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RESEARCH NOTE

Mathematical Intelligence and Mathematical Creativity: A Causal Relationship

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This study investigated the causal relationship between mathematical creativity and mathematical intelligence. Four hundred thirty-nine 8th-grade students, age ranged from 11 to 14 years, were included in the sample of this study by random cluster technique on which mathematical creativity and Hindi adaptation of mathematical intelligence test were administered with 4-month time lag. Cross-lagged panel analysis was used to analyze the data. The uncorrected cross-lagged correlations appeared to show no causal relation between mathematical creativity and mathematical intelligence. But after the correction the difference in the cross-lagged correlations was found to be small and does not give guarantee of unidirectional causal relation between these two constructs. It revealed that there is a mutually reinforcing (symmetric) relationship between mathematical intelligence and mathematical creativity, i.e., mathematical intelligence causes mathematical creativity and vice-versa.

Is a child intelligent or creative or both? The answer of this question is impossible without context: "Intelligent and creative in what?" In the field of creativity and intelligence, now there is an litigious debate over whether creativity is domain specific (Baer, 1994; Singh, 1985) or general (Mehdi, 1985); and similar for the existence of a general factor of intelligence *g* (Jensen, 1998; Johnson, Te Nijenhuis, & Bouchard, 2008) or specific factor (Sternberg, Kaufman, & Grigorenko, 2008). Furthermore, Plucker and Beghetto (2004) argued that creativity has both specific and general components. Most of theories (Runco, 2007; Simonton, 1999) agree that domain-general traits translate into domain specific accomplishments; but there is also ample evidence related to general to specific view. Everyone is creative, but the domain may be different. It is true that no one can creative in all domains. Due to this fact, the distinction between general and specific creativity clearly appears, however, specific creativity is distinct ability to create in specific field, for example in mathematics, science etc. Therefore, in this study, creativity and intelligence both are considered as domain specific, like; mathematical creativity and mathematical intelligence respectively.

Mathematical creativity has been currently proposed as one of the major components of education of the 21st century (Mann, 2005). It ensures the growth of the field of mathematics as a whole (Sriraman, 2004) and mathematical creativity is one of a greatest assets of a nation (Singh, 1985). It plays a vital role in the full cycle of advanced mathematical thinking (Ervynck, 1991). It is reasonable that every person may be a creative or intelligent in general, as well as in specific domain, but the degree may be different. Mathematical intelligence is the core of multiple intelligence theory proposed by Gardner (1983). It is a young field yet, and research is needed to develop a universally accepted definition of mathematical intelligence, culture- and gender-free tests for measurement, teaching-learning strategies for the development of mathematical intelligence, an understanding of the effect of socio-cultural and educational background of the family affecting mathematical intelligence, etc. Veenmana and Spaansa (2005) wrote that logical/mathematical intelligence is the core of multiple intelligence theory (MI) and can be regarded as the true manifestation of MI. Gardner (1993) suggested that great creative persons and novel laureates have relied on different intelligence to

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manifest their creativity in specific domain. For example, Sriramanujan, Aryabhatt, Newton, etc., became famous through mathematical intelligence; T. S. Eliot, Tagore, etc., through linguistic intelligence; Einstein through logical–mathematical intelligence, and so forth. This theory provides the evidence that creativity has required a certain extent of intelligence. Therefore, the average IQ level influences the relationship between these constructs (Cho, Nijenhuis, van Vianen, Kim, & Lee, 2010; Jauk, Benedek, Dunst, & Neubauer, 2013; Karwowski & Gralewski, 2013).

Creativity and intelligence do share an important attribute: They are both domain specific. Creativity often requires a minimum level of intelligence. Intelligence and creativity both are intercorrelated (Batey & Furnham, 2006; Guilford, 1967). Furthermore, meta-analytic findings suggested that the correlation between creative potential and intelligence generally is around r = .17 (Kim, 2005). Focusing on the domain-specific, mathematical creativity has been studied with different variables. The findings of previous research studies have shown that mathematical creativity was found to be significantly related with problem-solving performance (Singh, 1993; Tyagi, 2015), mathematical achievement (Brunkalla, 2009; Sak & Maker, 2006; Singh, 1986; Tuli, 1979), self concept in mathematics (Singh, 2000), attitude toward mathematics (Singh, 2000; Tuli, 1979), mathematical aptitude (Jensen, 1973; Tuli, 1979; Tyagi, 2014), personality characteristics (Singh, 1988), and emotional intelligence (Jhony, 2008).

Mathematical intelligence has been considered as a strong indicator of general intelligence. Fujita (1983) believed that mathematical intelligence was composed of mathematical thinking and mathematical literacy (as cited in Nagasaki, 2012); associated with mathematical giftedness and mathematical creativity (Juter & Sriraman, 2011). The analysis of literature has shown the evidence that mathematical intelligence was found to be significantly related with meta-cognitive strategies in English as a Foreign Language (EFL) context (Arani & Mobarkeh, 2012): students' mathematical functioning in general and in levels of application and reason (Niroon, Nejhad, & Haghani, 2012). Vandana (2012) found a positive and significant relationship between mathematical creativity and mathematical intelligence, which has led to speculation about the nature of relationship. Meanwhile, the question arises here, "Does mathematical creativity require a minimum level of mathematical intelligence?" As it is known that general creativity requires minimum level of intelligence, research has shown that, just as intelligence in one domain does not predict creativity in another domain and vice-versa. However, very ample evidence indicates that only correlational studies have been conducted in this area. Cross-lagged studies should be conducted to develop deep insight in the field to know whether the relationship between mathematical intelligence and mathematical creativity is causal or symmetrical or reciprocal. Therefore, this study has been conducted.

METHOD

Participants and Procedure

Four hundred and thirty-nine eighth-standard students were selected through a random cluster technique from nine intermediate and high schools located in Varanasi region, India. The students were from rural and urban locality. The age range was from 11 to 14 years. One hundred and twenty participants left out in the second phase. The final sample was 439 students (84 urban boy, 63 urban girls, 121 rural boys, and 171 rural girls).

The instruments were administered to the participants on the two occasions with an interval of 4 months in October 2013 (T_1) and February 2014 (T_2). The instructions of mathematical intelligence test were translated from English to Hindi, with back-translation procedure to ensure accuracy and equivalency. Before administration of both the tests, it was told to all participants that data were collected only for research purposes and that participation was completely voluntary and confidential in future.

Instruments

A mathematical creativity test developed by Singh (1985) was used to assess the mathematical creativity among middle-school students. The test items stimulate the students to freely play with the numbers and figures. There are five types of activities included in the test, namely patterns in mathematics, new relationship test activity, nine dot areas, subsets, and similarities. The tasks pertaining to fluency, flexibility, and originality (verbal & nonverbal) have been used in the construction of the test. Test-retest reliability of the mathematical creativity test was found to be .81. The correlation of the total activity scores with grand total for the urban sample was found to be ranged from .63 to .84 and for the rural sample .49 to .78. This indicates that mathematical creativity test possesses internal validity. The raw scores of each dimension, i.e., fluency, flexibility, and originality, were converted into t scores with a mean = 50 and SD = 10. The t scores of each dimension were added then to get the composite scores of mathematical creativity of each student. The test has been used by Singh (1988, 1990), Somashekhar (1998), Vandana (2012), and Tyagi (2014, 2015).

Hindi adaptation of Haselbaur's mathematical intelligence test was used to measure the mathematical intelligence. The test includes 25 items relating to the branches of mathematics i.e., arithmetic, algebra, and geometry. The test-retest reliability of the test was found to be 0.78 (df = 398). The concurrent validity of mathematical intelligence test was found to be .70; calculated on the basis of correlation between mathematical intelligence and mathematical aptitude on 160 participants. Mathematical intelligence test scores of each participant were converted into IQ scores with the help of conversion table given by Hauselbaur (2006).

Design and Analysis

The cross-lagged panel correlation (CLPC) analysis may be viewed as a special case of the multitrait-multimethod matrix (Kenny, 1975) in which at least two variables should be measured at least two times simultaneously; here, mathematical creativity (MC) and mathematical intelligence (MI) were measured by two times, T_1, and T_2, respectively, with a lag of 4 months between two successive phases. It is a quasi experimental design appropriate for field settings such as schools, thereby increasing representativeness of the findings. It has been used effectively in education research (e.g., Ahmed, Minnaret, Kuyper, & van der Werf, 2012; Campbell, 1963; Kenny, 1975; Tyagi, 2015; Tyagi & Singh, 2014; Verma, 1994; Watkins, Lei, & Canivez, 2007).

In Figure 1 the two variables X (MC) and Y (MI) and two lag (time 1, & time 2) generate four variables (X_1, X_2, Y_1, and Y_2), and these four variables generate six correlations: two autocorrelations ($r_{X_1X_2}, r_{Y_1Y_2}$); two synchronous correlations($r_{X_1Y_1}, r_{X_2Y_2}$); and two cross-lagged correlations ($r_{X_1Y_2}, r_{Y_1X_2}$). A cross-lagged panel correlation is a method for testing spurious relationships by comparing the cross-lagged differential: $r_{X_1Y_2}$minus $r_{Y_1X_2}$ ($r_{X_1Y_2} - r_{Y_1X_2}$). If cross-lagged differential is positive, we conclude the causal predominance to be that of *X* causing *Y*, and if the cross-lagged differential is negative, *Y* causing *X*. No significant difference in the cross-lags suggests that the correlation between the variables is spurious. The synchronous correlations should be at least .30 and large sample size for the effective use of cross-lagged analysis. The null hypothesis of CLPC is that the two variables are not causally related (Ho:$r_{X_1Y_2} = r_{Y_1X_2}$). It has two assumptions; synchronicity and stationarity (Kenny, 1975; Kenny & Harackiewicz, 1979). Synchronicity means that the variables involved are measured at the same point in time. Stationarity is tested by comparing the synchronous correlations, which means that the causal process did not change over time. No significant differences between the synchronous correlations indicates that variables are stationary. If it happens, the test for cross-lagged correlations should be conducted by using the Pearson-Filon test for establishing the quasi stationarity.

RESULTS

Mean score and standard deviations obtained for the mathematical creativity and mathematical intelligence tests from the two occasions with 4-month time lag on which they were administered are presented and summarized in Table 1.

Figure 2 presents the coefficients of correlations among the four variables in standard CLPC model. Significant and high auto-correlations were found between mathematical creativity at time-1 and time-2 ($r_{MC_1MC_2} = .78$) and mathematical intelligence at time-1 and time-2($r_{MI_1MI_2} = .82$). The data, therefore, appear not to satisfy the assumption of perfect stationarity. The synchronous and cross-lagged correlations must be corrected for changes in the reliability of the measures. Reliability ratios have been used to correct the synchronous and cross-lagged correlations. The estimated reliability ratio was used to correct the synchronous correlation for differential measurement error and to test the viability of the quasi-stationarity assumption. Otherwise, variables

TABLE 1
Participant's information

	Mathematical Creativity		*Mathematical Intelligence*	
	M	*SD*	*M*	*SD*
Ist Testing	104.01	27.63	9.22	5.71
2nd Testing	104.52	30.48	9.64	5.86

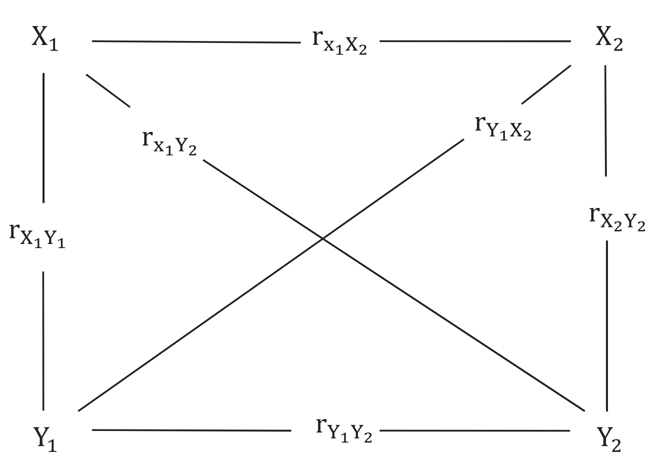

FIGURE 1 Cross-lagged panel correlation paradigm (X and Y are variables and 1 and 2 times).

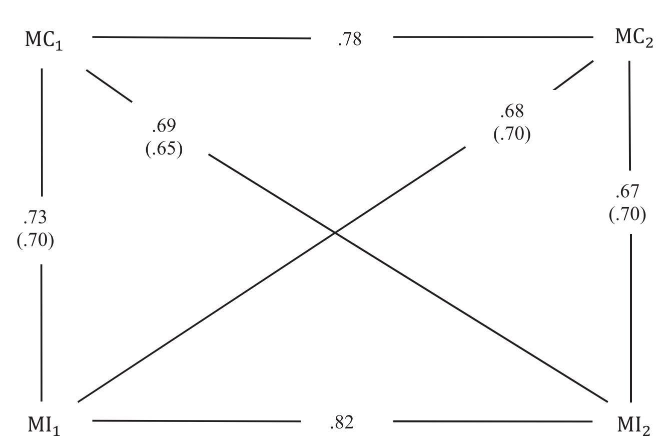

FIGURE 2 Cross-lagged panel correlations between mathematical creativity and mathematical intelligence.

TABLE 2
Corrected cross-lagged correlations between Mathematical Creativity (MC), and Mathematical Intelligence (MI) at Time-1 to Time-2 (N = 439)

	Coefficient of Correlations							
	Cross-lagged		*Stability*		*Synchronous*			
Relationship	$r_{MC_1MI_2}$	$r_{MI_1MC_2}$	$r_{MC_1MC_2}$	$r_{MI_1MI_2}$	$r_{MC_1MI_1}$	$r_{MC_2MI_2}$	*Pearson Filon z Value*	*p*
Mathematical Creativity (MC) Mathematical Intelligence (MI)	.65	.70	.78	.82	.70	.70	−1.80	NS

z is based on Pearson Filon. If z ≥ 1.96, Significant Difference in cross-lagged Correlations at .05 level

that decrease in reliability would erroneously appear to be causes and vice-versa (Campbell, 1963); (Kahle & Berman, 1979). The values in parentheses are used for the corrected correlations. Equal and corrected synchronous correlation indicated that quasi-stationarity exist($r_{MC_1MI_1}, r_{MC_2MI_2} = .70$). The uncorrected cross-lagged correlations appear to show no causal direction between mathematical creativity and mathematical intelligence ($r_{MC_1MI_2}$= .69, and $r_{MI_1MC_2}$= .68).

As can be seen from Table 2, the corrected cross-lagged correlations between mathematical creativity time-1 and mathematical intelligence at time-2 $r_{MC_1MI_2}$= .65 and mathematical intelligence at time-1 and mathematical creativity at time-2 was found to be $r_{MI_1MC_2}$= .70. The reliability ratios for mathematical creativity and mathematical intelligence were found to be .93 and .98, respectively. The Pearson-Filon *z* value (−1.80) of the difference between $r_{MC_1MI_2}$ and$r_{MI_1MC_2}$ was found not to be significant at .05 level with df = 437. Thus, the null hypothesis that the correlation between mathematical creativity and mathematical intelligence is spurious has been rejected. Hence, the relationship between mathematical creativity and mathematical intelligence was found to be symmetric, i.e., one variable causes the second and vice-versa.

DISCUSSION AND CONCLUSIONS

The main aim of this study was to investigate the direction of the causal relationship between mathematical creativity and mathematical intelligence. On the basis of theories and previous research findings, it was hypothesized that mathematical creativity and mathematical intelligence would be related to each other. The findings of the study show that there is not significant unidirectional causal relation between mathematical intelligence and mathematical creativity, but symmetric relationship between these two constructs. The major findings of the study reveals that mathematical intelligence was found to be a cause of mathematical creativity and vice-versa. We cannot rule out the existence of a third variable that affects the causal relationship between these two variables. No significant difference between the synchronous correlations between time-1 and time-2 indicates that causal structure does not change over time, i.e., a priori relationship between mathematical creativity and mathematical intelligence. The findings of the study should be viewed as one step forward the identification of relationship between mathematical creativity and mathematical intelligence and as one step prior to a true experimental study of the causal relationship between the two variables. However, CLPC procedure may be one of the most appropriate designs in which the variables are not typically subject to experimental manipulation or random assignment of participants is not possible. In this study, the values of $r_{MC_1MI_2}$ and $r_{MI_1MC_2}$ before the correction were almost similar to each other (.69 & .68), and after the correction the values were found to be .65 & .70, which shows very little difference. These results show little chance of unidirectional causality between these two constructs. The values may be affected due to post hoc fallacy, i.e., due to effect of a third variable that was not consider in the study. Hence, the results of this study show only a mutually reinforcing (symmetric) relationship rather than causal.

One of the strengths of this study is that symmetric relationship was investigated by using two measurement phases. The study also examined the cross-lagged relationship controlling for concurrent disturbance correlations and other effects which was one step forward than simple correlational research.

This study considered a relatively small sample and a short lag interval. Although a critical transition time of investigation was covered by the investigator, a longer time and larger sample size may help to present more clearly the unidirectional causal relationship between mathematical creativity and mathematical intelligence.

The aforementioned limitations notwithstanding, the findings of this study have important implications for theory and practice. Mathematical intelligence does influence mathematical creativity, and vice-versa. ‘Finally, It may be helpful for mathematics teachers, teacher educators, curriculum developers and administrators to develop curriculum and teaching learning strategies to nourish these two important constructs, i.e., mathematical creativity and mathematical intelligence.

Future researches by using cross-lagged panel analysis with variables such as mathematical curiosity, self-concept in mathematics, anxiety toward mathematics, and mathematical problem-solving performance may be conducted. It is possible that longer or shorter time gaps between two measurements may lead to significant or nonsignificant cross-lag differences. Furthermore, longitudinal and experimental research should be conducted to explicitly investigate the relationship between mathematical creativity and mathematical intelligence.

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