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Developmental Methods on Mathematical Higher-Order Thinking Skills in Indonesia: A Systematic Review

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Higher order thinking skills (HOTS) has been used as the standard for the Indonesian computer-based national examination (CbNE) in 2018. This study aims to review the recent research on HOTS-based mathematics education in Indonesia, and further observe its correlation to students' readiness and the outcomes of the national examination for mathematics. A systematic and descriptive review of recent published studies in regards to HOTS-based mathematics education in Indonesia has been undertaken in this study. The findings show that HOTS-based study plays an important role in improving students' thinking skills as well as supporting their success. However, various studies on the application of HOTS in mathematics education in Indonesia still require improvements, especially in shifting from lower order thinking skills to HOTS, which can be seen from the lower national score in the national exam for mathematics in 2018 compared to previous years. Research has shown there are several learning approaches to improve the mathematic HOTS of the students, such as Realistic Mathematics Education (RME), Relating, Experiencing, Applying, Cooperating, Transferring (REACT), Open-Ended Problems, Problem-Based Learning and Inquiry learning.

Key words: *Creative Thinking, Critical Thinking, Higher-Order Thinking, Mathematical Problem, Computer-based National Examination (CbNE).*

Introduction

Since 2018, the Computer-based National Examination (CbNE) in Indonesia began to apply Higher Order Thinking Skills (HOTS) as the national standards, after being previously based on the skills which are now categorised as Lower Medium Order Thinking skills. In the press release of the Indonesian Ministry of Education and Culture (Kemendikbud), it was mentioned that these changes also contribute to the decline in the average CbNE score in 2018 as compared to the previous years, especially in mathematics, physics and chemistry subjects (Kementerian Pendidikan dan Kebudayaan, 2018).

In HOTS learning, students are expected to be able to think at a high level, which consists of critical, logical, reflective, metacognitive and creative thinking (Adams & Hamm, 2010). In short, critical thinking is a person's ability to evaluate thought processes systematically and scientifically (Popil, 2011), whereas logical thinking is directed towards drawing logical conclusions from premises (Goldstein, 2011). Furthermore, reflective thinking is an active, persistent, and careful thinking process of knowledge based on a theoretical basis and on conclusion drawing (Dewey, 1933), while metacognitive thinking is an individual's ability to monitor, assess and modify the progress of their learning through mental processes possessed to obtain effective learning (Bransford et al, 2012). Creative thinking is the ability to think in a way that leads to the search for other alternatives to solving problems (Krulik et al, 2003).

Based on these definitions, it can be seen that students are required to have a variety of thinking skills in order to solve HOTS problems. This study aims to examine various studies on HOTS learning and its relation to education and mathematics issues, so as to provide information about HOTS and how it correlates with CbNE in mathematics.

Method

Systematic reviews of published articles and journals on Higher Order Thinking Skills (HOTS) and mathematics education were carried out in the preparation of the articles of this study. The used keywords for article selection were “HOTS” and “Mathematics Education”, with both contained in the abstract, keywords, and/or titles in the literature. A number of library studies that emerged were then selected based on the basic theory of HOTS, and then based on proximity to the focus of the study theme.

Results and Discussion

Higher Order Thinking Skills (HOTS)

Early research has shown that through HOTS, students can obtain clarity, relevance, consistency, logic, deepening, wholeness, and deep meaning in thinking (Lewis & Smith, 1993). The development of higher-order thinking learning began in ancient Greek times, as far back as the Plato era (Resnick, 1987). For decades, the term 'higher order thinking' was associated with critical thinking or reflective thinking, the idea coined by Lipman (Lipman, 1991), that distinguishes between lower-order cognitive skills and higher-order cognitive skills. The difference between both skills are determined by complexity, scope and thinking patterns on problems; the ability to think logically; and the intensity of qualitative thinking skills. In short, those researchers have defined HOTS as a way of thinking that goes beyond memorising, recalling and comprehending information comprehensively, and to reaching the stage of analysis, evaluation and the creation of new knowledge based on information already obtained (Lipman, 1991; Resnick, 1987).

Even though the definitions of HOTS still overlap one definition with another (Cuban, 1984), researchers generally agree that HOTS consists of complex cognitive activities such as developing hypotheses, describing, interpreting and analysing information received; compiling arguments; making comparisons and conclusions; integrating information; and resulting in several solutions (Bradley et al, 2007). Based on this, several aspects that make up HOTS can be named, specifically the ability to think critically, logically, reflectively, metacognitively and creatively (Adams & Hamm, 2010)

Critical thinking is a meaningful thinking activity, with an assessment that is controlled by each individual to interpret, analyse, evaluate and conclude, both in the form of explanations and considerations of a problem that is being thought about or faced (Abrami et al, 2015). This shows that someone with critical thinking ability is able to provide an independent assessment of the problem at hand. Woolfolk states that the ability to think critically is one aspect of higher level thinking that requires the conscious application of knowledge in abstract, heuristic and procedural form, which can be learned from a context in several new conditions or situations (Woolfolk, 1998).

The origin of logic as a key component of mathematical arguments can be examined onward from the time of Aristotle's logic and its use in syllogism, where the method is continually updated by scholars or thinkers through the found paradoxes. The importance of the function of formal logic in mathematical arguments continues to increase and reaches its peak in the 19th century and early 20th century (Umland & Sriraman, 2014). In general, logic in mathematics is related to two main aspects, namely mathematical language and mathematical functions in proof, argumentation and reasoning (Durand-Guerrier, 2014). Logic as a mathematical language has a role in the conceptualisation process (Vergnaud, 2009), where logic plays a role in determining 'true' or 'false', as a predicate function, and a complementary argument in the predicate. The relevance of logic in the preparation of evidence, arguments and mathematical reasoning has been developed by Durand-Guerrier (2014), where these aspects are part of the problem-solving process.

The classical theory of reflective thinking that has been widely discussed from year to year is Dewey's Theory (Dewey, 1933). This theory states that reflective thinking is an active, persistent and careful thinking activity towards a belief (theory) or a science, based on supporting theories and tendency conclusions. The theory was further developed by Taggart and Wilson (1998) who state that reflective thinking is a logical decision-making process and is based on information held and then assesses the consequences of those decisions. On mathematics education, Meissner (2006) states that reflective thinking is an important aspect on the study. Moreover, reflective thinking not only indicates an individual's competence, but also show one's ability to be able to act and think professionally (Barton & McCully, 2007). Solovieva and Quintanar (2004) and Gonzáles-Moreno (2012) in Sánchez-Martí et al (2018) add that students with reflective thinking skills will go through several thought processes, namely paying attention to learning attitudes (how they learn), being aware of what they are learning, and use them to regulate their own learning process.

Metacognitive abilities were first coined by Flavell (1979) who defined metacognitive abilities as "awareness of self-awareness" or "thinking about thinking". Research on metacognition is then continued by Brown and Palincsar (1989), who defined metacognition as something that is used by students in learning planning and problem solving, in awareness and the regulation of thought processes. Schraw and Dennison (1994) then developed the metacognitive definition as the ability to reflect, understand and be able to regulate the learning process. Veenman, Van Hout-Wolters and Afflerbach (2006) later defined metacognition activities as a method that facilitates and regulates awareness, which include monitoring and regulating the individual's learning process. Their research then categorises metacognition abilities as higher order thinking skills and as more difficult to teach compared to training cognitive abilities.

The definition of creative thinking can be adapted from Wallas's theory in his book "The Art of Thought", where creativity is divided into four stages of thinking: preparation, incubation, illumination (and its accompaniments) and verification (Wallas, 1926). The theory was later developed by Osborn in the 1950s (Osborn, 1953) when creative thinking was divided into seven step models: orientation, preparation, analysis, ideas, incubation, synthesis and evaluation. However, the definition of creative thinking is more deeply introduced by Taylor (1975), who states that creative thinking is a process of transformation of an individual with their environment through several stages: (1) exposure, where an individual becomes open and sensitive to their environment, assimilates and accommodates the information obtained, then classifies, differentiates and integrates that information; (2) initial differentiation, characterised by natural data interactions, unconscious incubation, induction, and even information overload; (3) conversion, characterised by the experience of new enlightenment, or commonly referred to as the "Eureka" phase, where in this phase a sudden new idea is derived from information reformulation, whether through literary thinking, analogy or metaphors; (4) the end of differentiation, in this phase new ideas are formed through deduction, conclusion drawing, verification and the extrapolation of ideas; and (5) expression, where creative ideas are implemented and conveyed. Mace and Ward (2002) then developed four stage models in understanding the process of creative thinking in their research. In the first stage students try to understand the concepts for creative thinking; in the second stage students begin to develop ideas by sorting and organising the creative ideas that have been obtained; in the third stage students begin to realise these creative ideas; and in the final stage, students decide and perfect the creative ideas used. Students then evaluate the creative products obtained by selecting and determining the best ideas. The whole process will undergo a trial of right and wrong or "trial and error", so that the wrong product will be eliminated and the best results will be obtained.

Based on the theories that have been elaborated on the aspects that make up higher order thinking ability or HOTS, it can be seen that each of these aspects complement each other. The ability of reflective thinking requires the ability to think logically, and awareness (cognitive) is needed to be able to think reflectively and critically. Furthermore, the ability to think metacognitively also requires the ability to think reflectively, and each of these abilities is used to be able to think creatively.

Higher Order Thinking Skills (HOTS) on Mathematics education

The development of HOTS-based education can be seen from the many international competency models that develop critical thinking models and problem solving in multidimensional and unpredictable situations (Vidergor, 2017). This is inseparable from various educational research results that show HOTS is an important indicator of one's success both in the academic field and in the world of work (Zohar & Dori, 2003). The policy of the Ministry of Education and Culture (Kemendikbud) of the Republic of Indonesia in applying HOTS questions for the Computer-based National Examination (CbNE) then shows an effort to improve national education standards. The policy also answers to many criticisms that are aimed at higher education/universities that have not been able to spur higher-level thinking skills to produce graduates with good problem-solving skills (Laurillard, 2002).

The ability to think at a higher level (HOTS) is an important aspect of learning. Students who have HOTS ability are known to be able to learn and have good performance and are able to suppress their own weaknesses (Yee et al., 2011). Students who have HOTS are trained to be diligent, resilient and confident in unusual situations, possessing great curiosity (NCTM, 2000). Students can have meaningful understanding if the concept is actively constructed by them through discovery, and by the association of these concepts with other concepts or with real context both in daily life or in students' minds (Mairing, 2017). Given the importance of

HOTS, and based on the constituent aspects of HOTS, the teaching of mathematics subjects with the HOTS approach can be carried out with methods that can enhance students' critical, logical, reflective, metacognitive and creative thinking abilities.

In teaching the improvement of critical thinking skills, applications in critical thinking must also be used as a basic foundation for the preparation of standard mathematical teaching methods, so that critical thinking skills in mathematics education can continue to be cultivated. This foundation also covers a broader social context, as has been proposed by various studies (Keitel et al, 1993), with the aim to expand students' thinking abilities beyond the instruments used through the inclusion of moral and political thinking. From an educational standpoint, logic in proof and mathematical reasoning has an important function. In spite of this, various empirical studies show that logic in mathematical language is still a scourge for students (Durand-Guerrier, 2014).

Reflective thinking ability has long been associated with mathematics education, given that mathematics education also directly provides a "natural laboratory" for students to solve problems, where the process requires reflective thinking ability (Sánchez-Martí et al., 2018). Contreras in Sánchez-Martí et. al. (2018) shows that reflective thinking training can be done through the reflective writing method, where students learn about themselves, by themselves, and involve themselves in the learning process. The research then formulates conditions that must be met to improve students' reflective thinking skills in the learning and teaching process. These are:

1. Learning activities can invite students to identify actions in various cognitive activities as well as being aware of the structure in the learning process, including components, functions, basic characteristics and learning rules.
2. Learning activities can stimulate students' cognitive interest, motivate and then guide students, and provide feedback on a regular basis.
3. Learning activities can maintain stability, responsibility and regularity in learning activities, so that it can improve the learning process and train students cognitively to manage the knowledge they have and provide a framework for subsequent understanding.
4. Encourage communication between teacher and students and have a good learning environment.
5. Provides mastery of a subject and material.

Metacognitive abilities are known to have a positive impact on student performance in learning mathematics. Research by Legg and Jr. (2009) shows that metacognition did not only affect the mathematical scores of students, but also increased the responsive time and their confidence in solving mathematical problems. A similar result is also obtained by Hoorfar and Taleb (2015), who found that concerns about learning mathematics will decrease alongside the increase in students' metacognition abilities. The practice of improving students' metacognition skills has been continuously observed and developed. Aarnos and Perkkila (2012) state that to improve students' metacognition, mathematics learning must also be accompanied by real life examples that lead students to real experiences. Wei (2010), in his research entitled *"The effect of pedagogical agents on mathematics anxiety and mathematics learning"* shows how teaching through animation can reduce anxiety in learning mathematical subjects. Furthermore, Zimmerman (2002) divides the three stages in metacognition thinking activities that can be utilised to practice students' metacognitive thinking skills. In the initial stage, students analyse the problem and draw up a plan to solve it. In the second stage, students learn and solve problems by paying attention to a problem and understanding the material that is in the problem that occurs (Kostons et al, 2010). The last stage is self-reflection, where students evaluate the learning process and the results of learning, so students can obtain information that can be used in solving problems in the future.

Research by Schunk (2012) shows that in the context of instructional learning processes, the condition of the social environment can affect creativity. However, Piaget's theory, which has been widely cited, is more about elaborating and focusing on students' knowledge alone in making an idea and pays less attention to the influence of the social environment. According to Hill et. al. (2003), students can obtain information both from internal and external factors. The internal factors in question are the knowledge students have based on previous learning and the knowledge gained spontaneously based on experience (cognitive ability), while the external factor is where students obtain data and information from others, such as teachers and friends, or other references (Sinaga et al., 2015). This statement is also supported by research from Oakley et al (2004), which suggest that teachers, as an external factor, can facilitate students by giving real examples of problems to be solved so that students can be able to solve problems that are more complex than cognitive abilities that have been owned. The teacher's role is also elucidated by Nadjafikhah et al (2012), in the incubation phase of the creative thinking process by students. The incubation process in question is the phase in which students think about problems subconsciously.

Weisberg (2006) states that creativity can be stimulated through specific training prior to entering the phase of making creative ideas. The training aims to improve students' abilities in creating creative ideas, so that they have more significant opportunities in compiling these ideas. One method that can be used to improve creative thinking skills in mathematics is through the Realistic Mathematics Education (RME) method, or realistic mathematics learning. Various studies have been carried out on realistic mathematics learning methods in improving logical and creative abilities (Usdiyana et al, 2013) and have shown positive results. Realistic mathematic learning methods require students to be able to arrange cognitive abilities that have been acquired into creative thinking processes that consist of:

preparation, incubation, illumination (and its accompaniments), and verification of information (Sitorus & Masrayati, 2016). In RME, mathematics is reflected as a subject, and how mathematics is learned and taught. The concept of reality in realistic mathematics learning is knowledge that has been understood by students, and then becomes a scheme of thinking that can be linked in the context and concepts of mathematics. These conditions are known to stimulate the creative thinking process of students (Heuvel-Panhuizen & Drijvers, 2014).

Various studies in various countries have been conducted to improve the ability of HOTS in mathematics. Foong (2000) compiled research on open-ended mathematical problems to improve HOTS ability in Singapore, Murray (2011) researched HOTS implementation in mathematics in junior high school students in Georgia (USA), while Ghasempour et al (2012) examined HOTS ability in engineering students through mathematical problems, in Malaysia. Tajudin (2015) reports on HOTS abilities in mathematics through algebraic problem solving in Turkey. Several studies conducted in Indonesia also examine methods to improve the ability of HOTS, such as realistic mathematics education (Kusumawati & Turisia, 2014), Relating, Experiencing, Applying, Cooperating, Transferring or known as REACT (Anisa, 2014), the application of open-ended problems (Pitajeng, 2006), problem-based learning (Prayanti et al, 2014) and study discovery (Sahrudin, 2014). These methods are known to improve students' HOTS abilities and can be applied in mathematics education in schools.

HOTS-based National Mathematics Examination in Indonesia

The national examination is one of the methods of assessing national basic and secondary education standards (Azis, 2015). The results of the national examination then become one of the cornerstones in the preparation of national education policies. The decline in the average score in mathematics in CbNE 2018 became a benchmark for the HOTS ability of students in Indonesia. These results are also consistent with the results of several other studies examining higher-order thinking skills of students in Indonesia. Research by Prastiti (Prastiti & Mairing, 2018) on high school students in Surabaya shows that only 5.4 percent of students were classified as very creative, while 67.7 percent were still classified as less creative and 4 percent are classified as not creative. A similar condition was found in high schools students in Gedangan Sidoarjo, Indonesia, where no more than 3 percent of these students had HOTS (Mahendra, 2015). Research by Aini et al (2017) on high school students in Jember, Indonesia, showed that around 26 percent of the study sample had the ability to think logically in mathematical subjects. However, the study added that as many as 100 percent of students who have the ability to think logically are also able to think creatively.

Research by Prasetyani et al (2016) on the ability to think at the higher level of trigonometric learning based on a problem high school class on Palembang, Indonesia, shows that less than half of the sample subjects had good high-level thinking skills. Research on high school students from Palangka Raya, Indonesia, shows that 3.1 percent of students are classified as less experienced problem solvers and none were classified as good problem solvers. These study results serve to elucidate the decline in the average CbNE score in mathematics, which is lower than previous years that have not applied HOTS questions yet.

Research by Tjalla and Putriyani (2018) on the mathematical metacognitive thinking abilities of grade junior high school students in Papua showed a low ability of their metacognitive thinking; the research also shows that students' metacognitive thinking abilities in Papua also play a role in problem solving abilities in studying mathematics. These results indicate that there is still a need for adjustments and improvements at the HOTS mathematics education stage, given that the standard has been applied to CbNE.

Conclusion

Higher Order Thinking Skills, or HOTS, is a high-level thinking ability that requires students to be able to think critically, logically, reflectively, metacognitively and creatively. The application of HOTS to the CbNE mathematics subject indicates government policy to improve the standard of students' thinking abilities. The results of this study show that HOTS standard education has an important role in the level of thinking ability and student success. The results show that HOTS standard on mathematics education is still needed. The decline in the average of CBNE 2018 score for mathematics is known to be caused by the low ability of HOTS in students in Indonesia, which has been demonstrated by several studies. HOTS standard education improvement can be implemented through several applications of learning approaches, for example realistic mathematics learning methods, REACT, open ended problems, problem-based learning and discovery learning.

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