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Research paper

A comparative study of the divergent problem solving abilities of mathematically and scientifically talented students and nongifted students



Yen-Wei Chen (Doctoral Candidate)^a, Wen-Hua Chang (Professor)^b,
Ching-Chih Kuo (Professor)^{a,*}

^a Department of Special Education, National Taiwan Normal University, 162 Heping East Rd., Sec.1, Taipei 106, Taiwan

^b Department of Life Science, National Taiwan Normal University, 88, Sec. 4, Ding-Jou Rd., Wen-Shan District, Taipei 116, Taiwan

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1. Introduction

Creativity is related to novelty and utility (Mumford, 2003). The effective use of creative thinking enables people to solve problems more effectively and flexibly (Flach, 1990; Mumford & Gustafson, 1988). Gifted students are individuals with higher general intellectual ability; they are expected to show higher performance in academic learning and behave more creatively than their nongifted (NG) peers (Dalia & Agne, 2013; Hong & Aqiu, 2004). However, some studies have argued that a low correlation exists between intelligence and creativity (Rotter, Langland, & Berger, 1971; Kim, 2005), and intelligence also appears to be an ineffective predictor of creativity (Furnham & Bachtiar, 2008; Russo, 2004). However, contradictory findings have also been reported. For example, several studies have observed a moderate or high correlation between intelligence and creativity (Cho, Nijenhuis, Van Vianen, Kim, & Lee, 2010; Gilhooly, Fioratou, Anthony, & Wynn, 2007; Kershner & Ledger, 1985; Preckel, Holling, & Wiese, 2006; Runco & Albert, 1986). The contradictory findings for the relationship between intelligence and creativity are probably related to the instruments used to measure intelligence or creativity and the argument that creativity is domain-specific (Sternberg & Davidson, 2004; Ayas & Sak, 2014; Yi, Plucker & Guo, 2015).

1.1. Domain-specific creativity

Various studies have shown that creativity is a domain-specific ability, beginning with Hudson's *Contrary Imaginations* (1966). Hudson (1966) indicated that physics students tend to use convergent thinking, whereas humanities students typically use divergent thinking. Baer (1991, 1994, 1998) investigated a series of studies that provided evidence of domain specificity based on low correlations among different domains. Han confirmed that it is difficult to use the creative ability in one domain to predict the creative performance in other domains (Han & Marvin, 2002; Han, 2003). Dow and Mayer (2004) found that the participation of students in spatial ability training increased their spatial creativity. Palmiero, Nakatani, Raver,

* Corresponding author.

E-mail address: kuokay50@gmail.com (C.-C. Kuo).

Belardinelli, and van Leeuwen (2010) found that visual ability is related to visual creativity. A recent study reported the significant modeling influence on divergent thinking and artistic creativity by comparing creativity scores between students exposed to creative examples and students who were not exposed to models (Yi et al., 2015). The results also illustrate the learning effect on both divergent thinking and artistic creativity. The aforementioned findings support that creativity is a domain-specific ability. Mohamed, Maker, and Lubart (2012) reported that people possessing knowledge in certain domains are more creative in the related domain creativity test.

1.2. Creativity and mathematic or scientific talents

Cultivating talents and creativity has always been the focus of gifted education. Among the different types of talent, mathematic and scientific talent is the largest talent group. Mathematical giftedness or scientific giftedness can be considered a domain-specific form of giftedness, similar to other forms of domain-specific giftedness (Ayas & Sak, 2014; Sternberg & Davidson, 2004). Experts in mathematical creativity typically conceive mathematical creativity as the ability to conjure novel problem solving methods for tackling mathematical problems. For example, Krutetskii (1976) defined mathematical creativity as mental flexibility that enables students to think outside the box and apply novel approaches to solve problems (Haylock, 1985, 1987, 1997; Sriraman, 2004). Balka (1974) similarly described mathematical creativity as obtaining solutions through unconventional mathematical approaches. Haylock (1987, 1997) therefore developed a divergent production test with the assumption that mathematical creativity can be assessed through process and products.

1.3. Measuring domain-specific creativity

Regarding the measurement of domain-specific creativity, Mann (2005) pointed out that the quantitative assessment of mathematical creativity applies the concepts of flexibility, fluency, and originality to students' answers. Ayas and Sak (2014) determined that domain-specific and technical knowledge is the foundation of creativity in domain-specific creativity. Ayas and Sak also defined scientific creativity as "the ability to generate novel ideas or products that are relevant to context and have scientific usefulness or importance" (2014, p. 195). Thus, the Creative Scientific Ability Test (C-SAT) was developed to assess the creative potential in science. Because the report provided empirical evidence for its reliability and validity, this test was suggested to be useful for identifying gifted and creative students (Ayas & Sak, 2014). By contrast, in the mathematics education field, numerous researchers have used divergent thinking tasks to investigate creativity (Haylock, 1987; Imai, 2000; Pehkonen, 1992) and have determined that divergent thinking ability is a crucial factor in mathematics (Unal & Demir, 2009). The Problem Solving of Divergent Production (PSDP) test has also been used as a domain-specific task to assess divergent thinking ability. The PSDP test is a modification of the nine dot areas test proposed by Haylock (1987, 1997) and developed by Peng, Chen, and Huang (2015) with reference to the questions involving the drawing of 2-cm² graphs by connecting nine dots. Because solutions to this task require graph drawing ability and mathematical knowledge, this PSDP test can be used to assess mathematical creativity.

1.4. Research motivation and goals

This study determined whether mathematically and scientifically talented (MST) students outperform NG students in divergent thinking ability, whether IQ significantly predicts divergent thinking ability, and whether MST students outperform NG students in divergent thinking ability after the influence of IQ is excluded.

2. Methods

This study recruited two groups of students, MST students and NG students. All participants were administered the Wechsler Adult Intelligence Scale and the Problem Solving of Divergent Production Test to examine the relationship between IQ, learning background and divergent thinking ability and to determine whether learning background can predict divergent thinking performance.

2.1. Participants

The participants comprised 84 senior high school and university students aged 16–25 years. These students were assigned to two groups depending on whether they have studied (or have been studying) in mathematics and science classes in senior high schools. In Taiwan, students who obtained a score of PR97 or higher on domain achievement or aptitude tests are qualified to apply for mathematics and science classes. The MST students were recruited from top-talent mathematics and science classes in senior high schools and from different departments in Taiwanese universities, such as electrical engineering, medicine, and biology. By contrast, the NG students were university or high school students who had never studied in the gifted and talented classes. Thus, 34 students were assigned to the MST group and 50 to the NG group, with a mean age of 19.67 (SD = 1.66) years.

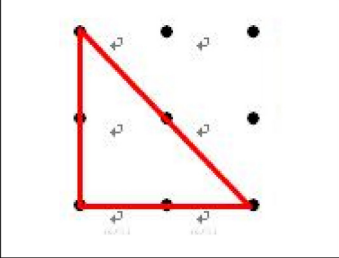
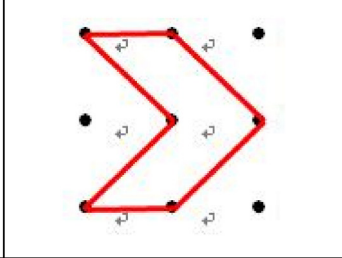
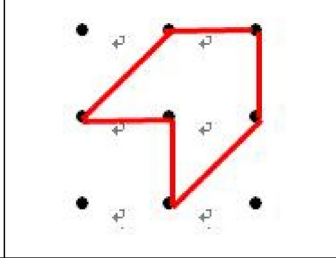
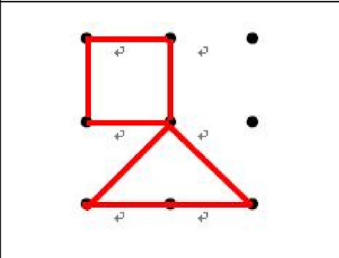
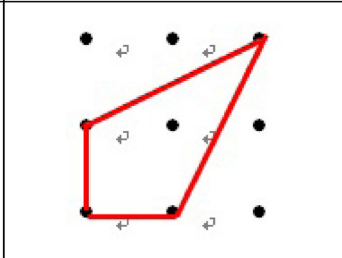
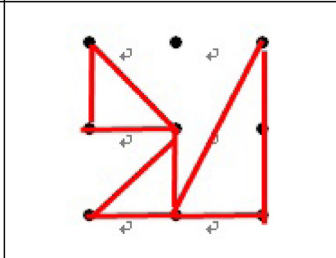
		
(92.9%) 0-point	(57.7%) 0-point	(46.4%) 0-point
		
(22.5%) 0-point	(1.4%) 2-point	(1.4%) 2-point

Fig. 1. Examples of responses for the Problem Solving of Divergent Production (PSDP) test.

2.2. Instruments

2.2.1. Wechsler adult intelligence scale, third edition

The Wechsler Adult Intelligence Scale (WAIS) is a test designed to measure intelligence in adults and older adolescents aged from 16 up to 89 years. The third edition of this test (WAIS-III) is a subsequent revision of the WAIS and the WAIS-R, released in 1997.

The WAIS-III Chinese version was developed in Taiwan (Chen & Chen, 2002). The Chinese version of the WAIS-III provides scores for verbal IQ (VIQ), performance IQ (PIQ), and full scale IQ (FSIQ). The WAIS-III also measures four secondary indices, as follows: (1) Verbal Comprehension Index (VCI), information, similarities, and vocabulary tests; (2) Working Memory Index (WMI), arithmetic and digit span; (3) Perceptual Organization Index (POI), block design, matrix reasoning, and picture completion; and (4) Processing Speed Index (PSI), digit symbol-coding and symbol search. VIQ includes seven tests; five tests are included in the two subindices of VCI and WMI, whereas two are not (letter-number sequencing and comprehension). PIQ includes seven tests; five tests are included in the POI and PSI, whereas two are not (picture arrangement and object assembly).

The internal consistency coefficient of the subscales and indices of the Chinese version of the WAIS-III ranges from 0.89 to 0.98. Regarding test–retest reliability, which was evaluated 2–11 weeks after the first test, participants obtained the highest score on the information subtest ($r=0.92$) and the lowest score on the matrix reasoning and object assembly subtests ($r=0.71$ for both tests), indicating that each subtest was stable. Concerning criterion-related validity, the correlation coefficient between the Chinese version of the WAIS-III and the Chinese version of WAIS-R for FSIQ, VIQ, and PIQ is 0.93, 0.94, 0.86, respectively. This finding shows that the two tests measure the same construct (Chen & Chen, 2004).

2.2.2. PSDP test

This test is a modification of the nine dot areas test proposed by Haylock (1987, 1997) and was developed with reference to the questions involving the drawing of 2-cm² graphs by connecting nine dots in tests used by Peng (2009). The scoring system is based on the New Creative Thinking Test developed by Wu et al. (1999). The participants received 1 fluency point for each 2-cm² graph drawn, with repeated graphs considered one response. The graphs drawn by the participants were classified into 35 types.

The participants received 1 diversity point for drawing each type of graph and received a perfect score if they drew all 35 types. Originality scoring was based on the participants' responses. After deleting repeated graphs, 291 different graphs remained. If the participants' responses accounted for 5% and higher, 2%–4.99%, or 1.99% and lower of all graphs, they received 0, 1, and 2 points, respectively. Regarding the reliability of the PSDP, the inter-rater reliability in fluency, flexibility, and originality was 0.997, 0.993, and 0.998, respectively. Fig. 1 shows six other solutions, the percentage of participants who produced these responses, and the originality scores.

Table 1
Group comparisons of IQ profiles and the score of the PSDP (N = 84).

Scale		MST(N = 34)		NG(N = 50)		t value
		mean	SD	mean	SD	
WAIS-III	Full scale	128.53	8.87	112.46	7.65	8.86***
	VIQ	128.65	9.58	113.52	9.42	7.18***
	PIQ	123.26	11.42	109.68	10.39	5.65***
	VCI	126.12	8.60	115.16	10.91	4.91***
	POI	122.94	11.08	110.08	11.49	5.11***
	WMI	124.91	11.94	108.28	10.18	6.85***
	PSI	120.74	12.86	105.88	15.78	4.55***
PSDP	Fluency	31.03	12.30	19.38	8.04	5.26***
	Flexibility	13.21	3.80	10.52	3.75	3.20***
	Originality	23.62	15.52	10.34	8.86	4.51***

Note: MST = mathematically and scientifically talented students; Nongifted students = NG

*** $p < 0.001$

2.3. Procedure

In this study, the students were recruited from senior high schools and universities in Northern and Central Taiwan. Data collection was conducted individually in classrooms on the university campus. The Chinese version of the WAIS-III was administered by licensed examiners and took 2–2.5 h to administer. The PSDP questions were presented using E-prime. Examiners followed the administrative procedure to guide the participants and explain the test questions. The participants recorded their answers on answer sheets.

2.4. Data processing

In this study, data processing and analysis were performed using SPSS version 20 (IBM SPSS Statistics, IBM Corporation, Armonk, NY). The independent samples *t*-test was used to compare the scores of the WAIS and PSDP between the MST group and the NG group. Correlations between the WAIS and PSDP were determined by computing Pearson's product-moment correlation. Furthermore, multiple stepwise regression analysis was used to fit the regression model for predicting divergent thinking ability from the composite IQ and four factor indices of the WAIS. The data were also processed using one-way analysis of covariance (ANCOVA) and Hedges' *g*, which were performed to control for the effect of intelligence on creativity between the MST group and the NG group and the estimated effect size.

3. Results

3.1. Comparison of IQ profiles and the PSDP score between the groups

Table 1 shows the comparisons of IQ profiles and the PSDP score between the groups. The *t*-test results indicated significant differences in the intelligence profile between the groups. Significant differences were observed in FSIQ, PIQ, and VIQ between the groups (FSIQ = 8.86, $p < 0.001$; PIQ = 5.65, $p < 0.001$; VIQ = 7.18, $p < 0.001$). Significant differences were also observed in the four indices of VCI, WMI, POI, and PSI between the groups (VCI = 4.91, $p < 0.001$; WMI = 6.85, $p < 0.001$; POI = 5.11, $p < 0.001$; PSI = 4.55, $p < 0.001$).

Table 1 also demonstrates significant differences in problem solving divergent thinking abilities between the groups (fluency = 5.26, $p < 0.001$; flexibility = 3.20, $p < 0.001$; originality = 4.51, $p < 0.001$).

3.2. Multiple regression analyses for predicting divergent thinking ability from IQ

3.2.1. Correlations between IQ and divergent problem solving abilities

The correlations between FSIQ and fluency, flexibility, and originality were 0.49, 0.24, and 0.46, respectively ($p < 0.01$). VIQ was significantly correlated only with fluency ($r = 0.31$, $p < 0.01$) and originality ($r = 0.29$, $p < 0.01$). PIQ was significantly correlated with fluency ($r = 0.57$, $p < 0.01$), flexibility ($r = 0.41$, $p < 0.01$), and originality ($r = 0.54$, $p < 0.01$). The result indicated PIQ had a higher correlation with the PSDP score than with FSIQ (see Table 2).

Regarding the four factor indices of the WAIS-III, POI was significantly correlated with each index of the PSDP ($.34 \leq r \leq 0.56$). WMI was significantly correlated with fluency ($r = 0.30$, $p < 0.01$) and originality ($r = 0.26$, $p < 0.05$). PSI was significantly correlated with fluency ($r = 0.39$, $p < 0.01$), flexibility ($r = 0.27$, $p < 0.05$), and originality ($r = 0.31$, $p < 0.01$). In this study, VCI was significantly correlated with fluency ($r = 0.22$, $p < 0.05$), but was weakly correlated with flexibility and originality ($p > 0.05$).

Table 2
Correlations between the scores of WAIS-III and PSDP (N = 84).

WAIS-III	PSDP		
	fluency	flexibility	originality
FSIQ	0.49**	0.24*	0.46**
VIQ	0.31**	0.04	0.29**
PIQ	0.57**	0.41**	0.54**
VCI	0.22*	0.03	0.20
POI	0.56**	0.34**	0.52**
WMI	0.30**	0.01	0.26*
PSI	0.39**	0.27*	0.31**

* $p < 0.05$.
** $p < 0.01$.

Table 3
Summary table of multiple regression between the WAIS-III and the PSDP (N = 84).

Independent variable	Dependent variable	Order	R ²	F	Regression coefficient B	Standardized regression coefficient β	t
VIQ, PIQ	fluency	PIQ	0.32	39.10**	0.51	0.57	6.25**
	flexibility	PIQ	0.17	16.26**	0.13	0.41	4.03**
	originality	PIQ	0.29	33.91**	0.58	0.54	5.82**
VCI, POI, WMI, PSI	fluency	POI	0.32	37.69**	0.43	0.48	5.03**
		PSI	0.35	22.03**	0.15	0.21	2.16*
	flexibility	POI	0.12	11.04**	0.14	0.46	3.93**
		WMI	0.16	7.72**	-0.07	-0.23	2.00*
	originality	POI	0.28	31.03**	0.55	0.52	5.57**

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

3.2.2. IQ predicts divergent thinking ability

Table 3 shows the multiple regression analyses for predicting divergent thinking ability from the composite IQ. The regression models demonstrated that PIQ is a statistically significant predictor. The explanatory values (R²) of fluency, flexibility, and originality were 32%, 17%, and 29%, respectively. This result indicated that PIQ is a more effective predictor of divergent thinking ability than FSIQ and VIQ.

Regarding the four factor indices of the WAIS-III, the first regression showed that POI is a significant predictor of the PSDP. The explanatory values (R²) of fluency, flexibility, and originality were 32%, 12%, and 28%, respectively. The second regression showed that POI and PSI accounted for 35% of the variance in fluency; the addition of PSI accounted for an increased 3% of the variance. The second regression showed that POI and WMI accounted for 16% of the variance in flexibility, but flexibility varied directly with POI and inversely with WMI.

3.3. Group comparison of divergent thinking ability after excluding the influence of IQ

To eliminate the influence of intelligence, the IQs were used as covariates to examine the differences in divergent thinking between the two groups. Tables 4 and 5 present the results of one-way ANCOVA. The MST students solved problems more flexibly and could fluently generate more original productions than their NG peers.

Table 4 shows the results of one-way ANCOVA when the influence of intelligence was eliminated. After excluding the influence of FSIQ, the MST students outperformed the NG students in fluency ($\eta^2 = 0.06$, $g = 3.86$, $p < 0.05$), flexibility ($\eta^2 = 0.06$, $g = 3.67$, $p < 0.05$), and originality ($\eta^2 = 0.06$, $g = 3.80$, $p < 0.05$). After excluding the influence of VIQ, the MST students outperformed the NG students in fluency ($\eta^2 = 0.17$, $g = 6.54$, $p < 0.01$), flexibility ($\eta^2 = 0.16$, $g = 6.18$, $p < 0.01$), and originality ($\eta^2 = 0.16$, $g = 6.32$, $p < 0.01$). After excluding the influence of PIQ, the MST students outperformed the NG students only in fluency ($\eta^2 = 0.08$, $g = 4.17$, $p < 0.05$) and originality ($\eta^2 = 0.08$, $g = 3.95$, $p < 0.05$).

Table 5 shows the results of one-way ANCOVA when the influence of four indices of the WAIS-III was eliminated. The MST students outperformed the NG students in all divergent thinking abilities. After excluding the influence of VCI, the MST students outperformed the NG students in fluency ($\eta^2 = 0.21$, $g = 7.14$, $p < 0.01$), flexibility ($\eta^2 = 0.13$, $g = 5.34$, $p < 0.01$), and originality ($\eta^2 = 0.20$, $g = 6.86$, $p < 0.01$). After excluding the influence of POI, the MST students outperformed the NG students in fluency ($\eta^2 = 0.10$, $g = 4.53$, $p < 0.01$), flexibility ($\eta^2 = 0.04$, $g = 2.81$, $p > 0.05$), and originality ($\eta^2 = 0.09$, $g = 4.35$, $p < 0.01$). After excluding the influence of WMI, the MST students outperformed the NG students in fluency ($\eta^2 = 0.18$, $g = 6.68$, $p < 0.01$), flexibility ($\eta^2 = 0.18$, $g = 6.69$, $p < 0.01$), and originality ($\eta^2 = 0.18$, $g = 6.58$, $p < 0.01$). After excluding the influence of PSI, the MST students outperformed the NG students in fluency ($\eta^2 = 0.16$, $g = 5.88$, $p < 0.01$), flexibility ($\eta^2 = 0.06$, $g = 3.47$, $p < 0.05$), and originality ($\eta^2 = 0.16$, $g = 5.96$, $p < 0.01$).

Table 4

Results of one-way ANCOVA with FSIQ and subscales of WAIS entered as a covariate between the MST and NG (N = 84).

Covariate	Dependent variable	Source of variation	SS	df	mean square	F	P value	η^2	Hedges'g
FSIQ	fluency	Covariance	2649.11	1	2649.11	27.78	0.00	0.26	3.86
		Between group	527.42	1	527.42	5.53	0.02 [*]	0.06	
		Error	7724.71	81	95.37				
		Total	59670.00	84					
	flexibility	Covariance	74.24	1	74.24	5.16	0.03	0.06	3.67
		Between group	71.81	1	71.81	4.99	0.03 [*]	0.06	
		Error	1165.98	81	14.39				
		Total	12629.00	84					
	originality	Covariance	3305.57	1	3305.57	23.66	0.00	0.23	3.80
		Between group	746.34	1	746.34	5.34	0.02 [*]	0.06	
		Error	11315.24	81	139.69				
		Total	36110.00	84					
VIQ	fluency	Covariance	1041.99	1	1041.99	10.35	0.00	0.11	6.54
		Between group	1704.62	1	1704.62	16.93	0.00 ^{**}	0.17	
		Error	8154.63	81	100.67				
		Total	59670.00	84					
	flexibility	Covariance	1.83	1	1.83	0.13	0.72	0.00	6.18
		Between group	205.78	1	205.78	15.09	0.00 ^{**}	0.16	
		Error	1104.43	81	13.63				
		Total	12629.00	84					
	originality	Covariance	1269.17	1	1269.17	8.72	0.00	0.10	6.32
		Between group	2302.26	1	2302.26	15.81	0.00 ^{**}	0.16	
		Error	11795.72	81	145.63				
		Total	36110.00	84					
PIQ	fluency	Covariance	3517.52	1	3517.52	42.08	0.00	0.34	4.17
		Between group	613.26	1	613.26	7.34	0.01 [*]	0.08	
		Error	6770.46	81	83.59				
		Total	59670.00	84					
	flexibility	Covariance	217.09	1	217.09	16.44	0.00	0.17	2.14
		Between group	25.48	1	25.48	1.93	0.17	0.02	
		Error	1069.46	81	13.20				
		Total	12629.00	84					
	originality	Covariance	4495.77	1	4495.77	36.22	0.00	0.31	3.95
		Between group	816.08	1	816.08	6.57	0.01 [*]	0.08	
		Error	10055.30	81	124.14				
		Total	36110.00	84					

* $p < 0.05$.** $p < 0.01$.

4. Discussion

4.1. MST students outperform NG students in divergent thinking ability

Our finding indicates that the MST students not only have high levels of intelligence but also outperform their NG peers in fluency, flexibility, and originality in mathematical-related divergent thinking ability tasks. The findings are consistent with those of several other studies, in which students with high IQ exhibited superior creativity compared with students with average IQ (Sligh, Connors, & Roskos-Ewoldsen, 2005), and mathematically talented students scored higher on the C-SAT than average students (Ayas & Sak, 2014). Scientifically talented students can be more creative than their typically developing peers and excel at divergent thinking because of their strong mathematical knowledge.

4.2. IQs predict divergent thinking ability

The results of the regression analyses demonstrated that PIQ significantly predicts fluency, flexibility, and originality. The correlation coefficients between PIQ and all variables of the PSDP were found to range from 0.41 to 0.57. Thus, PIQ is a significant predictor of fluency, flexibility, and originality (Gilhooly et al., 2007; Nusbaum & Silvia, 2011; Silvia & Beaty, 2012; Silvia, 2008). PIQ might be crucial in certain domains such as science, engineering, and mathematics. Previous studies have demonstrated that the correlation coefficients between intelligence and creativity range from 0.20 to 0.30 (An, Song, & Carr, 2016; Batey & Furnham, 2008; Cho et al., 2010; Gilhooly et al., 2007; Preckel et al., 2006; Runco & Albert, 1986; Silvia, 2008). However, in this study, the correlation coefficients were higher. The higher coefficients may be because the subtests of PIQ are nonverbal performance subtests, similar to the PSDP test. Moreover, in this study, the high correlation between POI and divergent problem solving ability indicates that the subtests of POI and PSDP are more domain related.

Table 5
Results of one-way ANCOVA with four factors index of WAIS entered as a covariate between the MST and NG (N=84).

Covariate	Dependent variable	Source of variation	SS	df	mean square	F	P value	η^2	Hedges'g
VCI	fluency	Covariance	522.97	1	522.97	5.20	0.03	0.06	
		Between group	2229.21	1	2229.21	22.16	0.00**	0.21	7.14
		Error	8149.05	81	100.61				
			Total	59670.00	84				
	flexibility	Covariance	1.04	1	1.04	0.07	0.79	0.00	
		Between group	173.96	1	173.96	12.39	0.00**	0.13	5.34
		Error	1137.03	81	14.04				
			Total	12629.00	84				
	originality	Covariance	614.18	1	614.18	4.22	0.04	0.05	
Between group		2971.18	1	2971.18	20.43	0.00**	0.20	6.86	
Error		11781.78	81	145.45					
		Total	36110.00	84					
POI	fluency	Covariance	3433.01	1	3433.01	41.30	0.00	0.34	
		Between group	735.38	1	735.38	8.85	0.00**	0.10	4.53
		Error	6732.84	81	83.12				
			Total	59670.00	84				
	flexibility	Covariance	155.71	1	155.71	11.37	0.00	0.12	
		Between group	46.70	1	46.70	3.41	0.07	0.04	2.81
		Error	1109.63	81	13.70				
			Total	12629.00	84				
	originality	Covariance	4218.97	1	4218.97	33.74	0.00	0.29	
Between group		1020.12	1	1020.12	8.16	0.01*	0.09	4.35	
Error		10128.06	81	125.04					
		Total	36110.00	84					
WMI	fluency	Covariance	945.83	1	945.83	9.40	0.00	0.10	
		Between group	1801.84	1	1801.84	17.90	0.00**	0.18	6.68
		Error	8153.57	81	100.66				
			Total	59670.00	84				
	flexibility	Covariance	0.13	1	0.13	0.01	0.92	0.00	
		Between group	237.88	1	237.88	17.94	0.00**	0.18	6.69
		Error	1074.03	81	13.26				
			Total	12629.00	84				
	originality	Covariance	1058.29	1	1058.29	7.28	0.01	0.08	
Between group		2528.94	1	2528.94	17.39	0.00**	0.18	6.58	
Error		11779.91	81	145.43					
		Total	36110.00	84					
PSI	fluency	Covariance	1638.42	1	1638.42	17.02	0.00	0.17	
		Between group	1467.12	1	1467.12	15.24	0.00**	0.16	5.88
		Error	7795.69	81	96.24				
			Total	59670.00	84				
	flexibility	Covariance	94.07	1	94.07	6.67	0.01	0.08	
		Between group	74.77	1	74.77	5.30	0.02*	0.06	3.47
		Error	1143.20	81	14.11				
			Total	12629.00	84				
	originality	Covariance	1494.00	1	1494.00	10.41	0.00	0.11	
Between group		2248.69	1	2248.69	15.67	0.00**	0.16	5.96	
Error		11624.44	81	143.51					
		Total	36110.00	84					

4.3. MST students outperform NG students in divergent thinking ability after controlling for intelligence

After controlling for the effect of the IQs, the MST students outperformed the NG students in divergent problem solving abilities. The MST students had the ability to generate new, original productions and multiple ways to solve mathematically divergent thinking problems. [Sriraman \(2005\)](#) stated that mathematically gifted students are more intuitive, think more analytically and more flexibly, and can think reversibly. The findings support the theory that their attitudes and achievement in mathematics and science favor their performance in mathematical-related creativity tasks.

Reduced values of η^2 and g were obtained for fluency, flexibility, and originality after controlling for the effect of PIQ. By contrast, increased values of η^2 and g were obtained for fluency, flexibility, and originality after controlling for the effect of VIQ. The finding shows that the PSDP test is a domain-specific task that provides assessment of creative potential in the graphic domains.

Reduced values of η^2 and g were obtained for fluency and originality after controlling for the effect of FSIQ in comparison with those after controlling for the effect of PIQ and VIQ. Moreover, reduced values of η^2 and g were obtained for flexibility after controlling for the effect of PIQ. The finding shows that PIQ has a higher effect on flexibility.

Higher values of η^2 and g were obtained after controlling for the effect of both VCI and WMI than those after controlling for the effect of both POI and PSI. This result indicates that the POI and PSI indices have a greater influence on fluency, flexibility, and originality. Moreover, higher values of η^2 and g were obtained after controlling for the effect of PSI than those after controlling for the effect of POI. No significant difference was observed in flexibility between the MST and the NG groups. This finding indicates that among the four indices, POI has a major effect on figural problem divergent thinking, particularly flexibility.

Creativity is domain-specific. In the PSDP test, participants connect nine dots to draw as many as possible, different 2-cm² graphs under a time limit. This PSDP test assesses abilities involved in figural reasoning, figural flexibility, originality, spatial processing, and visual-motor skills. POI is a subtest of PIQ and includes block design, matrix reasoning, and picture completion. It measures nonverbal and spontaneous reasoning, visual information preferences, comfort with novel and unexpected situations, and preferences for practical learning (Niolon, 2005). The tasks of the subtests of POI are similar to that of PSDP. Therefore, after excluding the effect of PIQ/POI, the mean difference in flexibility between the two groups decreased and did not reach significance. This finding indicates that creativity is a domain-related ability.

5. Conclusion

Our findings suggest that MST students have more fluent, flexible, and original ideas than their NG peers in the PSDP test. In this study, after controlling for the effect of intelligence, the MST students showed high creativity for solving mathematical-related problems. Thus, MST students exhibit high potential and high performance in mathematics and science, which prepares them to enter into the gifted and talented classes. Because of their abundant learning and knowledge, they excel in mathematical-related creativity. Even after controlling for IQ, the MST students with higher learning backgrounds were more likely to obtain higher scores than their NG peers in mathematical-related creativity tests. This result indicates a significant correlation between learning backgrounds and domain creativity, and that creativity is domain-specific. Similar results were reported by Tabach and Friedlander (2013), Ayas and Sak (2014), and Yi, Plucker, and Guo (2015). To assist students in developing their creative potential, education designed for gifted children should combine academic learning with creative thinking skills (Meador, 2003). Meissner (2006) also emphasized the importance of creative education for increasing mathematic achievement. More training in academics and creativity will lead to higher potential realization in MST students.

Numerous researchers have used divergent thinking to investigate creativity. Thus, the PSDP task used in this study may be used to examine the creative potential of gifted and creative students. However, the number of students involved in this study was small. Future research should include a larger sample size to provide higher external validity. The participants in our study were senior high school and university students. Future studies should recruit different samples, such as junior high school and elementary students, to analyze the effect of learning stages on domain-specific creativity tasks. Moreover, our study only used the PSDP to assess creativity. Future studies should use multiple instruments to measure mathematical creativity, such as those incorporating creative personality and spatial problems.

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