



Roles of Students' Creativity in Learning Mathematics in the 21st Century Classroom

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Abstract

The study examined the roles of students' creativity in learning Mathematics in the 21st century classroom. The 21st century classroom is digital in nature with technological features capable of inducing creativity in Mathematics. Traditional methods employed by mathematics teachers are devoid of creative thinking which poses serious threat to student's mathematical creativity. Possible ways to entrench creativity in Mathematics were discussed. The vital roles about exploring students' Mathematics creativity were examined. Criteria for improving mathematical creativity were discussed. The study highlighted the pre-conditional affective states of students for mathematical creativity. Teaching approaches that may foster mathematical creativity were examined. The study concluded that Mathematical creativity thinking is a mental process crucial to understanding Mathematics that can be improved and developed by teachers and the students. It was recommended that Mathematics teachers should be encouraged to provide students with technological and creativity based skills in learning Mathematics.

Keywords: Role, Creativity, Mathematics-Learning, Mathematics-classroom

Introduction

The primary purpose of education is to train individuals to actualize their potentials through frequent exercise of reasoning faculties in order to face global challenges. Due to increasing level of science and technology globally and knowledge sharing, the content of education is changing. In order to cope with the changes, knowledge and skills become essential part of Mathematics, where students exemplify, create, improve and apply knowledge (Akgul & Kahveci, 2016). Mathematics is involved in almost all fields of scientific research, playing crucial roles in most inventions. In the 21st century, Mathematics is considered as one of the most important subjects. The purpose of Mathematics education is to produce students who have skills in solving problems and foster high interest and motivation in Mathematics (Ayvaz & Durmus, 2021). It is important for students to be competent in knowledge construction, solving problems, be able to work with Information and Communication Technology (ICT) and develop their creativity through the use of digital technologies such as software for word processing Word, LaTeX and power point presentation, projecting videos, plotting graphs, GeoGebra, Dynamic Geometry Environment (DGE), among others in the 21st century classroom

(Baciu, 2021). The 21st century digital classroom is designed to carry out some mathematical activities which include presentation/demonstration, easier visualization, easier/faster computation accuracy, time optimization, checking paper-and-pencil task results, information, students' revision, exercises or drill and practice through interactive, or online resources, and communication using email and internet to enhance learning. These are some competencies that are called 21st century competencies (Boaler & Dweck, 2016). Competence is a combination of knowledge, skills and attitudes that are acquired at different stages of education. Some of the 21st century skills include planning skill, basic-skill, collaborating skill, adaptability through creative thinking and problem solving, basic technology skill, among others (Bolognese & Steward, 2017).

Presently, the implementation of the 21st century skills in Mathematics is a huge challenge because, Mathematics education is mainly structured to promote acquisition of low-level cognitive processes, students working alone and in silence and this does not stimulate the development of deeper understanding of Mathematics (Imai, 2010). Therefore, it is important to gain insight in the possibilities to implement these 21st



century skills in Mathematics education through students' mathematical creativity.

Creativity occurs whenever people solve problems that have not previously learnt about. Creativity is the production of something fresh or unique (Sadler-Smith, 2015). Kajander, Manuel, and Sriraman (2018) defined creativity as introduction of novel ideas, a different point of view, or a new way of looking at problem. In the context of this study, creativity is defined as a successful step into the unknown by going off the usual path, stepping on a novel pattern, being open to experiences, and letting one thing lead to another through combination of ideas that notice new relationships between ideas.

Numerous academics have looked into the value of creativity, notably in the teaching of Mathematics. This is consistent with the essence of Mathematics education, which entails learning by critical thinking and reasoning in order to become an effective problem-solver. Thus, it is applied in Mathematics to develop higher-order thinking skills and prominent of all skills is creativity. In agreement, Tuohilampi (2016) opined that the greatest degree of cognition, in accordance with the revised Bloom's taxonomy, is creativity. The ability to be creative makes one an excellent problem solver and innovator.

The advent of institutionalized teaching and learning, along with its critically summative examination has mainly weakened students' ability to acquire skills of high-order thinking, creativity and innovation, problem solving and confidence (Walia & Walia, 2017). No doubt the consistent use of lecture method in Mathematics learning in schools has contributed greatly to students' lack of understanding of basic Mathematical concepts, thus resulting to rote learning among Mathematics students. One of the things that are suspected to be the cause of the inactivity of students in Mathematics discussions is lack of abilities among students in creative thinking and reasoning, so students have difficulty giving ideas to solve problems.

Another factor fanning low reasoning ability among Mathematics students is teachers' inability to pose questions or assign tasks that require students to think at a higher level. This scenario has being the yearly results of students' learning of Mathematics with West African Examination Council (WAEC) Chief external Examiners' annual reports. Whereas the study tends to propose from all evidences of previous studies that creative thinking skills if encouraged properly, can improve students' better learning of Mathematics.

Ways to Entrench Creativity in Mathematics Education

Several researchers have found ways to make Mathematics more creative, fun and engaging. The followings are the ways to add more creativity to Mathematics education: Make problems open-ended: According to Kaolinsky (2020) giving students open-ended problems where multiple solutions are possible, as opposed to the traditional one right answer problem. The open-ended nature of the problem allows students to compute multiple options designs and finally identify the appropriate design out of many designs.

Students to create their own mathematical problems: Problem finding/posing in Mathematics is considered to be an important and integral aspect of creativity (Liljedahl, Santos-Trigo, Malaspina, & Bruder, 2016). For this activity, students are asked to come up with as many as they can with a given situation. For example, consider the following situation where 5 males and 5 females are standing in a line. A problem based on this situation, is what is the total number of people in the line? How many different ways could these people form line? Research studies have shown that creative students are able to pose questions from different fields of Mathematics.

Building divergent thinking skills: Mathematical problems that challenge students to think in different ways help build divergent thinking skills (Kattou, Christou, & Pitta-Pantazi, 2016). An example of such a problem is - suppose that instead of paper or whiteboard, geometry figures could be drawn on a large ball or a globe. List all the possible things that could happen as a result of doing geometry on the ball. For example, drawing a straight line on the ball will eventually end up at the starting point. Some more common responses are that geometrical figures would be distorted and measurement of distances that reflect higher originality include that Pythagorean Theorem would change or that there would be a need to establish a new mathematical system.

Overcoming fixation: According to Sadler-Smith (2015) a key aspect of creativity is to break free from routine patterns of thinking known as flexibility thinking. By forcing students to drop their establish mindsets helps them in examining a problem from different perspectives and arriving at better solutions. Giving students a series of questions where they are asked to find two numbers given their sum and difference. The first few examples use only positive integers, which sets the students' mindset to expect

solutions that use only positive whole numbers. Then the students are asked: Find two numbers such that the sum is 9 and difference is 2. A surprisingly large number of students could assert that this is not possible. To get the right solution as 5.5 and 3.5, they need to remove the self-imposed constraint of using only whole numbers.

Encourage analogical thinking: Analogical thinking is often considered relevant in the scientific domain, it is also a cognitive skill that underlies creative thinking and is equally relevant in Mathematics (Imai, 2010). For example, asking students questions as they solve a problem that traps into their analogical thinking. The questions may include: Can you think of a similar problem? Similar questions can jolt or nudge students towards using analogical thinking in problem solving. More illustration: The vertex of a pyramid opposite the base is called peak/apex. Supposed it is called pyramid isosceles if its apex is at the same distance from all vertices of the same base. By this definition, prove that the base of the isosceles pyramid is inscribed in a circle, the center of which is the foot of the pyramid's altitude. By using the analogous theorem for isosceles triangles where the foot of altitude is the mid-point of the base in an isosceles triangle. It becomes much easier to solve for the pyramid case.

Roles of Creativity in learning Mathematics

There are some vital roles about exploring students' Mathematics creativity. These roles according to National Council of Teachers of Mathematics (2014) are as followings: Empowers students to take ownership of their learning as active learners: Students can direct the focus of their learning according to their interests and prior knowledge. Students' creativity promotes investigative and problem solving skills: Creativity in Mathematics is all about developing problem solving skills which enables students to solve unfamiliar mathematical problems creatively. Students realize that there might be more than one possible solution to solve a given situation and learn how to diverse strategies towards problem-solving which best suit their learning styles, capabilities and situation. Students' creativity in Mathematics establishes connection to real life making learning more relevant: Teaching and learning should be ever more connected and contextualized in real life circumstances. Teachers cannot have students ask – why are we learning Mathematics? The more the established link between learning and real life, the better can students apply their knowledge and skills, and regard the learning as valuable and relevant. Such

examples of regalia include menus, TV schedules, informing web-sites, published newsletters, promotional leaflets, sports web-sites, among others.

Creativity provides opportunities for collaborative learning and communication: Creative learning tasks entail the exploration of diverse learning modes which include collaborative group work. Students learn to work with other learners who have different learning abilities and together attempt to find a strategy on how to produce something or solve a given task through interaction. It fosters initiative, innovation and creative thinking: Much focus is place upon the terms initiative and creativity, as part of the list of transversal skill required in the 21st century. Exploring Mathematics creativity involves providing open-ended opportunities for students to work collaboratively and to design innovative strategies and solutions to a given situation.

Creativity explores Mathematics through technology: Students are constantly surrounded by technology especially mobile devices such as android phones. Exploring Mathematics creatively acknowledges and values the potential and vast resources which technology provide. One great example of creative mathematics through technology is the soaring use of coding, which can be carried out either using apps such as online, mobile or tablet apps, or through floor robots such as the Pro-Bot. Students have the possibility to learn how to programme, design, engage in content creation and problem-solving whilst exploring different skills related to Mathematics such as shape, measure, fractions, angles and position. It supports students with diverse abilities: Adopting this approach towards exploring Mathematics in real life serves to cater for different students who are diverse in terms of learning ability and preferences. Students would have the chance to explore Mathematics from different perspectives while the learning becomes more appealing. The variety of learning modes enables most students to participate and to remain engaged on the task.

Creativity nurtures mathematical thinking and reasoning: Fundamental to mathematical learning is the ability to think and reason mathematically. It is important to present task whereby the students are able to explore the process of problem-solving through mathematical thinking and reasoning. Creativity heightens understanding and retention: Hands-on experiences allow students to apply their learnt skills and concepts. Such opportunities provide students with a repertoire of experiences which can allow them to

become more confident in applying their knowledge in future. Through hands-on practice, learners are able to self-assess where they require further support. This activity provides a meaningful context to learning and promotes retention of learnt mathematical skills and concepts. It links the boundaries among different curriculum areas: One very positive aspect about exploring mathematical creativity is that it does not only establish a more dynamic relationship among the teachers and the students, but it also establishes links with other learning areas, create a multi-disciplinary approach to learning. Creativity enables students learn to establish connections between mathematical language, art, history, science, technology, physical education and other aspects of the curricula. There are criteria for effective creativity through divergent thinking.

Criteria for improving Mathematical Creativity

The following are the criteria for improving Mathematical creativity through divergent thinking which is broken up into components: Fluency of responses – this involves generating many ideas in answering questions, answer with a number of answers, work faster than others, see the weakness of the object being observed (Kaplinisky,2020). Flexibility (different measures used in responses), according to Boaler and Dweck (2016) refers to interpreting a problem, implementation of the concept in other way, discuss something different from the others, and have different ideas in solving problems. Originality (where students showcase their creativity) – concerns with finding a new problem, ask the difference between old and new problems, give new idea on a problem, identify and immediately work on existing problems (Baciu, 2021). Elaboration – include looking for the meaning of the answer in detail, explore ideas, have broad answer, and connect between concepts (Ayvaz & Durmus, 2021). Divergent thinking and originality can be promoted through prioritizing collaboration, fostering open sharing and idea building, encouraging risk-taking and normalizing failure and crash or dead ends, though these could be affected by individual's affective states.

Pre-conditional Affective States for Mathematical Creativity

It is decisive to analyze student affect in relation to mathematical creativity. Insightful commentary on this relationship is compounded by Chamberlin and Mann (2014) known as pre-conditions of creativity as affective emotional states that are

recommended to increase creative output from an individual. These include iconoclasm, impartiality, intuition, and investment. Iconoclasm is a mental state of an individual to break away from iconic ideas, or solution paths, and to challenge convention. In Mathematics education, teachers often demonstrate a specific solution path for solving problems based on some algorithms. For most students this is sufficient, but this solution path may not be satisfactory to the student with high iconoclasm. This student may actively seek for a fresh solution path. This iconoclast goes forward to dispute the norm and begin an undertaking into the unknown where the creative and modernizing ideas lie.

Impartiality is the affective emotional state in which an individual has no inclination, or bias towards one solution or another. Impartial students may not like one solution because they are open to exploring varying solution paths. When students have found a solution path to be proficient, they can do one of two things: either make a bias toward that path, and repeatedly produce that modus operandi, or build no bias toward that path, but continue to look for and use fresh approaches.

Investment is another affective emotional state which refers to the internal drive toward achieving a goal. This is a construct that can be as a result of dedication to mathematical situation for some inherent reasons, as it could be commitment to one's own thoughts may endure at something demanding. When individual demonstrates investment in Mathematics, they are less likely to espouse a distinctive algorithm for the sake of ease, less likely to give-up on a creative flight of thought, and more likely to search for something exceptional. This is regarded as the instinctual constrain to accomplish a goal and the natural propensity, urge, or attempt that individuals demonstrate in multi-facets in their lives. Students who exhibit this intrinsic urge toward achieving a goal may have higher likely hood to produce creativity in Mathematics.

Intuition as an affective emotional state outlined by (Chamberlin and Mann) is an imperceptible urge that leads one toward something explicit. Once an individual is set for discoveries, one's psyche may then lead the problem solver in a direction seemingly by mere perception and the insight will nurture in the mind. Unexpectedly the thought can elucidate itself and be made consciously understood. Someone must have a high level of instinct to rely both the sub-conscious incubation and elucidation. The theorized relationship



of these four pre-conditional affective emotional states as building blocks of mathematical creativity may provide answers to why some students demonstrate higher levels of mathematical creativity than others. Teachers play a vital role in student development by supporting creativity through teaching methods and by nurturing students mathematical affect in the classroom.

Teaching Approaches that May Foster Mathematical Creativity

There are specific teaching approaches that best support creative thinking in Mathematics. The following four specific teaching approaches are mentioned and endorsed to promote creative thinking (Sriraman & Haavold, 2017). Problem-Solving and Problem-Posing Tasks (PSPPT), Mathematical Modeling (MM), Multiple Solution Tasks (MST), and Open-Ended Question (OEQ). More so, these approaches support divergent thinking at times and convergent thinking at other times. The approach in which teachers administer and evaluate students' Mathematics only to have potential for measuring specific skills rather than deeper level understanding describe traditional problems most often seen in the current education system.

Conclusion

Following the reviewed literatures on the roles of creativity in learning Mathematics in the 21st century classroom, it was concluded that students' creativity plays vital roles in learning Mathematics in as much as teachers are mathematically creative and are informed of the roles of creativity in Mathematics learning. The study also concluded that mathematical creativity thinking is a mental process that can be improved and developed by teachers and the students. The presented literature suggests that students' Mathematics learning can be fostered through support of their creativity, and also acknowledges that teachers approach, paired with the environment in which certain affective traits of the students are nurtured, may support the emergence of mathematical creativity.

Recommendations

Having identified the vital roles of students' creativity in learning Mathematics in the 21st century and the need for improvement, the following recommendations are made:

1. The global world is changing in terms of scientific and technological development, consequently, adapt these changes become

necessary to usher in Mathematical creativity in order to cope with the global trend.

2. Mathematics teachers should be challenged to provide their students with technological and creativity based skills in learning Mathematics.
3. The government and education stake holders should organize seminars, workshops and conferences to update Mathematics teachers' knowledge of creativity in Mathematics.

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