learning has both public and private landscapes. The public landscape focuses on active knowledge construction in a social environment whereas private landscape of learning occurs through individual's learning reflection (Chen, 2011).

3.2 Research Question

This study examines the effectiveness of the CT-integrated instruction in argumentation, particularly focusing on (1) students who are taking and those who are not taking CS subject; (2) students with high and low academic performance. The following research questions guide this study:

RQ 1. Is there a significant difference in scientific argumentation scores between academically high and low students from CS group in applying the five CT-dimensions?

RQ 2. Is there a significant difference in scientific argumentation scores between academically high and low students from non-CS group in applying the five CT-dimensions?

RQ 3. Is there a significant difference in scientific argumentation scores between the CS and non-CS groups in applying the five CT-dimensions?

RQ 4. Is there a significant difference in scientific argumentation scores between students with high and low levels of CT competencies among academically high and low students in CS and non-CS groups?

4. Research Methodology

To answer the aforesaid research questions, this study employs a factorial design to investigate the effect of CT-integrated instruction in Science lessons. The study adapted Science Talk Writing Heuristic (STWH) approach developed by Chen (2019). To build upon STWH approach, this study emphasises the scientific problem solving by integrating CT dimensions into argumentation, known as CT-argumentation (CTA). The teacher and student templates will be given as a guideline before the intervention. This study adopts the Computational Thinking Scale (CTS) developed by Korkmaz and colleagues (2017) to measure the five CT competencies. A pilot study will be conducted before the intervention. For the actual study, a total of four intact science classrooms will be chosen from two public secondary schools located in Selangor state. Each class consists of at least 30 students. For each school, there will be two groups of students which undergo the same intervention— one group who takes CS as a subject while the other group does not. During analysis, each group will be further divided into two levels (high and low academic) to compare the effects of intervention. The study will be conducted for six weeks, including the administration of pre-test, posttest, delayed posttest, and treatments. The CT-integrated lesson plans which developed for the intervention will be validated by a panel of science experts. In data analysis, the statistical test of two-way split plot analysis of variance (SPANOVA) will be used to answer the first and second research questions. Subsequently, two-way ANOVA will be used to address research questions three and four to determine the possible combined effects of the CT dimensions.

5. Proposed Contribution

This study serves the purpose to inform science teachers that it is possible to develop students' HOTS through argumentation. Meanwhile, it is crucial to make students aware of their CT competencies are closely related to their scientific problem-solving abilities. This study also serves to inform policy makers to focus on the development of students' CT competencies as this can have an impact on the effectiveness of their learning. Further, this study can contribute to the existing body of the research on the integration of CT in STEM education, particularly to propose the design principles of CT-integrated instruction in science education.

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