Predictors of Preservice Teachers` Mathematical Creativity

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Abstract: This quantitative study aimed to examine the predictive relationship of mathematical achievement, general creativity, and the three dimensions of personality (psychoticism, extraversion, and neuroticism) with mathematical creativity. Demographic characteristics were likewise considered for a holistic analysis. The data was obtained from 33 preservice teachers in a state university in the Philippines. By employing a hierarchical regression design, the demographics were grouped in block 1; mathematical achievement and general creativity were added for block 2, while block 3 involved the three dimensions of personality. Descriptive and inferential statistics were used in the analysis of the research data. As a result, age, sex, income class, extraversion, and neuroticism were not significantly related to mathematical creativity. On the other hand, mathematical achievement and general creativity positively predicted mathematical creativity, suggesting that a preservice teacher reporting a high level of mathematical achievement and/or perceiving themselves with a high level of general creativity would likely report a higher level of mathematical creativity. Further, the analyses revealed that psychoticism was negatively related to preservice teachers' mathematical creativity. It suggests that students reporting a lower level of psychoticism would likely report a higher level of mathematical creativity.

Key Words: mathematical creativity; general creativity; mathematical achievement; dimensions of personality

1. INTRODUCTION

Creativity is necessary for almost all endeavors of this era, wherein the ever-changing landscapes demand innovative ideas to motivate progress (Sternberg & Lubart, 1999). In mathematics education, mathematical creativity (MC) is one of the most studied areas in recent years. MC has been defined as "(a) the process that results in unusual (novel) and/or insightful solution(s) to a given problem or analogous problems, and/or (b) the formulation of new questions and/or possibilities that allow an old problem to be regarded from a new angle requiring imagination" (Sriraman, 2005). In the Philippines, mathematics education encourages critical and analytical thinking (SEI-DOST & MATHTED, 2011). Hence, preservice teachers' MCs should also be investigated since they will help future students acquire cognitive values like flexibility and creativity.

"Mathematical achievement (MA) is the competency shown by the student in the subject of mathematics" (Pandey, 2017). As a necessity to offer solutions to mathematical problems, MA has been positively related to MC (Bicer et al., 2021; Sebastian & Huang, 2016). Creative thinking activities facilitate student achievement, and achievement motivates students to think creatively. Brunkalla (2009) explained that increased academic achievement motivates students to engage in creative mathematics activities.

General creativity (GC) has been defined as "the interaction among aptitude, process, and the environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" (Plucker et al., 2004). GC has been one of the most studied constructs that predict MC. One's creative tendency is intertwined with mathematical creativity since general creative processes are similar across domains (Schoevers et al., 2020). Indeed, creative thinking skills are imperative in developing the mathematical creativity of the learners (Arikan, 2017).

Hans Eysenck's personality theory is based on

biological factors. Eysenck identified three personality domains: psychoticism, extraversion, and neuroticism (PEN). Psychoticism (P) is associated with aggression, hostility, intolerance, and recklessness. People with higher creativity generally have higher psychoticism than those with lower creativity (Eysenck,1993). Extraversion (E) is characterized by being outgoing, talkative, high on positive affect (feeling good), and needing external stimulation. Evidence asserted that neuroticism might contribute to creativity (Strong et al., 2007). The third dimension, neuroticism (N), is characterized by high levels of negative affect such as depression and anxiety. In 2012, Bas argued that neuroticism was not correlated with the creativity scores.

This study aimed to explore the predictive relationship of personality domains, general creativity, and mathematical achievement to mathematical creativity of selected preservice teachers. The demographics (i.e., age, sex, and income class) were also considered predictors for a holistic analysis. This quantitative study used hierarchical regression for the data analysis.

2. METHODOLOGY

2.1 Measures

2.1.1 Demographic Information

Demographic information such as sex, age, and income class was elicited. The latter was based on the 2020 Philippine Poverty, the Middle Class, and Income Distribution amid COVID-19, which presents the family income threshold for socio-economic classification (Albert et al., 2020)

2.1.2 Reisman Diagnostic Creativity Assessment (RDCA)

RDCA is a self-report creativity assessment that diagnostically identifies an individual's creative strengths rather than predicting creativity. It assesses an individual's self-perception on eleven (11) major creativity factors synthesized from the creativity research. Cronbach`s alpha for its seven (7) factors were deemed to fall into acceptable to good range on the commonly accepted scale (Reisman et. al., 2016); originality ($\alpha = 0.93$), extrinsic motivation ($\alpha = 0.89$), fluency ($\alpha = 0.87$), tolerance of ambiguity ($\alpha = 0.77$), divergent thinking ($\alpha = 0.67$), elaboration ($\alpha = 0.66$), and flexibility ($\alpha = 0.65$).

2.1.3 Mathematical Creativity Scale

Creativity has been one of the focal agendas of mathematics research due to its imperative value in understanding mathematics (Barraza-García et al., 2020). Akgul & Kahveci (2016) enhanced and validated an MC scale developed upon previously accepted MC tests. It has five (5) tasks covering geometric properties, problem-posing skills, creating different solutions, and identifying patterns and relationships. The responses of the students were rated in terms of fluency (i.e., number of correct solutions/answers), flexibility (i.e., category of ideas produced), and originality (i.e., the rarity of the response/solution). The MC scale was validated by experts and was pilot tested to compute the reliability. Alpha value ($\alpha = 0.80$) adapted from pilot-testing scores was interpreted as suitable for assessing mathematical creativity (Akgul & Kahveci, 2016).

2.1.4 Eysenck Personality Questionnaire-Revised (EPQ-R)

The Eysenck Personality Questionnaire-Revised (EPQ-R) assesses three major personality dimensions: Extraversion, Neuroticism, and Psychoticism. It recorded an acceptable reliability for male ($\alpha = 0.78$) and female ($\alpha = 0.76$) respondents. Extraversion (E) is characterized by being outgoing, talkative, high on positive affect (feeling good), and in need of external stimulation, whereas neuroticism (N) or emotionality is characterized by high levels of negative affect such as depression and anxiety. The third dimension is psychoticism (P), which is associated with the liability of having a psychotic episode and aggression. The P, E, and N dimensions were predicted on a biologically based personality theory (Eysenck et al., 1985).

2.1.5 Mathematical Achievement Test

This study measured mathematical achievement based on the respondent's score in the 50-item researcher-made test. The table of specifications for the test items covered identified specialization courses for the bachelor of secondary education-mathematics program prescribed by the Commission on Higher Education (CHED). The researcher pilot-tested the instrument before its administration. The gathered data was used for item analysis and test improvement. Kuder-Richardson Formula 20 (KR-20) was computed for the test's internal consistency. The computed value of KR-20 = 0.69 was observed, implying moderate internal consistency.

3. RESULTS AND DISCUSSION

3.1 Demographics and descriptive measures

Table 1. Demographic Characteristics ($N = 33$)

Attribute	f	%
Sex		
Female	24	72.7 %
Male	9	27.3 %
Income-class		

Table 1. Demographic Characteristics (N = 33)

Attribute	f	%
Poor	16	48.5 %
Low-income Class	10	30.3 %
Lower middle-income Class	3	9.1 %
Middle middle-income Class	2	6.1 %
Upper middle-income Class	1	3.0 %
Upper-income Class	1	3.0 %

The data for this study was drawn from 33 fourth-year preservice teachers (24 females and 9 males) at a state university in the Philippines aged from 21to 24 years (M = 22.0, SD = 0.73). Most of the respondents were poor, accounting for 48.5%; 30.3% belonged to the low-income class; 9.1% were from the lower-middle-income class, and; 6.1% were from the middle middle-income class. For the upper-middle-income class and upper-income class, each recorded 3.0%.

Table 2. Descriptives

	N	Missing	Mean	SD
Age	33	0	22.0	0.73
MA	33	0	22.2	4.61
GC	33	0	190.0	19.60
MC	32	1	33.0	11.10
E	33	0	13.0	3.83
N	33	0	16.6	4.04
P	33	0	5.7	2.35

The mean score for the 50-item test for MA was 22.2 (SD = 4.61). It could be deduced that the students performed low in the test covering identified specialization courses for the mathematics teacher education program. Concerning the perceived GC, the mean score was 190 (SD = 19.6), interpreted as a moderately high general creativity level. Education must facilitate creativity (Levanon, 2021). Preservice teachers have been trained to take on the challenges of teaching in the classroom; hence, they have developed a certain level of creativity, which is imperative in teaching. Creativity is a vital component of the learning process, and learning can result in creative contributions (Beghetto, 2016, as cited in Schreiber, 2018). The mean score for the MC test was 33 (SD = 11.1, N = 32). One of the respondents did not take the test due to her absence during the assessment. The respondents` MC was moderate in terms of the three factors. It could be attributed to the fact that they are in their final year of the program; hence, they have received considerable experience in accomplishing the creative tasks given-aligned with mathematics. This result concurs with Andrade & Pasia's (2020) findings that preservice teachers have a moderate level of mathematical creativity.

Extraversion is one of the components of the EPQ-R related to the social skill of an individual. The respondents' mean score was 13.0 (SD = 3.83), implying an average extraversion level. On the other hand, neuroticism is the component associated with emotional stability. The mean score was 16.6 (SD = 4.04) in this component. This figure suggests that a typical individual from the group would have a high neurotic tendency or emotional instability. Most of the respondents were female (72.7%). There is empirical evidence that women have scored higher than men on neuroticism (Costa et al., 2001). Lastly, the mean score of psychoticism was 5.7 (SD = 2.35), suggesting a low psychotic tendency. A low psychoticism score means a lower tendency for aggression, impulsivity, aloofness, and anti-social behavior. Education influences one's psychotic tendencies (Loch, 2017). The socialization process of education equips learners with the capacity to hold off aggression and conform to the accepted norms of the group.

3.2 Regression Analysis Interpretation

Normality, collinearity, assumption of independent errors, and homoscedasticity were evaluated before regression analysis. The data screening revealed that the data assumes normality (W = .98, p > .05). The data also met the assumption of collinearity indicating that multicollinearity was not a concern (Age, Tolerance = .73, VIF = 1.37; Sex, Tolerance = .93, VIF = 1.08; Income Class, Tolerance = .83, VIF = 1.21; MA, Tolerance = .81, VIF = 1.24; GC, Tolerance = .71, VIF = 1.41; E, Tolerance = .82, VIF = 1.21; N, Tolerance = .83, VIF = 1.21; P, Tolerance = .86, VIF = 1.17). Further, the data met the assumption of independent errors (Durbin-Watson statistic = 1.77) with the computed value falling within the range of 1.5 to 2.5 which are considered to be relatively normal. For the homoscedasticity, figure 1 shows that there was no clear pattern in the distribution; Thus, the data is not heteroscedastic, and the residuals are distributed with equal variance.

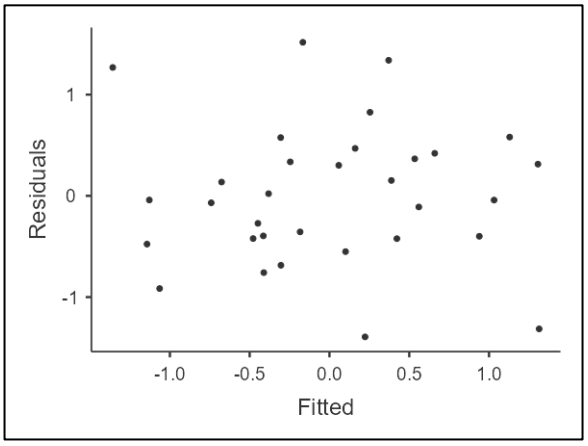

Figure 1: Residual Plot

The researcher employed hierarchical linear regression in which more variables are added to the

model in separate steps called "blocks." For step 1, age, sex, and income class were predictors. Mathematical achievement and general creativity were added for the second step, whereas the three personality traits were included for the third step.

Table 3. Model Fit Measures

			Overall Model Test			
Step	R	R^2	F	df1	df2	p
1	0.167	0.028	0.27	3	28	0.849
2	0.585	0.343	2.71	5	26	**0.042***
3	0.721	0.519	3.11	8	23	**0.016***

For step 1, the R-value is .167, indicating a negligible correlation; R^2-value is .028, implying that the demographic can only explain 2.8% of the total variation of MC. Step 1 was not statistically significant ($F(3,28) = .27$, p = n.s.). The model for step 2 was found to be significant ($F(5,26) = 2.71$, $p < .05$). There was a moderate positive correlation between the predictors and the dependent variable (R = .585). It accounted for 34.3% ($R^2 = .343$) of the total variation in preservice teachers` MC. Lastly, when the three personality traits were added for step 3, the predictors could collectively explain 51.9% ($R^2 = .519$) of the total variance of MC. This model was also significant ($F(8,23) = 3.11$, $p < .05$) with a high positive correlation between all the predictors and MC (R = .72).

Table 4. Model Coefficients

Predictor	t	p	ß	R^2	Δ R^2
Step 1				0.028	0.028
Age	-0.309	0.760	-0.06		
Sex	0.019	0.985	0.00		
Income Class	0.717	0.479	0.14		
Step 2				0.343	0.315
Age	0.635	0.531	0.11		
Sex	0.377	0.709	0.06		
Income Class	1.235	0.228	0.21		
MA	1.926	0.065	0.31		
GC	2.661	**0.013***	0.45		
Step 3				0.519	0.176
Age	0.166	0.610	0.09		
Sex	0.329	0.434	0.12		
Income Class	0.124	0.431	0.13		
MA	0.158	**0.015***	0.42		
GC	0.172	0.069	0.33		
E	0.160	0.747	-0.05		
N	0.161	0.614	0.08		
P	0.157	**0.009***	-0.43		

Table 4 presents the different model coefficients for the relationship between MC and its predictors. Age, sex, and income class collectively explained 2.8% of the variance in the dependent variable. All these demographic characteristics, age (ß = -.06, t = -.309, p = n.s.), sex (ß < .00, t = .019, p = n.s.) and income class (ß = .14, t = .717, p = n.s.) did not significantly predict MC among preservice teachers.

When MA and GC were added into the model, the R^2 increased to 34.3%. It implies that the addition uniquely explains an extra 31.5% of the variance in MC. For this model the demographic characteristics were still not significant predictors, age (ß = .11, t = .635, p = n.s.), sex (ß = .06, t = .377, p = n.s.) and income class (ß = .21, t = 1.235, p = n.s.) as well as MA (ß = .31, t = .6926, p = n.s.). In contrast, GC (ß = .45, t = 2.661, $p < .05$), was found to be a significant predictor of MC. This is empirical evidence to support that GC positively predicts preservice teachers` MC.

The addition of the personality components in step 3 increased the R^2 to 51.9%. The three variables explained an additional 17.6% of the total variance in MC. Demographics were still not significant predictors, age (ß = .09, t = .166, p = n.s.), sex (ß = .12, t = .329, p = n.s.) and income class (ß = .13, t = 0.124, p = n.s.). Surprisingly, GC (ß = .33, t = .172, p = n.s.) for this model did not significantly predict MC, while MA (ß = .42, t = .158, $p < .05$), became a significant predictor. The analysis revealed that MA was positively related to MC. In terms of personality traits, E (ß = -.05, t = .160, p = n.s.) and N (ß = .08, t = .161, p = n.s.) were not significant predictors whereas, P (ß = -.43, t = .157, $p < .05$) was found to significantly predict MC exhibiting a negative relationship.

Table 4 provides an insight into the predictive relationship of the demographic characteristics, MA, GC, and dimensions of personality to preservice teachers` MC. Age, sex, and income class did not significantly correlate with the dependent variable throughout the blocks. This result agrees with Andrade & Pasia's (2020) study, reporting no significant statistical relationship between preservice teachers' age and their MC but contradicts the result that a significant positive relationship exists between them (Tubb et al., 2020). In terms of sex, there was empirical evidence to support that substantive sex differences in the creativity variable do not exist (Taylor & Barbot, 2021). However, there are also reports that male students have higher MC than female students (Sholy, 2012). For income class, evidence points out that as the socio-economic level increases, so does creative ability (Castillo-Vergara et al., 2018; Sholy, 2012). Mathematical creativity differs significantly for high and low socio-economic students, with high socio-economic status students scoring higher for mathematical creativity. The present study reported otherwise, revealing that income class did not significantly predict mathematical creativity.

The relationships of the demographic characteristics to the dependent variable suggest that

MC is unrelated to age, sex, and income class. It is an appealing insight since it places the students on equal footing. Students would not be affected by their baseline characteristics, given the opportunities to develop their mathematical creativity.

The second step provided evidence that GC is related to MC. GC is expected to be related to MC since general creative processes are similar across domains (Plucker, 1999). In 2017, Arikan observed a positive correlation between creativity and mathematical creativity; however, it was also noted that there had been no conclusive result linking general creativity to mathematical creativity; thus, additional research should be conducted to shed light on this matter.

The analysis for step 3 revealed that MA predicts MC. There has been empirical evidence supporting that MA and MC are positively related (Bicer et al., 2021; Huang et al., 2017; Sebastian & Huang, 2016; Walia, 2012). MA is a necessity for MC. A certain level of mathematical knowledge is a prerequisite to being mathematically creative (Sak & Maker, 2006; Weisberg, 1999, as cited in Schoevers et al., 2020).

Combining the second and third steps` results revealed that those with a higher level of general creativity and mathematical achievement are likelier to report a higher level of mathematical creativity. This result supported the notion that mathematical knowledge and general creative thinking skills are needed to solve mathematical problems creatively. When students possess more knowledge in mathematics, they perform better with creative tasks.

Contrary to MA and GC, P was negatively associated with MC, as shown in the analysis from step 3. This result implies that the lower the psychoticism level of the students, the more likely their mathematical creativity would be higher. Eysenck defines psychoticism as a personality type prone to take risks and might engage in anti-social behaviors, impulsiveness, or non-conformist behavior. One of the principal variables to predict creative behavior is psychoticism (Aguilar-Alonso, 1996). This study contradicts reports that psychoticism positively correlates with creativity, and their relationship is significant (Stavridou & Furnham, 1996; Eysenck, 1993; Martindale, 2007). The other dimensions (i.e., extraversion and neuroticism) did not significantly correlate with MC. This result agrees with Bas (2012) that extraversion was unrelated to creative tendencies. On the contrary, the present study contradicts Daguar's (1982) thesis that neuroticism significantly discriminates people in their composite creative thinking.

4. CONCLUSIONS

The analysis provided empirical evidence that preservice teachers' mathematical creativity could be predicted by their general creativity, mathematical achievement, and level of psychoticism. Hence, in developing mathematical creativity among future mathematics teachers, these factors should be justly considered in instructional decisions.

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