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A Comparison of Student Affect after Engaging in a Mathematical Modeling Activity

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Abstract

The study was a comparison of general students of promise affect and mathematical students of promise affect after doing a mathematical modeling activity. Participants' gender (n=160), in grades 7-8, were nearly equal in number (81 girls & 79 boys). After completing a Model-eliciting Activity (MEA) in groups of three, participants completed the 31-item Chamberlin Affective Instrument for Mathematical Problem Solving, hereafter referred to as CAIMPS (Chamberlin, Moore, & Parks, 2017). Using four subconstructs, it was determined that the only statistically significant difference in student affect among the groups was self-esteem and self-efficacy (SS) with the general students of promise group having a mean of 3.43 and the mathematical students of promise group having a mean of 3.76. Implications are that the difference in SS may have surfaced because of the mathematical demands of the problems that ultimately influenced participants' ratings. Three subconstructs (Attitude Value Interest [AVI], Anxiety [ANX], and Aspiration [ASP]) may not have realized a statistically significant difference because they were not as contingent upon mathematical content knowledge as was SS. The final implication is that similar affective ratings may be an indication that MEAs are similarly suitable for use with groups containing individuals with varying talents.

Introduction

In the past several decades, standardized assessments have become commonplace in schools as a means of assessing student achievement in mathematics (Brown, 2016; Ryan, Ryan, Arbuthnot, & Samuels, 2007). Assessments such as the Programme for International Student Assessment (National Center for Educational Statistics, n. d. a), the Trends in International Mathematics and Science Study (National Center for Educational Statistics, n. d. b), and in the United States the National Association for Educational Progress (National Center for Educational Statistics, n. d. c), have provided copious amounts of data with respect to students' knowledge of mathematics. Despite such information, mathematics educators are often left with questions relevant to students' cognition (Cragg, Keeble, Richardson, Roome, & Gilmore, 2017; Daher, Anabousy, & Jabarin, 2018; Pease, Guhe, & Smaill, 2013; Sullivan, Borcek, Walker, & Rennie, 2016), affect (Furinghetti & Morselli, 2011; Lee, Lee, & Bong, 2014; Schorr, Epstein, Warner, & Arias, 2010; Schorr & Goldin, 2008; Tee, Leong, & Abdul Rahim, 2019; Zan, Brown, Evans, & Hannula, 2006), and conation (Goldin, 2019; Tait-McCutcheon, 2008).

In addition to the aforementioned three learning factors, mathematical modeling has recently become a focus in mathematics psychology (Guerrero-Ortiz, Mejía-Velasco, Camacho-Machín, 2016; Lesh, Galbraith, Haines, & Hurford, 2010, Stillman, Blum, & Salett-Biembengut, 2015). This may be due to its prospect for advancing students' cognition, creative thinking, and/or its propensity to promote Didactic Transposition Theory (Chevallard, 1985; Kang & Kilpatrick, 1992). Nevertheless, little empirical data exist that helps mathematics educators understand the relationship between mathematical modeling and affect. As shown in the literature review, most studies with a focus on affect do not involve the context of mathematical modeling and most studies on mathematical modeling do not have affect as a studied factor. With the recent validation of the CAIMPS (Chamberlin, Moore, & Parks, 2017), researchers are now in a position to collect data regarding students' feelings, emotions, dispositions, attitudes, and beliefs (Chamberlin & Sriraman, 2019; McLeod & Adams, 1989, McLeod, 1994) while mathematical modeling. No other similar study has ever been conducted.

In this paper, students' affective ratings after completing a mathematical modeling activity called a Model-Eliciting Activity (Lesh, Hoover, Hole, Kelly, & Post, 2000) are detailed. The sample for the study, *n*=160, was comprised of students identified as promising overall and students identified as promising specifically in mathematics. Their self-report affective ratings are reported using the CAIMPS (Chamberlin, Moore, & Parks, 2017). Subconstructs of affect, including Attitude, Value, and Interest (AVI), Self-esteem and Self-efficacy (SS), Aspiration (ASP), and Anxiety (ANX) are reported, with the only statistically significant difference in SS.

Literature Review

The literature review is comprised of a discussion of affect in mathematics and mathematical modeling. In the first section, affect in mathematics is discussed and in the second section, mathematical modeling is discussed, with a brief description of Model-eliciting activities (Lesh, Hoover, Hole, Kelly, & Post, 2000), as they were the problem type used for this research.

Studies of affect from the domain of mathematics psychology are predominantly utilized in this literature review. Prior to the discussion of extant literature, several caveats are issued. First, the discussion is limited to affective studies in mathematics with participants in middle grades or junior high (roughly, grades 5-9). Second, subconstructs of affect are often highly correlated and many researchers currently study more than one subconstruct in a study. Third, a very common approach to studying participants' affect is self-report (Anderson & Bourke, 2000), which was the approach used in this study.

Affect

In reviewing the several hundred-year discussion of affect, it is apparent that consensus regarding one commonly accepted definition of the construct does not exist (Chamberlin, 2019). Furthermore, experts in the broad domain of educational psychology, and its descendent mathematical psychology, cannot come to agreement regarding precisely what subconstructs constitute affect.

Seminal Studies on Affect in Mathematics

Affect is like many psychological phenomena in that it has existed since people have, though it was not formally defined. Early academic writings about affect have been traced to the mid-1700s (Smith, 1759). Much of the early writings about affect pertained to feelings, emotions, and dispositions in general, and were not discipline specific. The field of mathematics was one of the first domains in which affect was studied (Higgins, 1970; Romberg & Wilson, 1969). Several seminal studies were conducted throughout the 1970s and 1980s, with perhaps the studies of greatest significance by the National Longitudinal Study of Mathematical Abilities (Higgins; Romberg & Wilson), Richardson and Suinn (1972), Aiken (1974), and Fennema and Sherman (1976). By 1989, McLeod added desperately needed structure to the discussion of affect in mathematics, and he subsequently added considerably to the knowledge base with a 25-year review of affective studies in mathematics (1994), and a chapter in Grouw's *Handbook of Research on Mathematics Education* (1992). Throughout all of his work, he suggested that affect in mathematics was comprised of beliefs, attitudes, and, emotions. Later, DeBellis and Goldin's research efforts (1991, 1993, 1997, and 1999) and most notably their discussion in 2006 about affect, meta-affect, and the tetrahedral model, were instrumental in providing direction to mathematical psychologists. The 2006 publication was significant as the construct meta-affect was defined as affect about affect, or one's sentiments about their affect, while engaging in mathematical learning episodes. In addition, their tetrahedral model of affect expanded the construct by adding values, which included morals and ethics in relation to mathematics.

In the midst of DeBellis and Goldin's work, Malmivuori was engaged in research (2001; 2006) that encouraged mathematical psychologists to consider the construct of self-regulation in relation to affect. When one successfully self-regulates emotions, one is able to monitor, which is a precondition for controlling one's emotions. In the context of solving mathematical problems, being aware of or monitoring one's emotions and then controlling them can enhance the likelihood of identifying a successful solution, which can be crucial in finding success in solving mathematical problems. With the foundation laid for what affect is in the context of mathematics and mathematical problem solving, many studies have been conducted in the last decade, notwithstanding a plethora of academic books on the construct (e.g., Chamberlin & Sriraman, 2019; Bernack-

Schüler, Erens, Leuders, & Eichler, 2015; Grootenboer & Marshman, 2016; Hannula, et al., 2016; Maaß & Schlöglmann, 2009; Pepin & Roesken-Winter, 2015).

Recent Empirical Studies about Affect in Mathematics

In 2017, Markovits and Forgasz substantiated Hart and Walker's (1993) theory by showing that early upper elementary mathematics students (grade 4) report far more positive affect than later upper elementary students (grade 6) do. In fact, the original Hart and Walker theory has been quite well known, but did not have empirical data to (dis)prove it until the Markovits and Forgasz study. They also substantiated a recent trend relevant to affect and gender when they found that some comparisons resulted in no statistically significant difference between boys' and girls' affective ratings in mathematical contexts, while in other instances there were statistically significant gender differences (e.g., research conducted in Israel). Sarouphim and Chartouny (2016) also found no true gender differences existed (in affective ratings) between males and females in grades 7-9, once affect is believed to have stabilized. Interestingly in their study, teacher beliefs did not necessarily synchronize with this finding, as teachers viewed mathematics as predominately a male domain and attributed the success of males to ability, while any success that females realized was due to effort.

Regarding self-efficacy, Foster (2016) investigated student confidence in responding to mathematical prompts. This study was interesting insofar as the previous study had been conducted at the tertiary level and in this study, the researcher investigated its application with students (n=336) in school years 7-9, ages 11-14 in England. Participants were asked to complete a relatively simplistic worksheet and respond to, "Whether their answers made sense" (p. 277), and, "How sure they were about their response." A correlation was then conducted between the number of correct responses and the confidence level reported by students. The r=.546 was moderate and girls reported lower confidence in correct responses than boys did.

In another study on self-efficacy, by Street, Malmberg, and Stylianides (2017), an instrument was developed in an attempt to assess student facet specificity, level, and strength of self-efficacy. Utilizing a sample of 756 Norwegian students (grades 5, 8, & 9), they found a strong connection between the three constructs of self-efficacy and national mathematics assessment performance. The strongest of these correlations was found between test scores and tasks of middle level difficulty, with test scores and low-level difficulty also producing a strong correlation. The researchers thus suggested that teachers and test designers should strongly consider difficulty of items in relation to self-efficacy when selecting tasks.

With respect to mathematical emotions, Bieg, et al. (2017) investigated the effect(s) of teaching methods and the subsequent student emotions in mathematics in Switzerland. Utilizing an n of 141 grade nine students, Bieg and colleagues ultimately analyzed 591 data points, comprised of student responses to prompts about emotions. The data set yielded information about teacher approaches to instruction and accompanying student emotions. Ironically, rather dichotomous emotions, enjoyment and boredom, were the two most prevalent ones reported by students. Various teacher approaches were predictors for student emotions. As an example, perceived choice and instruction pace were predictors of enjoyment.

At the same time, Buff, Reusser, and Dinkelman (2017) conducted a similar investigation on emotions in which they ascertained parent support for students' enjoyment of mathematics and the eventual student impact. Perhaps the most salient findings were that parent interaction with their children could have positive or negative influences on pupil affect. As an example, highly controlled teacher centered environments often result in negative experiences for students. Moreover, many of the findings serve as predictors. For instance, perceived parent value and control serve as predictors for a high degree of enjoyment in learning mathematics.

In a study (n=471 Australian students in grades 3-10) with an emphasis on emotions, cognition, and interest, Carmichael, Collingham, and Watt (2017) confirmed the long-standing hypothesis and found that students were highly capable of interpreting their teachers' enthusiasm for (teaching) mathematics. Moreover, teacher enthusiasm positively predicted a confounding variable, classroom mastery environment, which then predicted student interest. Likely, the strongest implication from the study was that teacher preparation programs should focus not only on content, but also on facilitating positive affect among young teachers, so that students may ultimately have a positive perspective of mathematics.

A recurring myth in interest research is that a problem's connection to reality has a direct (positive) correlation with student interest. In their study, Rellensmann and Schukajlow (2017) investigated this issue with 163 pre-service teachers and 100 grade 9 students. They found the opposite of what they hypothesized, which is that interest in problems with non-real contexts is higher than it is with problems that have real world contexts. Pre-service teachers, on the other hand, supported the belief (substantiated through data) that students' interest would be highest in real-world problems.

Regarding anxiety, Lauermann, Eccles, and Pekrun (2017) investigated United States' students' (n=805) anxiety and value of mathematics in grades 3, 4, and 6. They identified an inverse correlation between student self-concept of ability and worry, relative to performance in mathematics. In addition, they found a connection between students' academic values and worry (anxiety) in mathematics. Practically speaking, these findings suggest that students worry greatly about mathematics when they realize that their parents place a high value on it and see their abilities as low.

Mathematical Modeling

The concept of mathematical modeling is not novel to the domain of mathematics, with the first academic writing appearing over 100 years ago (Hertz, 1894). However, in the last 100 years, increasing attention has been invested in it through formal studies, explicated in literature. Mathematical modeling is defined in several manners and in this study, it is considered a mathematical process in which problem solvers create explanations, in the form of non-physical models, of mathematical information to make sense of situations (Chamberlin, 2019). To design a mathematical model, the process of mathematizing (de Almeida, 2017; Lesh, Hoover, Hole, Kelly, & Post, 2000) must occur. When one mathematizes, ostensibly non-mathematical information must be adapted and considered in the context of mathematics so that factors and components may be quantified.

The corpus of literature has been bolstered by empirical and theoretical articles, chapters, and books. Regarding books, the International Community of Teachers of Mathematical Modelling and Applications (ICTMA) has likely contributed the most efforts from their conferences (Kaiser, Blum, Borromeo Ferri, & Stillman, 2011; Lesh, Galbraith, Haines, & Hurford, 2010; Stillman, Blum, & Biembengut, 2015; Stillman, Kaiser, Blum, & Brown, 2013). It is likely that an infusion of mathematical modeling research is a by-product of the Common Core State Standards Mathematics (NGA & CCSSO, 2010) inserting it as its fourth mathematical practice. Additional efforts for practitioners, with respect to implementation and assessment approaches, have been published (Chamberlin, 2016; Chamberlin, 2013). Several empirical investigations have contributed to understanding how students make sense of mathematical phenomena while modeling. Two foci have surfaced recently in academic studies, relevant to this study, and they are, (1) students' reasoning while modeling, and (2) investigations of affect while modeling.

Reasoning during Modeling

In 2015, Hitt and González-Martín investigated the relationship between covariation of variables in an attempt to see its impact on understanding functions and graphical representations of functions. Using grade nine Canadian students (n=60), they found that having students create mathematical models to understand covariation of variables enhanced the likelihood of success in making sense of functions and their graphical representations. Practically speaking, such findings have implications for what (particularly algebra and pre-calculus) teachers should do prior to introducing the mathematical concept of a function.

In 2018, Plath and Leiss found that unlike many procedurally based problems, problem solvers' ultimate success in mathematical modeling was highly dependent on language proficiency. Moreover, the greater problem solvers' depth of linguistic knowledge, the more likely they were to find success in comprehending the problem statement and ultimately developing a comprehensive mathematical model. With the 634 students, it was also determined that there could be a point at which linguistic complexity negatively influenced the ability to solve problems successfully.

In a similar study, Degrande, Van Hoof, Verschaffel, and Dooren (2018) investigated grade 5 and 6 students' (n=279) penchant for using additive or multiplicative reasoning in solving modeling problems. Over two-thirds (67.9%) of participants defaulted to an additive strategy while 29.9% used a multiplicative strategy. The remaining 2.2% did not consistently use either approach. Grade 6 students tended towards multiplicative reasoning strategies more than grade 5 students did. Findings may have implications for (re)shaping learning episodes in future years in Belgium, as being unable to utilize multiplicative reasoning may have negative ramifications for understanding proportional reasoning.

English and Watson (2018) also studied student reasoning when they investigated how grade 6 students interpreted, organized, and operated on data as well as drew informal inferences while creating mathematical models. Using 89 participants (43% of whom were English as Second Language students in Australia), the researchers confirmed that students had strong foundational understanding of statistical principles. They also found that concentrating on just one variable in model-construction was inadequate.

Affective and Non-cognitive Factors and Modeling

In a study conducted by Krawitz and Schukajlow (2018), self-efficacy and value were investigated as 90 students completed 8 modeling problems, 8 intra-mathematical problems, and 8 'dressed-up' word problems. Surprisingly, students valued the intra-mathematical problems and 'dressed-up' word problems as more important than mathematical modeling problems. Regarding self-efficacy in solving problems, statistical significance was not reached in comparing the three types of problems. These findings have implications for learning, motivation, and achievement. Perhaps most importantly, this was the only study identified in which participants (*n*= 52% female) were from the general population and the more advanced population in Germany, thus possibly a harbinger for results in this study.

Another study in which metacognition, a form of self-regulation, was a principal focus was one conducted by Vorhölter (2018). In the article, Vorhölter proposed a new instrument for monitoring metacognition and suggested that metacognition is crucial for success in modeling and it is domain specific. Utilizing 431 students in grade 9 (48% girls), it was found that throughout the task 67% of students were motivated or highly motivated to participate in the task. Creating the instrument was quite challenging and the three areas investigated were strategies for (a) organizing the planning the solution process, (b) monitoring and regulating the working process, and (c) evaluating the modeling process. One commonality with all of this research is that nearly all participants are students of average ability; only two studies appear to have any connection to students of promise in mathematics.

MEAs are specific types of mathematical modeling activities with six specific design principles (Lesh, Hoover, Hole, Kelly, & Post, 2000). The chief objective when students solve MEAs is to encourage them to create mathematical models to make sense of mathematical information. Often solvers need to mathematize information, or take ostensibly non-mathematical information and make it mathematical. In so doing, solvers may see the mathematical nature of information that others may not deem mathematical. Moreover, in creating mathematical models, problem solvers may make their interpretation of the mathematical situation highly efficient and therefore be able to generalize it to future situations.

Method

Participants and Characteristics

Participants were drawn from a large school district in the Rocky Mountain Region of the United States. Of the five middle schools that comprise the school district, three schools chose to participate in the data collection process, indicating that this was a convenience sample (Huck, 2012). In total, eight classes were visited with approximately 30 students in each grade seven or eight class (ages 12-14). All students had been identified as either promising in mathematics (n=90) or promising overall (n=70), using a battery of assessments. Students promising in mathematics held higher scores in one form of a mathematics assessment than did the promising overall students, while students identified as promising overall held higher scores in other domains (e.g., perhaps promising in an artistic, literacy, or music domain) than did those promising in mathematics only. The total number of participants, n=160, included 81 girls and 79 boys.

Sampling Procedures

Every student in each class (n=241) was solicited to participate in the research and only those that returned the proper permission forms, student assent and parent consent, were allowed to participate in data collection. The response rate was thus 66.4%. The district was located in a suburban area, with a combined area population of approximately 350,000 people. Approximately 90% of students in the district qualified for free or reduced lunch, a metric employed in the United States that indicates a low socio-economic status. Over 95% of the students spoke English as their first language.

Research Design

The 31-item CAIMPS (found in appendix A) was utilized to collect data. Using Confirmatory Factor Analysis (CFA), the instrument was found to have strong psychometric properties (Chamberlin, Moore, & Parks, 2017). In specific, the reliability of the four affective subcomponents was high (detailed in Table 1 below). An interesting characteristic in this instrument is that subcomponents (i.e., AVI, SS, ANX, and ASP), did not correlate highly. Anxiety should negatively correlate (highly) with the other components (e.g., high anxiety suggests low self-efficacy).

In this case, nearly all correlations were relatively low, <.50, negative or positive. For additional commentary on the psychometric properties of the instrument, see Chamberlin, Moore and Parks (2017). In a field that has difficulty separating all of these subcomponents, low correlations are an encouraging component of this instrument because it means that the closely intertwined subconstructs were distinguished as separate subconstructs (Anderson & Bourke, 2000), thus enabling researchers the opportunity to look individually at subconstructs. The Root Mean Square Error of Approximation (RMSEA) was 0.079, which MacCallum, Browne, and Sugawara (1996) consider a decent fit.

Procedures

Participants completed one of four problem-solving activities known as a Model-Eliciting Activity (MEA). Every student in the participating classes solved their respective problem, regardless of their participation in the data collection process. The entire data collection process, that entailed eight total classrooms, transpired over a three-week period and individuals that submitted data about their affect were intermingled for group creation with individuals that did not submit data on affect after solving their respective MEA.

Students typically worked in groups of three, but periodically groups of two or four were required, given the number of students in the class. Classroom teachers were asked to create student groups prior to the implementation of the activity. Prior to implementing the activity, problems identified by the researchers were shared with participating teachers to secure feedback. Feedback was solicited to determine which problems, from a larger database, would support district mathematics standards and would be relatively free of gender bias, to seek a theoretically similar response from each gender. All activities were initially written or revised by the first author.

To begin the activity, participants were provided with pages one and two of the activity. The first page of all MEAs is an article that is relevant to the subsequent problem. The second page is one that entails a list of readiness questions about the article. Some of the readiness questions are simple comprehension questions and others are inference questions, designed to prompt problem-solvers to consider a mathematical construct that is purposefully ill defined. Participants read the article and answered the questions the night before the activity was to be done in class. As students entered class the next day, they were separated into groups and responses to the readiness questions were discussed as a whole class to set the context for the problem statement. In groups, students were then provided between 45 and 60 minutes, the time varied slightly by class pending several factors, to complete the activity. Successful completion of the activity required the development of a mathematical model and a letter written in which problem solvers explicated the process entailed to develop their mathematical model.

Upon immediate completion of the activity, the host teacher and researchers distributed a paper and pencil version of the CAIMPS for participants to complete. The CAIMPS is a 31-item instrument, comprised of four Likert scales, all using a rating of 1 (strongly disagree) to 5 (strongly agree). All participants were given at least 10 minutes to complete the instrument. Fidelity was controlled for in considering several factors. For instance, all activities were implemented by the first and second authors, all activities were written in accordance with the six design principles (Lesh, et al., 2000) and by the same author, and the time permitted to engage in and complete the respective MEAs and to complete the instrument was carefully controlled.

Data Analysis

Using the CAIMPS, data were separated into two groups, generally promising and mathematically promising, and there are 31 items from each respondent. Of the 31 items, each item falls into one of the four subconstructs listed below in Table 1.

Table 1. Items, Constructs, and Reliability Coefficients for Instrument

Constructs	Attitude, Value, & Interest (AVI)	Self-esteem & Self-efficacy (SS)	Aspiration (ASP)	Anxiety (ANX)
Items	1*, 2, 6, 9, 12*, 18, 19, 21, 24, 26	3, 4, 5, 10, 11, 14, 20*, 25, 31, 29, 30	7, 16, 22, 27, 28*	8, 13, 17, 23*
α	.923	.839	.637	.713

*Indicates reverse coded items

After entering all data into SPSS 24, group affiliation (i.e., math promising or generally promising) was indicated so that four separate *t*-tests between the respective subconstructs (AVI, SS, ASP, and ANX) could be performed. Comparisons were analyzed for significant differences in the four subconstructs between groups.

Results and Discussion

Though there are differences in the means of each subconstruct between the two groups, the only subconstruct in which the difference was statistically significant, is SS or self-esteem and self-efficacy (see Table 2). Practically speaking, this means that no real difference was found to exist between the two groups in subconstructs AVI (Attitude, Value, and Interest), ASP (Aspiration), or ANX (Anxiety). However, a statistical difference in participants' self-esteem and self-efficacy existed, with students identified as promising in mathematics having the higher (3.76) arithmetic mean, while their generally promising counterparts had the lower (3.43) rating.

Table 2. t-test Data on Subconstructs of CAIMPS for Study

Constructs	AVI	SS	ASP	ANX
		General, *n*=70		
$\bar{X}$	3.43	3.43	3.91	2.39
SD	.75	.62	.65	.76
		Math, *n* = 90		
$\bar{X}$	3.60	3.76	3.89	2.20
SD	.72	.64	.62	.65
P-value	.134	.001	.858	.091
t	-1.5	-3.27	.18	.1.67

$\bar{X}$=arithmetic mean of the sample
SD=standard deviation of the sample

Conclusion

Of particular importance in empirical studies are the implications, or actual pragmatic effects on students' learning of mathematics. From this data, three implications exist. After explicating the implications, limitations of the study and areas for future research are presented.

Implication #1: Students Strong in Mathematics Report Higher SS Given Their Background

Successful completion of MEAs is contingent upon several processes in learning. For instance, to be successful in formulating a mathematical model while doing Model-eliciting Activities, problem solvers must comprehend literature (Plath & Leiss, 2018), understand a mathematical statement/expectation, create a mathematical model, explicate and communicate the mathematical model, and document the construction of the model (Lesh, et al., 2000). Given the mathematical demands, it is not surprising that individuals identified as stronger in mathematics may have greater self-esteem and self-efficacy in completing these tasks than their peers less capable in mathematics (e.g., those identified as generally promising, but not in mathematics per se). This statistical difference may exist because little is known about the demographics of the generally promising group. For instance, the generally promising group is likely comprised of individuals that were nearly identified as mathematically promising, while also being comprised of individuals that may not be particularly strong in mathematics. Hence, it is a safe assumption that the generally promising group may be more heterogeneous in mathematical abilities than the mathematically promising group was. As a reminder, individuals identified as generally promising may have been identified as extremely promising in creative arts, literacy, humanities, or some other domain.

Nevertheless, there are contributions that individuals with less advanced mathematical abilities can make, though their self-perception (so measured by self-concept) and their perceived confidence in doing mathematics (so measured by self-efficacy) may have revealed these differences. For instance, in ultimately formulating the written statement of the mathematical model, individuals with advanced communicative skills may serve as an asset to the group. In addition, such peers (i.e., pupils identified as generally promising) might help in decoding the problem statement, so that mathematically strong(er) students can formulate a mathematical model. It is thus likely that as the entire mathematical modeling process transpires, each member of the group is chiefly responsible for a different responsibility, although in reality, most decisions are a shared responsibility of the group and are the result of input from multiple constituents. Moreover, intermingling generally promising students with mathematically promising students may enable groups the opportunity to pull on various strengths to formulate a comprehensive mathematical model.

Implication #2: Both Groups Report Similar Affective Ratings in the 3 Subconstructs

It may be the case that students that comprised the two groups, mathematically promising and generally promising, have similar ratings in the three remaining subconstructs (i.e., AVI, ASP, and ANX), because the mathematical demands of the respective MEAs do not weigh as heavily in responding to the items as they do when responding to the SS items. More precisely, problem solvers' self-efficacy and self-esteem may be more dramatically influenced as a direct result of their mathematical content knowledge relative to AVI, ASP, and ANX self-ratings. The one subconstruct on which this finding may be somewhat counterintuitive is anxiety (ANX), as content knowledge may be closely related to one's anxiety in solving a problem, given that success in solving problems of this complex nature may require somewhat extensive content knowledge.

It is possible that an underlying reason exists for the differences not being significant, and the reliability (.713) may be the reason. Still, the difference in means of anxiety was somewhat dramatic (.19) and may have approached statistical significance. Moreover, the reported similar levels of affect can be perceived as a positive component of MEAs (Chamberlin, 2002) as it may imply that MEAs are an encouraging curricular approach that may result in similar affective, such as engagement, properties for slightly varied samples and populations. In specific, MEAs may have undiscovered properties that similarly attract students with rather diverse backgrounds. This outcome is discussed in detail in implication #3.

Implication #3: Reported Levels of Affect Being Similar is Positive

The final implication is that reported similar levels of affect may be attractive from a curriculum perspective in the sense that multiple constituencies may be similarly engaged in MEAs (Chamberlin, 2002), with respect to feelings, emotions, and dispositions. Consequently, MEAs may work particularly well with heterogeneous groups. For instance, MEAs may be a positive approach to learning mathematics and formulating models when disparity exists in several groups' mathematical abilities. If, for instance, groups are comprised of individuals that are somewhat capable in mathematics and quite advanced in mathematics, it appears as though affective ratings may be similar in the two constituencies. Some disagreement may exist in whether students should be heterogeneously or homogeneously grouped when doing mathematics problems. Assuming this data and problem solving approach (MEAs) is an indication of what could transpire with respect to student affect, then it is a positive step in engaging students affectively in worthwhile mathematical tasks.

In addition, the reported levels of affect are encouraging with this age range. In fact, SS and ASP are nearly 4, on a 1 to 5 scale with 5 being the highest rating. As well, AVI clusters around the 3.5 range and anxiety is relatively low (near 2.25), with 1 being very low and 5 being very high (or a negative rating for anxiety). Given results in recent studies that indicate decreased affective ratings in mathematics among upper elementary/early middle grade students (Markovits & Forgasz, 2017), it is encouraging that this sample of 160 students exhibit overwhelmingly positive affective states. Part of this outcome may be explained by the fact that the sample employed was identified as promising in one or more domains. However, as Phillips and Lindsay (2006) illustrate, promising students are not always motivated for every academic activity and it may be the case that when students of promise engage in a task for which the solution is not known, they report dissatisfaction with the activity. As with general population students, they have ebbs and flows in affect.

Limitations

Certainly, the small sample size may call into question the generalizability of the results. This is because the greater the number of participants in the sample, the more reflective of the population the sample will be. With an *n* below 200, the ability of the sample to reflect the population accurately may be in question. Nevertheless, the sample is a large enough number for use in a statistical procedure such as *t*-tests.

A second consideration with the sample is the similarities of the two groups. With all participants coming from one district, albeit a relatively large district, the nature of the data may further be called into question. Moreover, all students were identified as promising in some capacity. Consequently, generalization from the sample to general population students may be compromised. Another limitation is the measurement of individual affect, though students completed the activities in groups (Magiera & Zawojewski, 2011). This disconnect may have slightly compromised the accuracy of student ratings.

Areas for Future Research

When quantitative data provide much-needed information with respect to phenomena in mathematical psychology, qualitative procedures may need to be employed to supplement the understanding for the difference. This research is evidence of this claim in that the lack of statistical significance in mathematics anxiety in the two groups is somewhat enigmatic. Hence, having additional insight through the use of a varied research approach might provide an alternate perspective with respect to the outcome of the study. Another point of empirical interest may be investigating participants' self-esteem and self-efficacy (SS) in greater depth than was provided in this study. This is because the statistically significant difference is of interest to researchers, given the fact that the other three subconstructs did not result in a difference.

Recommendation

Given the outcome of this study, the recommendation is that affect among students of promise must have attention invested in it. This is because the connection between affect and academic outcomes, such as achievement, has an established relationship. Moreover, positively manipulating student affect is not perhaps simplistic to accomplish, but it is important in relation to achievement. In some situations, teachers investing attention in utilizing student interests, positively reinforcing them, and valuing their input in mathematical discourse may be able to adjust student affect.

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Appendix A. Affect Instrument for Mathematical Problem Solving

This instrument was designed to measure your feelings about the mathematics problem solving activity that you just completed. In this instrument, the mathematical problem solving task that you just completed is referred to as the math problem. Using the scale provided, rate the following items:

A) Strongly agree
B) Agree
C) Undecided
D) Disagree
E) Strongly disagree

______ **1.** I did not have a good attitude about solving this problem
______ **2.** Doing the math problem was worth my time
______ **3.** I'm proud of the mathematical solution that I just created
______ **4.** This math problem was easy because I work hard at math
______ **5.** I had great confidence when I did the math problem
______ **6.** I would like to have one of these math problems to do in my free (leisure) time
______ **7.** Being able to solve problems like the one I just did will help me accomplish future goals
______ **8.** When I did this math problem, I was nervous
______ **9.** Investing my time in this math problem was useful for me
______ **10.** Solving this problem was easy for me because I'm good at math
______ **11.** If given a more difficult math problem than we had, I probably would have succeeded
______ **12.** This math problem bored me
______ **13.** I felt uncomfortable doing this math problem
______ **14.** In general, my attitude about math problem solving is good
______ **15.** This math problem kept me curious
______ **16.** To succeed in the future, I will do math problems like this one
______ **17.** I felt uptight as I was completing this math problem
______ **18.** The math problem that I just did brought me enjoyment
______ **19.** Doing this math problem was a valuable use of my time
______ **20.** As I was doing the math problem, I wasn't sure how well I did on it
______ **21.** I was engaged in this math problem
______ **22.** An objective of mine is to do well on math problems
______ **23.** I was relaxed as I did this math problem
______ **24.** Doing this problem improved my self-esteem in mathematics
______ **25.** I trust that I did well on this math problem
______ **26.** Doing this math problem did not increase my interest
______ **27.** It is my ambition to become a better problem solver than I am
______ **28.** I felt at ease when I did this problem
______ **29.** I liked the math problem that I just did
______ **30.** Knowing how to do math problems such as the one I just did is very important
______ **31.** The completion of this problem showed that I am a reliably strong problem solver