Effects of Creative Pedagogical Environment on Student Mathematical Ability and Creativity

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Abstract

This study investigated the effects of pedagogical environment on students' mathematical creativity and ability. It also probed if mathematical ability predicts mathematical creativity. A quasi-experimental pretest-posttest two-group design was utilized involving 98 students in two third year high school geometry classes. **Creative pedagogical environment** effectively enhanced and developed mathematical creativity aspects, particularly, fluency, flexibility, originality, frequency, synthesis, and structuring as well as mathematical ability processes, namely, problem solving, reasoning, communication, connection, and representation. Mathematical ability significantly and positively predicts mathematical creativity. However, when the effects of mathematical ability processes were simultaneously considered, only problem solving and reasoning remained as positive predictors, with reasoning as the more significant predictor. Further research can be done on the effects of pedagogical environment on self-efficacy, mathematics anxiety, mathematical imagination, and creativity-attitude.

Introduction

Present and future generations of learners are challenged with industrial and technological advances. Societal needs have changed, so do expectations from learners. Many thinkers characterize the emerging new world system in four principles — universalism, globalism, interdependence, and creativity. Creativity is considered an important requirement to survive in the next generation. The 2002 Basic Education Curriculum (BEC) reflects the same goal to produce graduates who are active participants in the society and are empowered for lifelong learning.

However, creativity is often neglected in mathematics teaching. Devlin (2000) identified four facets of mathematics teaching as (1) computational, formal reasoning, and problem solving, (2) a way of knowing, (3) a creative medium, and (4) applications. Of these facets, he pointed out that current teaching practices focus on the first, partly touch on the fourth, and ignore the other two. Hong and Aqui (2004) and Renzulli (1998) stressed that mathematical competence is equated with speed and accuracy of a student's computation with little emphasis on problem solving, reasoning and proof, communication, connection and representation. Students have very limited opportunities to experience mathematical activities that require creative thinking.

The 11th International Congress on Mathematics Education (2008) emphasized that creativity must be an essential part of the mathematics program. Approaches on creativity research dwelt only on (1) identification of the distinctive characteristics of a creative person, (2) the cognitive components of the creative process, (3) aspects of the creative product, and (4) social environments most strongly associated with creative activity (Pehkonen 1997; Puccio 1999; Simonton 2000). Studies are rich on the first three approaches resulting in the identification of the characteristics of creative thought and qualities of a creative person. The present study dealt with the fourth approach —investigating how mathematical creativity and ability can be developed and nourished in the context of learners in mixed-ability classrooms.

If mathematical creativity can be developed, what may constitute this process? It can be inferred from the studies of Shalley (1991) and Ogena (1990) that mathematical creativity may be associated with ability in mathematics and that some intervention (cognitive activities and environmental influences) may be conducted to nurture both. Some educators asserted that mathematical creativity is confined to those having mathematical intelligence as implied in the multiple intelligences theory (Gardner 1999). But Mina (2008) contended that excellence and creativity are not altogether synonymous but may have aspects in common. In consideration of these differences, the present study examined the relationship of mathematical creativity aspects, namely, fluency, flexibility, originality, frequency, synthesis, and structuring to the five mathematical ability processes of problem solving, reasoning, communication, connection, and representation.

Some mathematics educators related mathematical ability to a form of literacy. The Mathematics Council of the Alberta Teachers' Association (MCATA 2001) proposed on the development of students' ability in mathematics as manifestation of mathematical literacy. This includes (a) connecting mathematics to the real world, (b) using mathematics appropriately in a variety of contexts, (c) communicating using the richness of the language of mathematics, (d) synthesizing, analyzing, and evaluating the mathematical thinking of others, (e) appreciating the utility and elegance of mathematics, and (f) understanding what has been learned mathematically. The proposal was a response to the movement for national and state standards which include among others, the five standard mathematical ability processes of problem solving, reasoning, communication, connection, and representation to improve mathematics teaching (NCTM 2000). Orrill and French (2002) referred to this as mathematical power characterized as student's overall ability to gather and use mathematical knowledge through exploring, conjecturing, and reasoning logically; solving non-routine problems; communicating about and through mathematics; and connecting mathematical ideas in one context with mathematical ideas in another context.

Some educators have implied relationships between mathematical ability and creativity. Plucker and Beghetto (2004) defined creativity as the interplay between ability and process wherein an individual produces an outcome that is both novel and useful as defined within some social context. But some educationists contended that creativity is many times correlated with self-expression and necessitates intellectual abilities involving analytical, creative, and practical thinking skills (Hansen-Smith 2008; Kadijevich 2008).

Many studies have focused on problem solving and reasoning. Most of the previously discussed studies implied connections between problem solving and reasoning to mathematical creativity. Hence, the study also aimed to identify the mathematical ability processes that can predict develoment of mathematical creativity.

If students' mathematical creativity and ability can be developed, is the current system of education conducive to nurturing it? Are the contemporary approaches to instruction suitable in fostering students' creative ability in mathematics? Cognizant of the importance of developing students' mathematical creativity in a highly technological world and knowledge society, there must be some modifications on the delivery of instruction, in particular and the environment where the teaching-learning process occurs, in general. Many studies have found relative effects of the environment on the effectiveness of teaching and of students' learning. Bell (2007) expanded the term learning environment as the environment where learning experiences take place that includes the physical environment of the learning space, the emotional environment that the learner brings to the learning endeavor, and the social environment that the student finds in the learning space.

Instruction and environment play a critical role in creativity as they can stimulate, encourage, and reward innovative thinking (Weisberg 2006). In support of this, Nickerson (1999) stated that there have been several attempts to develop approaches to enhance creativity in the classroom which has been a sub-goal to improve students' thinking. However, he also argued that a clear and indisputable answer on how creativity can be enhanced in ordinary classrooms is not yet found in psychological literature since most of the indicators are largely indirect and/or in need of further substantiation.

In this perspective, the study proposed the *creative pedagogical environment*. It is an environment where the teacher deliberately considers the primary goal of developing and enhancing students' mathematical creativity aspects and mathematical ability processes in formulating a teaching philosophy, planning the lesson, delivery of the instruction, and assessment. The study investigated the effects of the creative pedagogical environment on students' mathematical creativity aspects and mathematical ability processes. It investigated further if mathematical ability processes positively predict mathematical creativity.

Methodology

This was a quasi-experimental study utilizing the pretest-posttest two-group design. It involved 98 third year high school students of Geometry in a regular public school. Two intact and heterogeneously grouped classes were randomly assigned to different pedagogical environments, the creativity-oriented group of 48 students exposed to creative pedagogical environment and the conventional group of 50 students exposed to conventional pedagogical environment. The average age of students in both groups was 15 years old.

The *Modified Mathematics Creativity Test* (MMCT) and the *Mathematics Ability Test* (MAT) were the primary instruments used in the study. The MMCT is an adapted 6-item examination designed to measure divergent and convergent thinking. Each of the four items on divergent thinking is worth 20 points to quantitatively measure all aspects of mathematical creativity –5 points for fluency, flexibility and originality; 3 points for frequency; and 1 point each for synthesis and structuring. The 2 items on convergent thinking is 1 point each. On the other hand, the MAT is a researcher-made 10-item test designed to measure student's mathematical ability. Each item is worth 8 points to measure the five mathematical processes –2 points for problem solving, reasoning, and communication; 1 point for connection and representation. Scoring rubrics for both instruments were developed.

The coefficients of reliability were 0.613 and 0.745 for the MMCT and MAT respectively. Based on the item analysis and the suggestions of the panel of experts, necessary revisions were done in the instruments. Instruments were administered both as pretest and posttest.

The actual experiment was conducted in the first grading period from June 2009 to August 2009. To control the teacher factor, the researcher handled both groups, strictly in compliance with the planned lessons. Observers were requested to sit in the class sessions at least three times a week. During the experiment, there was a conscious effort to keep all conditions the same for the two groups except for the pedagogical environment.

Intervention

The creative pedagogical environment was researcher-developed where developing and enhancing students' mathematical creativity aspects and mathematical ability processes are deliberately demonstrated in the formulation of a teaching philosophy, planning of the lesson, delivery of the instruction, and assessment. The comparative differences between the two pedagogical environments are highlighted in table 1.

In the group exposed to the creative pedagogical environment, every lesson started with creativity-stimulating activities in various forms such as challenge/ non-routine problems, paradoxes, optical illusions, puzzles and investigative tasks which were designed to develop creative thinking skills. These stimulants served as springboard for introducing the new topic. Review of prerequisite concepts was incorporated. The activities encouraged students to come up with many quick but different and unusual ideas (fluency, flexibility, frequency, originality), relate these ideas to previously learned concepts (synthesis), or express their answers in a different approach (structuring). Also, there were activities that challenged students to solve a problem (problem solving), justify their answer (reasoning), and explain the answers (communication). Connection and representation were also tested as these were similar to the synthesis and structuring aspects of creativity. On the other hand, every lesson in the conventional group basically commenced with a review of previous lessons. Activities, if any, were designed to develop only the critical thinking skills.

TABLE 1 Comparison of the creative and conventional pedagogical environments

Component	Creative pedagogical	Conventional pedagogical environment
Primary Goal	develop and enhance creative thinking skills (mathematical creativity aspects and mathematical ability processes) of the earners	attain the instructional objectives of the subject and develop critical thinking skills
Teaching philosophy	belief that creativity and ability in mathematics are potentials of every learner and that these can be developed or enhanced in teaching	belief on individual differences and multiple intelligences

TABLE 1 Comparison of the creative and conventional pedagogical environments (continued)

Component	Creative pedagogical	Conventional pedagogical environment
Planning the lesson	aspects of mathematical creativity (fluency, flexibility, originality, frequency, synthesis and structuring) and mathematical ability processes (problem solving, reasoning, communication, connection, representation) in the instructional objectives whenever possible	aspects of critical thinking in the instructional objectives
	creativity-stimulating activities (challenge/non-routine problems, paradoxes, optical illusions, puzzles and investigative tasks) to develop and enhance mathematical creativity aspects and mathematical ability processes	activities to develop critical thinking skills
	cooperative/ collaborative learning strategy	predominantly whole class learning strategy
	creative thinking strategies (functional modeling, analysis of ill-defined problems, and open-ended problems)	traditional routine problems or problems that yield only one solution or answer
Delivery of Instruction	creative SPICE (stimulation-presentation-investigation-conjecturing -extension)	review-lecture/discuss-do exercises/ activity-evaluate sequence
	creativity-stimulating teacher characteristics (as facilitator of divergent thinking, experimentation, and creativity)	teacher as mere facilitator of learning
	creativity-focused group structure (based on student's learning style and personality type)	traditional count off method in structuring workgroups whenever group activity is utilized
	four-seat together arrangement for collaborative work	straight parallel rows suggesting a lecture-style lesson
	creativity-hub bulletin boards (posters on creative art in mathematics, problem-of-the-week, showcase of creative work, and creative accomplishment of prominent mathematicians)	bulletin boards for utilitarian purposes (announcements, schedules, assignments calendars, and list of class officers)
	wide selection of manipulative materials	cabinets as storage of books and notebooks

TABLE 1 Comparison of the creative and conventional pedagogical environments (continued)

Component	Creative pedagogical	Conventional pedagogical environment
Assessment	creativity-appraisal methods (practical work, projects, portfolio)	paper-and-pencil tests and exercises emphasizing more on accuracy of solutions and computational speed
	creative questions that challenge the flowing, linking, and organizing of different but quick ideas	questions in assessment that are answer/ product-oriented
	student-formulated problems	teacher-formulated problems
	creative production evaluation as added feature in the grading system	traditional bases in the grading system such as written tests, assignments and problem sets, attitude, and class participation

In the creativity-oriented classroom, questioning style of the teacher focused on divergent thinking and challenged the flow, linking, and organizing of different mathematical ideas. These were related to the mathematical creativity aspects of fluency, flexibility, synthesis, and structuring as well as to mathematical ability processes of connection and representation. In addition, the questions thrown in class aimed to (a) draw out as many possible answers/ solutions, (b) provide alternative, new and unusual answer/solution, (c) seek for consequences or connections between ideas and concepts, (d) speculate or guess about what would happen if some conditions of a problem are changed, and (e) challenge different ways of representing solution. However, questioning style in the conventional group was answer/product-oriented. Discussion questions were mostly on the levels of the cognitive domain related to critical thinking.

Most lessons of the creativity-oriented group utilized cooperative/ collaborative learning strategy. Students were grouped based on their learning style and personality type. A "four-seat together" arrangement was designed to enable students of the same learning style and personality type to sit together. Investigative tasks/activities were employed to promote creative thinking strategies such as functional modeling, analysis of ill-defined problems, and open-ended problems. In functional modeling strategy, students were presented a problem depicting real-world situation. As they worked in groups, they went through the problem solving process and tried to model a mathematical solution. The other strategy, analysis of ill-defined problems, engaged students in problems where there was no obvious and clearly defined method at the start.

The investigative tasks encouraged mathematical creativity aspects and mathematical ability processes as students provide authentic input to the design of the mathematical solution to the problem. Some tasks required the groups to generate as many different and unusual ideas (fluency, flexibility, frequency, and originality). Other tasks challenged them to link the present problem to previously learned concepts (synthesis or connection) or to come up with a different model for the answer (structuring or representation). There were tasks which enhanced the mathematical ability processes when they were confronted with a problem with no apparent solution (problem solving), asked to justify their solution (reasoning), instructed to present their outputs to class (communication). On the other hand, whole class learning strategy was generally utilized in the conventional group. Problem solving exercises were traditional and generated only one solution/answer. Students were not or minimally exposed to reasoning, communication, connection, and representation processes. Students were seated in the traditional parallel rows.

The assessment strategy in the group exposed to the creative pedagogical environment maximized the use of creativity-appraisal methods (practical work, project, and portfolio). These were integrated in the discussion of the lessons. In fact, these were collectively factored in the grading system as creative production evaluation. There were test items which measured the mathematical creativity aspects and mathematical ability processes, whichever were necessary and relevant to the topics discussed. In contrast, the conventional group was given the usual paper-and-pencil tests and exercises that emphasized accurate solutions and speed in computation.

Results and discussion

Pedagogical Environment and Mathematical Creativity

In the pretest with the highest possible score of 82 points, students in both groups had relatively low scores in mathematical creativity and in all its aspects (at most 1.40 out of 5 points for an aspect). In fact, all students in the sample obtained a total score of 0 in the synthesis aspect. This implies that the students had poor ability to connect mathematical ideas together. The conventional group had much lower mean scores in the test but registered the maximum scores in the aspects of fluency, flexibility, and originality. Table 2 shows the results when the pretest total scores were subjected to independent t-test.

The two groups were initially comparable in terms of mathematical creativity. The creativity-oriented group had higher mean (m = 3.89, SE = 0.648) in the pretest than the conventional group (m = 3.42, SE = 0.672). This difference was not significant, $t(96) = 0.503$ with $p > 0.05$. Therefore, there was no significant difference between the two groups on mathematical creativity at the start of the experiment.

To determine if the two groups were initially comparable on the different aspects of mathematical creativity, the MMCT pretest subtotal scores were subjected to multivariate analysis of variance (MANOVA) with the mathematical creativity aspects as the dependent variables taken singly and as a whole. The results of two most common and tenable (Field, 2005) multivariate tests, Pillai's Trace and Wilks' Lambda, are shown in table 2.

TABLE 2 MANOVA Results on Modified Mathematics Creativity Test pretest subtotal scores

		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.382	11.388	5	92	0.000
	Wilks' Lambda	0.618	11.388	5	92	0.000
Group	Pillai's Trace	0.052	1.006	5	92	0.419
	Wilks' Lambda	0.948	1.006	5	92	0.419

Table 2 shows non-significant *F* - ratios ($p > 0.05$) for Group. This indicates that, at the start of the experiment, the two groups did not differ significantly on the different mathematical creativity aspects. This result is verified in the tests of between-subjects effects.

To determine the effects of pedagogical environment on mathematical creativity as a whole, the MMCT posttest total scores were subjected to independent t-test. The creativity-oriented group obtained a higher mean (m = 28.35, SE = 1.760) in the MMCT posttest than the conventional group (m = 11.98, SE = 1.073). This difference was significant, *t*(78.09) = 7.947 with p = 0.000. Hence, there was a significant difference between the two groups on mathematical creativity after the experiment. That is, the group exposed to the creative pedagogical environment exhibited higher mathematical creativity than the group exposed to the conventional pedagogical environment.

To probe on the effects of pedagogical environment on mathematical creativity aspects when taken singly and as a whole, the multivariate analysis of variance (MANOVA) was utilized to the posttest subtotal scores in MMCT. Table 3 presents the results.

TABLE 3 MANOVA Results on Modified Mathematics Creativity Test posttest subtotal scores

		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.905	145.014	6	91	0.000
	Wilks' Lambda	0.095	145.014	6	91	0.000
Group	Pillai's Trace	0.828	73.073	6	91	0.000
	Wilks' Lambda	0.172	73.073	6	91	0.000

The multivariate test statistics attain the criterion for significance (p = 0.000) which indicates a significant between-group differences. This implies that the type of pedagogical environment has had significant effects on the mathematical creativity aspects when taken singly and as a whole. After the experiment, the two groups differ significantly in mathematical creativity and in all its aspects, with the creativity-oriented group scoring significantly higher than the conventional group.

The findings suggest that creativity can be enhanced in mixed-ability classrooms which, according to Nickerson (1999), is not yet found in psychological literature. Most of the indicators are largely indirect and/or in need of further substantiation. The findings also contradict what several theorists claim (Weisberg 2006) that the process of creativity is different from ordinary thinking. The study showed the significant effect of the creative pedagogical environment in developing and enhancing the different aspects of students' mathematical creativity.

Pedagogical Environment and Mathematical Ability

Students in both groups had relatively low scores in MAT pretest considering that the highest possible score in the test was 80 points. About 40% of the students in the creativity-oriented group (CrPE) and 60% in the conventional group (CnPE) got a total score of 0 in the test. Almost all students got 0 in using the language of mathematics to express mathematical ideas precisely (94% in CrPE, 98% in CnPE), in understanding how mathematical ideas interconnect in contexts outside of mathematics (85% in CrPE, 92% in CnPE), and in attempting to model a solution in a different form (83% in CrPE, 92% in CnPE). This result was quite expected since students were not used to communicating, connecting, and representing mathematical ideas. To find out if the two groups differed significantly in their mean pretest total scores in MAT, the independent t-test was utilized.

The Levene's test for equality of variances yields a non-significant value (p = 0.092) which signifies that this assumption has not been violated. The creativity-oriented group attained higher mean (m = 1.35, SE = 0.288) in the pretest compared to the conventional group (m = 0.74, SE = 0.178). However, this difference was not significant, *t*(96) = 1.831 with p = 0.070. This suggests that there was no significant difference between the two groups on mathematical ability when the experiment started.

The MAT pretest subtotal scores were subjected to multivariate analysis of variance with the different mathematical ability processes as the dependent variables when considered one at a time. Table 4 shows the results.

TABLE 4 MANOVA Results on Mathematics Ability Test pretest subtotal scores

		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.383	11.428	5	92	0.000
	Wilks' Lambda	0.617	11.428	5	92	0.000
Group	Pillai's Trace	0.048	0.935	5	92	0.462
	Wilks' Lambda	0.952	0.935	5	92	0.462

Table 4 bears non-significant *F*-values (p > 0.05). This implies that both groups did not differ significantly on the different mathematical ability processes when the experiment commenced. This result is confirmed when the tests of between-subjects effects were conducted on the MAT pretest subtotal scores.

The creativity-oriented group acquired a higher mean score (29.73) in mathematical ability compared to that of the conventional group (8.64) after exposure to the creative pedagogical environment. The same group obtained higher mean scores in all processes compared to the conventional group. Their highest mean score (8.75) was recorded in problem solving. To investigate whether both groups significantly differ in their mean posttest total scores in MAT, the independent t-test was applied.

The creativity-oriented group marked a higher mean score (m = 29.73, SE = 1.962) in the posttest than the conventional group (m = 8.64, SE = 0.735). This group difference in the mean scores was very significant, *t*(59.98) = 10.065 with p = 0.000. Therefore, there was significant difference between the two groups on mathematical ability after the experiment.

The MAT posttest subtotal scores were subjected to multivariate analysis of variance with the mathematical ability processes as the dependent variables if taken singly and as a whole. Table 5 presents the results.

TABLE 5 MANOVA Results on Mathematics Ability Test posttest subtotal scores

		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.876	130.583	5	92	0.000
	Wilks' Lambda	0.124	130.583	5	92	0.000
Group	Pillai's Trace	0.686	40.173	5	92	0.000
	Wilks' Lambda	0.314	40.173	5	92	0.000

The two multivariate test statistics register significant F-values ($p < 0.05$). The type of pedagogical environment had significant effects on mathematical ability processes. The two groups differed significantly on mathematical ability processes after the experiment in favor of the creativity -oriented group. The creativity-oriented group scored significantly higher than the conventional group in mathematical ability processes. The group differences could be attributed to the design of the pedagogical environment in the creativity-oriented group which required that the delivery of instruction and the assessment strategies should challenge the ability of the students to solve problems, reason out/justify their answers, communicate, connect, and represent mathematical ideas.

The study revealed the significant effect of the creative pedagogical environment in developing and improving the mathematical ability of the students. This validates the assertion of Carbone and Sheard (2002) that higher cognitive skills can be developed in a highly creative environment after evaluating a studio-based teaching and learning environment model in a first year subject. Results showed evidence of students' development of metacognitive skills. Also, Weisberg (2006) emphasized that instruction and environment play a critical role in developing ability in mathematics. It conforms to the results of Gardner's (1999) investigation of the developmental nature of different intelligences considering the environment and teaching practices. It is quite apparent since mathematical ability belongs to one of the intelligences.

The creative pedagogical environment was successful in developing and enhancing students' mathematical ability and the five processes associated to it. This result is consistent with the findings of studies which probed the role of learning environment and instruction in the development of mathematical ability (reasoning, in particular). There was a positive effect on mathematical achievement after the implementation of a two-year program designed to promote formal operational thinking (Shayer and Adey 1993). It was concluded that improvements in mathematical ability as a consequence of instruction are possible (Hurst and Milkent 1996; Johnson and Lawson 1998). Likewise, in this study, after about two-and-a-half months of exposure to the creative pedagogical environment, the students manifested a very significant improvement in the five standard mathematical processes.

Predictive Power of Mathematical Ability on Mathematical Creativity

The study further investigated if mathematical ability positively predicts mathematical creativity. The posttest total scores in mathematical creativity were subjected to simple linear regressions with mathematical ability posttest total scores as the predictor variable. The *R*-value (0.719) represents the simple correlation coefficient between mathematical ability and mathematical creativity since there is only one predictor in the model. About 51.6% of the variation in MMCT posttest total scores can be accounted for by mathematical ability. The results of the analysis of variance show that the regression model for mathematical ability significantly predicts mathematical creativity scores, $R^2 = 0.52$, $DR^2 = 0.52$, $F(1, 96) = 102.47$, $p = 0.000$, 95% CI [0.51, 0.76]. This is confirmed in the value of the regression coefficient for mathematical ability which is notably different from zero, $t(96) = 10.123$, $p = 0.000$. Results suggest that mathematical ability posttest total score makes significant contribution in predicting mathematical creativity posttest total score. The linear regression equation for mathematical creativity (MMCT) score in terms of the mathematical ability (MAT) score is:

$$\text{MMCT score} = 7.934 + 0.636\ (\text{MAT score})$$

The result of the simple linear regression is reasonable because mathematical ability has been correlated to mathematical creativity in some studies but the correlation was most often implied. Plucker and Beghetto (2004) defined creativity as the relationship between ability and process wherein an individual produces a novel and useful product. Sternberg (2001) asserted that creative ability involves a discussion of the creative process and vice versa. He pointed out that there is a process where a person performs his/her creative ability and the variation in creative outcomes resulting from some particular process varies as a function of the person's ability. In addition, Kadijevich (2008) contended that creativity creativity demands good intellectual abilities involving analytical, creative, and practical thinking skills.

When the five standard mathematical processes associated with mathematical ability were considered in the equation simultaneously, the results were modified.

The correlation matrix shows that mathematical creativity had large positive correlation ($R > 0.5$) with the five mathematical processes associated to mathematical ability. Three predictors had high correlation with mathematical creativity, namely, problem solving ($r = 0.717$, p = 0.000), reasoning ($r = 0.725$, p = 0.000), and representation ($r = 0.653$, p = 0.000). Among the mathematical processes, reasoning correlates best with mathematical creativity posttest total scores and is more likely to predict the latter. There is multicollinearity in the data since a substantial correlation ($r > 0.9$) is evident between reasoning and communication. It seems logical since a part of mathematical reasoning is to communicate mathematical ideas.

The multiple correlation coefficient ($R = 0.769$) between the five predictors and the outcome shows that when all the five mathematical processes are considered, 59.1% of the variance in the mathematical creativity posttest total scores can be explained by the predictor variables. The regression model significantly predicts mathematical creativity score, $R^2 = 0.59$, $DR^2 = 0.59$, $F(5, 92) = 26.56$, $p = 0.000$. However, only problem solving [$t(92) = 2.299$, p = 0.024] and reasoning [$t(92) = 3.953$, p = 0.000] scores are making significant contributors to the regression model. The multiple regression equation for mathematical creativity (MMCT) score in terms of problem solving and reasoning scores is:

MMCT score = 6.488 + 2.563 (reasoning score) + 1.335 (problem solving score)

This equation suggests that the scores in reasoning and problem solving can positively predict the score in the modified mathematics creativity test. The value $B = 2.563$ indicates that as the reasoning score increases by one point, the model predicts 2.563-point increase in the mathematical creativity score. But this interpretation is true only if the effect of the problem solving score is held constant. Likewise, the value $B = 1.335$ implies that as the problem solving score increases by one point, the model accounts 1.335-point increase for mathematical creativity score but this only holds true when the effect of the reasoning score is held constant. These results suggest that when the effects of the five mathematical processes are considered simultaneously, the effects of reasoning and problem solving outshine the effects of the other processes.

The results seem reasonable since communication, connection, and representation are processes that are seldom deliberately emphasized in mathematics classrooms. The last two processes are new foci of mathematics teaching (NCTM 2000). The reality in mathematics classrooms reveals that students are not exposed to these processes. Hence, these three processes appear as non-significant predictors of mathematical creativity.

Conclusions and recommendations

This study strongly indicates that the **creative pedagogical environment** is effective in enhancing the aspects of mathematical creativity, namely, fluency, flexibility, originality, frequency, synthesis, and structuring of mathematical ideas. Likewise, it is effective in enhancing the mathematical ability processes, particularly, problem solving, reasoning, communication, connection, and representation.

Moreover, mathematical ability is a significant and positive predictor of mathematical creativity. That is, mathematical creativity is a function of mathematical ability. Enhancing students' mathematical ability provides a corresponding positive effect on students' mathematical creativity. Specifically, of the five mathematical processes, only problem solving and reasoning predict mathematical creativity. Hence, to develop students' mathematical creativity, their problem solving and reasoning abilities must be developed first.

Based on the findings and conclusions, it is recommended that mathematics teachers utilize the **creative pedagogical environment** in their classrooms to develop and enhance the mathematical creativity and ability of their students. To achieve maximum benefits of this pedagogical environment, mathematics teachers can adopt closely the different features and strategies suggested from the formulation of the teaching philosophy, planning the lesson, delivery of instruction, choice of assessment techniques, and methods of reflection.

Further investigation may be conducted on the negative influence of communication and connection on fluency as well as on flexibility and synthesis aspects. The language of communication may be looked into. Of the mathematical processes, emphasis needs to be placed on the reasoning ability as the best predictor of mathematical creativity aspects. More studies can be generated on how the type of pedagogical environment affects students' self-efficacy, mathematics anxiety, mathematical imagination, and creativity attitude.

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