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Critical and Creative Thinkers in Mathematics Classrooms

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Abstract

There has been increased recognition of the need for teachers to equip students with critical and creative thinking skills. This paper argues the importance of critical and creative thinking skills in the context of a mathematics classroom. In particular, it will address the role of teacher pedagogy in creating a collaborative and supportive learning environment to foster the development of critical and creative thinking skills. The principles of constructivism are emphasised, as effective pedagogical considerations that may enhance critical and creative thinking skills in mathematics classrooms.

Keywords

mathematics; critical thinking; creative thinking; constructivism; pedagogy; supportive learning environment

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Critical and Creative Thinkers in Mathematics Classrooms

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There has been increased recognition of the need for teachers to equip students with critical and creative thinking skills. This paper argues the importance of critical and creative thinking skills in the context of a mathematics classroom. In particular, it will address the role of teacher pedagogy in creating a collaborative and supportive learning environment to foster the development of critical and creative thinking skills. The principles of constructivism are emphasised, as effective pedagogical considerations that may enhance critical and creative thinking skills in mathematics classrooms.

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Introduction

Education plays a powerful role in shaping students' knowledge and skills for the 21st century (Australian Curriculum Assessment and Reporting Authority (ACARA), 2012; Mumford, Medeiros & Partlow, 2012). Teachers' attitudes and constructions of knowledge have been shown to influence the classroom culture and students' performance (Bray, 2011; Hunter & Back, 2011). A classroom culture that builds and extends students' thinking processes is central for effective learning (ACARA, 2013a). Critical and creative thinking are essential skills to be applied across the curriculum and beyond the classroom (ACARA, 2013a). These skills ensure students think purposefully and work effectively in independent and group contexts, for example, students are able to make individual and collaborative learning goals and decisions to monitor their learning. Teachers have a role to facilitate these experiences to support successful, confident and informed citizens of the future (ACARA, 2013a). This paper will focus on the development and application of critical and creative thinking skills in mathematics classrooms. Underpinning the principles of constructivism, teacher pedagogy such as peer communication and construction of knowledge are described as effective pedagogical practices (New South Wales Department of Education and Training (NSW DET), 2003). These considerations have been shown to create a supportive and collaborative environment that fosters critical and creative thinking skills (Kong, 2015; Kwan & Wong, 2014; Tunca, 2015).

Theoretical background

Constructivism is a philosophical theory of how individuals learn and make sense of their world (Yuliani & Saragih, 2015). The principles of constructivism are grounded

in the established works of Piaget and Vygotsky (e.g., Piaget, 1964; Vygotsky, 1978). Piaget's theory of cognitive development focuses on the role of individuals as active constructors of knowledge in the learning process (Piaget, 1964). Piaget believed students learn by doing through manipulating objects and connecting experiences to their prior knowledge in order to construct new meaning (Tunca, 2015). Both Piaget and Vygotsky valued the role of social processes and interactions as essential components to shape learning (Yuliani & Saragih, 2015). Learning from a Vygotskian perspective involves the process of internalisation, within the zone of proximal development (ZPD)[1]. In an educational context, Vygotsky believed in the important role of the learning environment, whereby a student interacts with the teacher and their peers, thus, the experiences and processes become internalised as their own belief and understanding (Tandiseru, 2015).

Policy frameworks

The Australian Curriculum Assessment and Reporting Authority (ACARA, 2013a) is an independent statutory body that is responsible for the development of the national school curriculum and national assessment program from Kindergarten to Year 12. ACARA's principles are built upon the Melbourne Declaration on Educational Goals for Young Australians (MCEETYA, 2008), which contributes to a high-quality and equitable curriculum to develop successful, confident and informed citizens in the 21st century (ACARA, 2012). There are three dimensions of the Australian Curriculum: learning areas, general capabilities and contemporary cross-curriculum priorities. The learning areas provide the knowledge and foundation of learning in schools and include English, Mathematics, Science, Humanities and Social Science, The Arts, Languages, Health and Physical Education and Technologies (ACARA, 2012, 2013a). Both MCEETYA (2008) and ACARA (2012, 2013a, 2013b) recognise the need for students to develop general capabilities, which are skills and behaviours to be applied across the curriculum and beyond the classroom. The general capabilities include ICT capability, critical and creative thinking, ethical understanding and intercultural understanding (ACARA, 2013a). Moreover, the cross-curriculum priorities inform students of contemporary issues within Australia, such as Aboriginal and Torres Strait Islander histories and cultures, as well as links between Asia and Australia (ACARA, 2013a; MCEETYA, 2008).

The NSW Quality Teaching Framework (NSW DET, 2003) embodies similar principles to the Australian Curriculum (ACARA, 2013a) and the educational goals of the Melbourne Declaration (MCEETYA, 2008). The framework is a pedagogical model that encourages quality teaching practice and the application of the Australian Curriculum in New South Wales. The model is comprised of three dimensions: *intellectual quality*, *quality learning environment* and *significance* (NSW DET, 2003). *Intellectual quality* refers to a pedagogy focused on developing deep knowledge and understanding of concepts and skills (NSW DET, 2003). In this dimension, students are encouraged to actively construct and demonstrate their knowledge (NSW DET, 2003). The dimension of *quality learning environment* builds upon the notion of

[1] The difference between a learner's independent performance and their potential achievement under guidance or in collaboration with a more-knowledgeable other (Vygotsky, 1978).

learning as a social process (see Vygotsky, 1978, for a discussion of this process). Teachers are encouraged to create a positive learning environment to facilitate authentic communication and relationships between the students, peers and the teacher (NSW DET, 2003). The dimension of *significance* focuses on a pedagogy that connects to students' prior knowledge and experiences (NSW DET, 2003). This dimension enables students to form meaningful connections between prior knowledge and new concepts explored (NSW DET, 2003).

Policy application

The Australian Curriculum's general capabilities of critical and creative thinking requires students to generate and evaluate knowledge, clarify concepts, seek possibilities, consider alternatives and solve problems (ACARA, 2013b). In national collaboration with the educational goals of the Melbourne Declaration, ACARA has developed a learning continuum of critical and creative thinking skills, across the curriculum, for students to meet in order to become confident and autonomous learners (ACARA, 2013b; MCEETYA, 2008). These policy documents provide a framework curriculum to inform both state and territory application of curriculum standards.

The NSW Board of Studies Teaching and Educational Standards (BOSTES, 2015) is responsible for the structure and implementation of the Australian Curriculum for school authorities and teachers within NSW. The syllabi are consistent with the Australian Curriculum framework and educational goals of the Melbourne Declaration. The NSW BOSTES documents provide the application and pedagogy of learning within each key learning area (KLA) (BOSTES, 2015). In the context of Mathematics, the NSW K–10 Mathematics syllabus supports the critical and creative thinking learning continuum with the application of the working mathematically strand (Board of Studies, New South Wales (BOS NSW), 2012), as this facilitates the different forms of thinking. In mathematics, students become critical and creative users of mathematics as they develop the five working mathematically processes of communicating, reasoning, problem solving, understanding and fluency (BOS NSW, 2012). These processes are embedded across the mathematics continuum of learning to develop confident, creative and informed users of mathematics (BOS NSW, 2012).

The federal and state support documents set consistent and high-quality curriculum outcomes, which place an onus on informed teacher training and knowledge. It is not possible to improve students' cognitive development without improving the skills and abilities of the professional educators within the school (Kong, 2010). Therefore, professional development must train both pre-service and in-service teaches how to explicitly teach thinking skills, and transform the classroom into a thinking culture (Kong, 2010). Teachers' knowledge and attitudes of mathematics have a profound impact upon the students' performance and the learning environment (Sun & van Es, 2015). Further, the literature argues that teachers from conventional educational systems may view cognitive training for teachers as a separate field and lack the adequate knowledge and preparation to teach higher-order cognitive skills, such as problem solving and decision making (Hunter & Back, 2011; Kong, 2010). Across KLAs, curriculum specialists argue that it is increasingly unlikely that teachers will incorporate general capabilities in learning experiences, as subject content and knowledge are considered more important (e.g., Atweh & Goo,

2011; Hoepper, 2011; Tambyah, 2011). This argument suggests the need for the development of the understanding, knowledge and application of the general capabilities in the curriculum to enhance critical and creative thinking skills.

Types of thinking

It is of paramount importance for teachers to create a supportive and collaborative environment to foster the development and application of thinking skills (Kwan & Wong, 2014; Liljedahl, 2012; Sun & van Es, 2015; Tunca, 2015; Walshaw & Anthony, 2008). A classroom that engages in purposeful thinking is central to effective learning (ACARA, 2013b; Liljedahl, 2012; Sun & van Es, 2015). The Australian Curriculum highlights two types of thinking – critical and creative – as essential general capabilities for confident students in the 21st century (Australian Curriculum Studies Association (ACSA), 2015). Critical thinking skills require students to organise, interpret and analyse information (ACARA, 2012; 2013b; Yuliani & Saragih, 2015), and can be interpreted as the information processing skills that are core to higher-order thinking and problem-solving (Yuliani & Saragih, 2015). Conversely, creative thinking skills can be interpreted as the generation and application of new inventions and ideas (Sharma, 2015). Creative thinking processes enable students to investigate alternative strategies, design and construct new solutions to a problem (ACARA, 2013b; Robson, 2014).

Critical and creative thinking skills can be considered to be fundamental to the learning and application of mathematics. The development of these thinking processes enable students to work mathematically and become effective problem solvers. In the problem-solving process, students think mathematically as they generate and evaluate knowledge, discover possible strategies, justify and reflect upon their strategies selected (BOS NSW, 2012; Hunter & Back, 2011; Tunca, 2015).

Critical Thinking

Critical thinking skills are information processes that enable a person to evaluate and justify information to develop an argument or solve a problem (ACARA, 2012, 2013b; Kong, 2015). Examples of critical thinking skills include comparing, contrasting, categorising, analysing and evaluating (ACARA, 2012, 2013b; Kong, 2015; Tunca, 2015). These higher-order thinking skills are integral to students working mathematically (BOS NSW, 2012), as students interpret and justify their decisions based on logical thought and actions (BOS NSW, 2012; Yuliani & Saragih, 2015).

Teachers' attitudes and beliefs towards mathematics influence the quality of the learning environment (Hunter & Back, 2011; Sun & van Es, 2015). The culture of a classroom and type of learning environment are suggested to have a significant impact on students' ability to think critically (Sun & van Es, 2015). A supportive learning environment that builds upon the principles of constructivism, enhances critical thinking skills in mathematics classrooms (Kong, 2015; Kwan & Wong, 2014; Sun & van Es, 2015; Tunca, 2015; Widyatiningtyas et al. 2015; Yuliani & Saragih, 2015).

Learners as communicators

It is imperative that teachers create a collaborative environment focusing on supporting students' interactions and discussions of mathematical ideas (Kong, 2015; Kwan & Wong, 2014; Tunca, 2015). The constructivist learning environment builds upon Vygotsky's (1978) theory of the ZPD which proposes higher-order thinking skills are improved while learning in a collaborative process. This theory is consistent with research, suggesting that a collaborative environment where students are engaged in sustained conversation and group activities enhances the development and application of critical thinking skills in learning mathematics (Kwan & Wong, 2014; Tunca, 2015). The constructivist learning environment principles are embodied within the NSW Quality Teaching Framework (NSW DET, 2003), encouraging teachers to facilitate peer-to-peer interactions, for example, students can develop critical thinking when they are asked to reason and justify their choice of calculation or strategy to solve a problem (ACARA, 2013b). Problem solving investigations provide students with opportunities to share their ideas, strategies and explanations of how to work out the problem. In this example, both the teacher and students can provide prompts to challenge and extend their thinking within the context of the original task. These experiences can be adapted across year stages and support critical thinking through sustained communication and social interactions (Kwan & Wong, 2014; NSW DET, 2003; Tunca, 2015).

Learners as active constructors

A student-centred environment emphasises the student's active role in the learning process, which leads to agile thinking. Active learning experiences has the potential to move beyond knowledge and understanding and meaningfully stimulate students' engagement, interaction, and higher-order thinking skills (Bellanca, Fogarty & Pete, 2012; Kong, 2010). Building upon the principles of constructivism, teachers can facilitate inquiry investigations whereby students think mathematically to explore and construct concepts (BOS NSW, 2012). Students become active constructors of knowledge as they explain representations, interpret problem situations and justify logical thought and actions (Tunca, 2015).

Yuliani and Saragih (2015) developed a guided discovery model and investigated the impact on high school students' critical and mathematical thinking ability. Students were guided through open-ended, hands-on investigations in which students' actively explored concepts and patterns (Yuliani & Saragih, 2015). The authors argue guided discovery is an effective model for learning as fosters active participation, as students take responsibility and ownership of their learning (Yuliani & Saragih, 2015). Further, students are encouraged to investigate strategies and extend upon their own thinking. The authors found these experiences to improve students' critical and mathematical thinking skills (Yuliani & Saragih, 2015).

The constructivist learning approach reflects the NSW Quality Teaching Framework and educational goals of the Melbourne Declaration. This is evident when students are given the opportunity to formulate their own mathematical ideas and justify their decision-making process (MCEETYA, 2008; NSW DET, 2003). Hence, teachers are encouraged to provide experiences for students to explore mathematical concepts and techniques which are suggested to improve students' critical thinking skills.

Creative Thinking

Creative thinking skills involve the synthesis, investigation and application of new ideas and solutions to problems (ACARA, 2013b). Also referred to as divergent thinking (Mumford, Medeiros & Partlow, 2012; Siswono, 2010), creative thinking skills are evident when a student builds upon known ideas through investigating a range of alternative solutions (ACARA, 2013b; Siswono, 2010). Siswono (2010) suggests creative thinking in mathematics problem solving can be assessed by the three components of fluency, flexibility and novelty. A student demonstrates fluency, flexibility and novelty in problem solving by their ability to explore different strategies and solutions to open-ended questions and generate new problems (Siswono, 2010). These creative processes are recognised as essential skills for students to think purposely, investigate alternative strategies and respond to challenges of the twenty-first century (ACARA, 2013b).

The pedagogical considerations for critical and creative thinking underpin similar applications and principles of constructivism. Critical and creative thinking skills can be developed in student-centred learning environments, which provide a space for growing intellectual and independent thinkers (Tandiseru, 2015). This highlights the role of the teacher to establish a culture that not only encourages student thinking and participation, but inhabits individual and collective knowledge construction and communication (Liljedahl, 2012; Tandiseru, 2015; Tunca, 2015).

Learners as risk takers and problem posers

A collaborative learning environment encourages students to actively explore problems using their own ideas and strategies (Bray, 2011; Sharma, 2015). Often, mathematics classrooms focus on correct answers, rather than fostering the students' thinking and understanding (Sun & van Es, 2015). This type of environment has been shown to lead to negative experiences, which can impede students' willingness to participate in class (Bray, 2011; Sun & van Es, 2015). Bray (2011) argued student contributions are contingent upon the creation of a supportive environment in which students feel comfortable to take risks in decision making, asking questions and defending ideas (Sharma, 2015). A pedagogical strategy to promote conceptual risk taking is rich tasks.[2] Problem-solving games through investigations allow for multiple methods and encourage creative thinking in application of knowledge (Sullivan, 2011). The tasks have the potential for explicit whole-class and small-group discussions as a means for students to communicate their ideas, critically evaluate strategies and justify upon their reasoning (NSW DET, 2003; Robson, 2014; Sharma, 2015).

Further, rich tasks can encourage creativity and imaginative application of knowledge as students create their own problems (Sullivan, 2011). Siswono (2010) argues when students construct and compose their own questions, students develop creative thinking skills of fluency, flexibility and novelty. Teachers have the potential to extend students' thinking skills, as students apply their mathematical content knowledge to construct their own new investigations or educational mathematics game. Students are encouraged to generate new and alternative ideas, strategies and

[2] A rich task includes depth of content, engagement and decision making by students (Sullivan, 2011).

solutions (ACARA, 2012, 2013b). However, Sternberg (2003) argued the development and application of creative thinking skills relate to students' personal attitudes and confidence in the learning environment. This highlights the necessity for teachers to orchestrate a safe and supportive environment which builds upon students' responses and collaboration of mathematical ideas (Robson, 2014; Sharma, 2015). In creating this quality supportive environment, students are shown to feel confident in creating their own ideas and solutions to problem solving (Mann, 2006; Robson, 2014; Sharma, 2015).

Conclusion

The Australian Curriculum advocates critical and creative thinking as essential skills to develop successful and autonomous learners across curriculum (ACARA, 2012, 2013a, 2013b). Quality teaching pedagogy aligned with current literature highlight the importance of establishing a mathematically thinking culture for students to generate and evaluate knowledge, and seek ideas and solutions (ACARA, 2013b; Bray, 2011; Kwan & Wong, 2014; NSW DET, 2003; Siswono, 2010). Mathematics learning environments that encourage students to actively participate in open-ended investigations and explore multiple techniques and solutions can have a profound impact on students' critical and creative thinking skills (Kwan & Wong, 2014; Tandiseru, 2015; Tunca, 2015). In doing so, teachers become facilitators of classroom discussions and encourage students to take an active role to communicate and construct their own ideas. Further, a supportive atmosphere is established where students feel safe and comfortable to take risks and generate new ideas (Bray, 2011; NSW DET, 2003; Sharma, 2015). In summary, a constructivist perspective of teaching and learning offers the potential for students to develop capability in critical and creative thinking skills (ACARA, 2013b; Tunca, 2015). Thus, it is integral for teachers provide experiences to foster thinking skills in order to prepare confident and informed students for lifelong learning beyond the classroom (ACARA, 2013b).

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