

Student Ambiguity Tolerance as Predictor of Problem-Solving Ability in Mathematics

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Abstract

Development of problem-solving ability among students is one of the main goals of mathematics education. This study investigated the relation between student ambiguity tolerance and their problem-solving ability in mathematics. In particular, it sought to determine whether or not students' positive reaction toward unfamiliar or uncertain stimuli predict their ability to solve non-routine word problems. A total of 182 junior high school students participated in the study. Two instruments were used namely, the McLain Multiple Stimulus Types Ambiguity Tolerance (MSTAT-II) Scale and a problem-solving ability test. Both tests were subjected to validity and reliability analyses. Results showed that ambiguity tolerance predicts problem-solving ability in mathematics. In addition, ambiguity tolerance and problem-solving ability have moderate and positive association. A detailed analysis of student solutions and empirical evidences suggest that the use of open-ended problems be employed across various subject matters in mathematics to develop not only problem-solving skills but critical and logical reasoning as well as creativity among students.

Keywords: ambiguity tolerance, non-routine word problems, problem-solving ability

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Introduction

According to the National Council of Teachers of Mathematics (2000), emphasis should be given on the development of problem-solving skills in the realm of mathematics. There have been a number of researchers who conducted studies on problem-solving in relation to mathematical standards, curriculum, and pedagogies (Sriraman, 2005). In the typical classroom set-up, it was found out that students are more accustomed to dealing with routine problems that are usually found in the textbooks (Lee, 2011; Sibbaluca, 2009). This type of problems is content-specific and usually requires multiple steps that call for a structured solving process. This suggests lack of creativity in the teaching and learning of mathematics. On the other hand, non-routine problems that use ambiguous situations could be helpful in addressing issues related to problem-solving abilities of the students. Researchers affirm that tolerance for ambiguity positively influences one's performance and adjustment in cross-cultural settings (Furnham & Marks, 2013; Jokinen, 2005; Yamazaki & Kayes, 2004). Eisinger (2011) noted that understanding of the abstract and the ambiguous is oftentimes missing both in the K-12 and university classroom.

In the usual classroom set-up, learning ambiguity and accepting the abstract are not being emphasized inside the classroom, yet most of the time, certain attributes of uncertainty are involved in one's daily life encounters, as well as in researches around the world. In addition, open-ended views in mathematics are being neglected in the conduct of pedagogical approaches inside a mathematics classroom. It is a common observance that teachers/ facilitators/ educators often do not use open-ended problems in the set of exercises or tasks given to the students. The teaching practices most often than not deal with textbook mathematics problems that are routine and do not involve engaging activities that will provide opportunities for students to think deeply and perform independently (Lee, 2011).

Considering a comprehensive research about ambiguity tolerance as a means to evaluating students' abilities creates openness for different points of views in the teaching and learning process (Eisinger, 2011). Solving ambiguous problems in mathematics will provide opportunities for the students to think of different solutions and will make way for their creative juices to flow in generating novel ideas and meaningful answers (Tallent, 2016).

Ambiguity and Tolerance

According to Arquero and McLain (2010), ambiguity can be most suitably defined as the lack of necessary information to understand a specific circumstance and come up with comprehensible decisions with expected outcomes. While the definition of ambiguity is closely tied to concepts of generality and indeterminacy, it relies heavily on basic concepts in semantics such as: meaning, denotation and connotation. An expression is ambiguous if and only if the expression has more than one meaning. Another technical definition by linguists is that an expression is ambiguous if and only if the expression can accommodate more than one structural analysis. Tolerance of ambiguity "indicates the capacity to live with ambiguity, endure ambiguity, to operate with and within ambiguity" (Stoycheva, 2011, p.1).

Ambiguity tolerance is considered to be an intrinsic psychological characteristic of a person (Brown, 2007; Steenkamp & Wessels, 2014). It is also defined to be the tendency of an individual (group) to perceive and process information on ambiguous situations. An individual with high ambiguity tolerance may contradict positively or tolerate contradiction in his/ her beliefs and understanding. Individuals with low-tolerance of ambiguity view ambiguous situation as a threat that causes them to react hastily and avoid such stimuli. On the other hand, individuals with high-tolerance of ambiguity could view the situation as an interesting encounter (Brown, 2007 and McLain, 2009).

Since 1990, there were many studies that focus on the relationship of ambiguity tolerance to several fields of interest. In particular, in the realm of foreign language reading and learning, research showed that the ambiguity tolerance of the students, their self-perceived success and strategy training in reading were significantly correlated to each other. Further, research results indicate that the more ambiguity tolerant the learner is, the more successful he could be. This underscores the role of learner training in improving the ambiguity tolerance of the students (Erten & Topkaya, 2009). Since ambiguity demands evaluation or choice, it may pose as a cognitive challenge (Arquero & Tejero, 2009) and therefore more assistance and encouragement from the teachers are needed in learning among low ambiguity tolerant individuals (Chu et al., 2015).

Mathematical Problem-Solving Ability

Problem solving is one the most important components of mathematics. It requires combined creative skills and concepts to deal with specific mathematical situations called real-world problems. However, many researchers acknowledge that most of the students encounter difficulties in solving such problems. Problem-solving is a higher-order thinking process composed of major intellectual abilities and cognitive processes. It is not just about recalling simple facts or applying well-learned methods. Factors that are deemed significant in the problem-solving performance include intelligence, creativity and originality, spatial ability, verbal ability, working memory, and knowledge, all of which are identified as cognitive abilities (Bahar, 2015). Solving problems involves both analytical and creative skills. Through problem solving, students can understand and develop innovative solutions to problems or challenges that may vary in context.

There have been a lot of discussions on the restrictions involved in solving problems inside a mathematics classroom. Sriraman (2005) noted that there are particular ways of solving being prescribed and a standard procedure in teaching how to solve a problem. However, the basic idea of the existing problem-solving models has not yet been defined properly and is being used in a shallower approach. He further explains that the skills intended to be learned by the students in problem-solving have been overshadowed by universal standards and considerations. Unfortunately, the means to understand the process of deepening, synthesizing, and analyzing problems has been ignored and put aside behind the curriculum.

Bahar (2015) also investigated the influence of cognitive abilities on mathematical problem-solving performance of elementary students, separating their performance in open-ended and closed problems. Results showed that mathematical problem-solving

performance can be explained by open-ended (32.3%) and closed (48.2%) problems in variance. Considering the results, general creativity and verbal ability were significant predictors of mathematical problem-solving performance in open-ended problems. On the other hand, mathematical knowledge and general intelligence contributed significantly to closed problem-solving performance.

There have been studies conducted on the use of open-ended questions in mathematical problem solving. Lumpas (1997) identified mathematical errors, difficulties and thought processes of students when he analyzed their solutions to open-ended mathematics problems. He found out that the students had difficulty in the basic concepts such as measurement, perimeter, length of a side of a square, linear equation, ratio, and proportion. Students' lack of understanding in these concepts resulted from their use of wrong mathematical operations, misapprehension of the mathematical language, English language deficiencies, difficulty in translating verbal phrases to mathematical expressions or equations, lack of completeness in the learned concepts, wrong use of data given, defective and incomplete algorithm, computational errors and random responses in the study. Moreover, because of their misconceptions in the lessons learned prior to the conduct of the study, the students were not able to generate or provide correct responses to some questions.

Open-ended problems give much emphasis on the real world and daily experiences of the students. Using these kinds of problems will definitely provide them an opportunity to think deeply and critically as if solving real life problems involving logic and critical thinking. The students are given opportunities to reveal their conceptual understanding through experiences with open-ended problems (Mann, 2006).

Ambiguity Tolerance and Problem-Solving Ability

Ambiguity tolerance helps students handle challenging tasks, cognitive and emotional complexity, and thus enables them to have personal, intellectual and social growth (McLain, 2009). Students with high ambiguity tolerance attain higher scores on tests, produce unique solutions to open-ended problems and perform better in answering various types of puzzles. In addition, ambiguity tolerant students were observed "to deal better with vague language, partial information, tasks with little structure, and multiple perspectives in problem solving" (Williams, 2006, p.85). Teachers therefore, have important roles in helping students cope with ambiguity and use it to their advantage. Teachers' underscoring the importance of critical and creative thinking even when encountering ambiguity offers a good opportunity for the students to extract their creativity and participate in solving complex problems (Eisinger, 2011).

In another study, Dianco (2014) determined the moderator effects of gender and school type on ambiguity tolerance and mathematical ability among students from private and public schools. He used a problem-solving ability test that includes some ambiguous problems, a reasoning skill test and an ambiguity tolerance test. The findings showed that student gender and school type did not moderate the effects of ambiguity tolerance on students' reasoning skills and problem-solving ability. However, results showed a significant difference between public and private high schools in terms of their ambiguity tolerance. He attributed the difference in the ambiguity tolerance of the students from the two schools to the diverse experiences

and social life of the students. Dianco further emphasized that the “complexity of the personal experience and social life brings confusion to the young generation therefore challenging their abilities to deal with uncertainty” (p. 53). Furthermore, his study concluded that ambiguity tolerance correlated negatively with problem-solving ability.

Methodology

This study aimed to determine whether ambiguity tolerance predicts students’ problem-solving ability in mathematics. It is a non-experimental research that employed mixed methods wherein both quantitative and qualitative data collection and analyses were utilized. Data were collected among 182 grade 8 students. Two instruments were used namely, the Multiple Stimulus Types Ambiguity Tolerance (MSTAT-II) Scale (McLain, 2009) and the Problem-Solving Ability Test (PSAT).

The MSTAT-II is a 5-point Likert scale developed by David L. McLain in 2009 to measure the ambiguity tolerance of individuals. It is a 13-item scale with an internal consistency reliability of .83. MSTAT-II was a modification of MSTAT-I, which was likewise developed by McLain in 1993. In this study, the latter was used to obtain the ambiguity tolerance of each student. On the other hand, the PSAT is a researcher-made test composed of six open-ended problems on intermediate algebra. The topics covered are: basic mathematical operations, order of operations, algebraic expressions, set of real numbers, exponents, mathematical sentences, factoring, quadratic polynomials, and complex fractions. All the items in PSAT were devised to stimulate critical thinking and generate creative mathematical solutions and answers. The PSAT was subjected to content validation of mathematics experts. It had reliability coefficient of $\alpha = .518$ when pilot-tested to students after revisions on the were done.

Prior to the administration of the first instrument, the researcher informed the students of the goals of study and their significance in the study. The respondents were also rest-assured of the confidentiality of the information that they will provide to the researcher through the instruments.

Results and Discussion

A simple linear regression analysis was applied to the Problem-Solving Ability Test (PSAT) scores with ambiguity tolerance scores from MSTAT-II as the predictor variable. Table 1 presents the results.

Table 1
Simple Linear Regression on Problem-solving Ability Test Scores Using MSTAT-II Scores as Predictor

Variable	Figural Creativity				
	Model 1 <i>B</i>	Std. Error	<i>Beta</i>	T	p
Constant	-2.07	1.22		-1.69	.093
MSTAT-II	.27	.035	.50	7.69	<.001*
<i>R</i>	.50				
<i>R</i> ²	.25				
ΔR^2	.24				
<i>F</i>	59.1				<.001*

Note. **p*<.05, *N*=182

The model summary table shows the simple correlation coefficient between ambiguity tolerance and problem-solving ability, $R(181) = .50$, $p < .001$, which indicates that there is a significant positive association between the two variables. Adjusted R Square value is .24, which means that only 24% of the variation in the problem-solving ability scores can be explained by ambiguity tolerance. The result of the analysis of variance indicates that the regression model is significant, $F(1,180) = 59.1$, $p < .001$. Therefore, problem-solving ability can be predicted by ambiguity tolerance, significantly.

The linear regression model for Problem-solving Ability Test score in terms of Ambiguity Tolerance Test score is given by:

$$\text{PSAT score} = -2.07 + .27 \text{ MSTAT-II score}$$

A point increment in the MSTAT-II score will yield to an increase of .27 in the PSAT score. The ambiguity tolerance score from MSTAT-II has a significant positive weight on problem-solving ability indicating that those students with higher MSTAT-II scores are expected to have higher PSAT scores. Moreover, there is a moderate strength and positive association between ambiguity tolerance and problem-solving ability.

McLain (2009) suggested that students with high ambiguity tolerance attain higher scores on tests, produce unique solutions to open-ended problems and perform better in answering various types of puzzles. In addition, ambiguity tolerant students were observed “to deal better with vague language, partial information, tasks with little structure, and multiple perspectives in problem solving” (Williams, 2006, p.85).

The results somehow contradict the result obtained by Dianco (2014) wherein problem-solving ability correlates negatively with ambiguity tolerance. The difference in the result of the present study and that of Dianco’s can be attributed to the difference in the instruments used in measuring the ambiguity tolerance of the students. Moreover, the sample in the present study came from the set of Grade 8 students who came from a public (laboratory) and a private school whereas in Dianco’s study, the sample came from the set of fourth year students from a regular public and a co-educational private high school. Hence, the background of the students from the two sets of samples might have affected the contradicting results.

Conclusion

This study aimed to determine if ambiguity tolerance is a significant positive predictor of problem-solving ability. After analyzing all the relevant information quantitatively and qualitatively, it was concluded that ambiguity tolerance was a significant positive predictor of problem-solving ability in mathematics, specifically with the use of open-ended problems. Ambiguity tolerance and problem-solving ability have moderate and positive association.

It can also be inferred that the use of ambiguous open-ended problems provided opportunities for students to think critically and creatively, hence providing meaningful solutions. Moreover, the conceptual understanding of the students can be revealed with the use of open-ended problems in mathematics.

Taking into consideration the results and the conclusion, the researcher recommends the following: The use of open-ended problems should be employed by the teachers across various subject matters in Mathematics across grade levels so as to encourage critical and logical reasoning as well as creativity among students. School administrators should create extension/ training programs that will equip their faculty/ personnel as well as other neighboring schools the know-how of ambiguity tolerance, its effects and usability to better enhance approaches and techniques in the teaching and learning process. The Teacher Education Institutions should create programs that will expose pre-service and in-service teachers to the idea of incorporating ambiguous open-ended problems in their lessons in mathematics. Moreover, they should encourage their teachers to also measure their ambiguity tolerance so that they can be equipped with the appropriate tools needed in teaching diverse types of learners.

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