A RIGOROUS EXPLORATION OF STUDENTS' AFFECTIVE MATHEMATICS ENGAGEMENT ACROSS SAMPLES AND CONTEXTS

A Dissertation

by

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ABSTRACT

The primary purpose of the research conducted in this dissertation was to explore how students' affective mathematics engagement was revealed in mathematical learning situations. All three studies included in this dissertation used quantitative data to investigate whether the students' affective mathematics engagement was affected by diverse factors (gender, language, immigration status, school characteristics, country or culture, motivation, and implementation of STEM PBL). The research discussed in the first article employed the Trends in International Mathematics and Science Study (TIMSS) 2015 dataset to explore whether the students' affective mathematics engagement was influenced by demographic factors related to the students and the schools. The second article compared a sample of Korean students to a sample of U.S. students in order to understand how culture affects and complicates the understanding of intrinsic and extrinsic motivators, and how this impacted the students' affective mathematics engagement. The research conducted for the third article compared two conditions (STEM PLB instruction and non-STEM PBL instruction) in order to examine how the students' affective mathematics engagement were affected by changes based on participation in STEM PBL instruction, in comparison to those who were taught using traditional mathematical instruction.

The results of the first article revealed that students who were male, mainly spoke English at home, or were born in the U.S. had more positive affective mathematics engagement, in comparison to their peers who were female, did not use English at home, or were not born in the U.S. Moreover, students in economically advantaged schools had more positive affective mathematics engagement than students in economically disadvantaged schools. The second article revealed that affective mathematics engagement variables (attitude, emotion, self-acknowledgement, and value) were directly related to motivation variables (intrinsic and extrinsic motivation). Furthermore, this model was supported by the empirical comparison between Korea and the U.S. The third article revealed that students in STEM PBL instruction experienced greater positive affective mathematics engagement in comparison to students in non-STEM PBL instruction.

Overall, the results of this dissertation indicate that the affective mathematics engagement of students is impacted by diverse factors, such as gender, language, immigration status, school characteristics, country or culture, motivation, and implementation of STEM PBL. The findings of this dissertation contribute to a better understanding of the factors that can positively impact the affective mathematics engagement of students.

DEDICATION

To my parents,

Jongil Lee and Suyoung Yoon.

I cannot describe how blessed I am to have amazing parents in my life.

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NOMENCLATURE

-2LL	-2 restricted Log Likelihood
CFI	Comparative Fit Index
CTO	Check This Out
DDM	Don’t Disrespect Me
EFA	Exploratory Factor Analysis
ELL	English Language Learners
GTJD	Get the Job Done
HLM	Hierarchical Linear Modeling
ICC	Intraclass Correlation Coefficient
IRIT	I’m Really into This
IRT	Item Response Theory
JCR-SSCI	Journal Citation Reports Social Sciences Citation Index
LHSIA	Look How Smart I Am
LMTY	Let Me Teach You
MAME	Measurement of Affective Mathematics Engagement
NCTM	National Council of Teachers of Mathematics
NRC	National Research Council
OECD	Organization for Economic Cooperation and Development
PBL	Project-Based Learning
PD	Professional Development

PCA	Principal Components Analysis
PCAST	President’s Council of Advisors on Science and Technology
PE	Pseudo Engagement
RMSEA	Root Mean Square Error of Approximation
RUMESI	Rutgers Instrument for Mathematics Engagement
SEM	Structural Equation Modeling
SJR	SCImago Journal Rank
SOOT	Stay Out of Trouble
SPSS	Statistical Package for the Social Sciences
SRMR	Standardized Root Mean Square Residual
STEM	Science, Technology, Engineering, and Mathematics
SNIP	Source Normalized Impact per Paper
TEKS	Texas Essential Knowledge and Skills
TIMSS	Trends in International Mathematics and Science Study
U.S.	United States
WLSMV	Weighted Least Squares Mean and Variance adjusted

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CHAPTER I

INTRODUCTION

The way students learn in the mathematics classroom is characterized by constructed identity, which is created through engaging in the mathematics learning situation. “The view of learning as becoming more adept at participating in distributed cognitive systems focuses on engagement that maintains the person’s interpersonal relations and identity in communities in which the person participates” (Greeno, Collins, & Resnick, 1996, p. 26). The manner in which students engage in mathematical activity proceeds through the interaction between their mathematical identity and the mathematical situation (Op’t Eynde & Turner, 2006). Affective mathematics engagement includes both the students’ sense of belonging, importance, and appreciation, and also their positive or negative emotional reactions to their teachers, classmates, curriculum, and school (Fredricks & McColskey, 2012; Hospel & Galand, 2016). Affective mathematics engagement refers to the feelings students experience while engaged in mathematical activity (Goldin, 2002; Wang & Degol, 2014), and helps to interpret student behavior in a mathematics learning context. Affective mathematics engagement is defined as “a level of emotional response characterized by feelings of involvement in school as a place and a set of activities worth pursuing” (Finn & Zimmer, 2012, p. 103). Although affective mathematics engagement itself is short-term and situational, it leads to the construction of long-term, non-situational, and stable affective structures toward mathematics (Goldin, 2002; Linnenbrink, 2007). Therefore, the investigation of affective mathematics engagement may be helpful in understanding the learning situation of students.

Statement of the Problem

Affective mathematics engagement has been considered an essential key to improve students' mathematics academic performance, because of its relationship with cognition and behavior in their mathematical learning situations. Students who have negative affective mathematics engagement have limited opportunity to take part in the mathematical learning process. On the other hand, when the students have positive affective mathematics engagement, they are likely to focus continuously on mathematics learning. And then, it is aligned to the depth of the mathematical concept they are learning. In particular, a multitude of factors combine to impact students' affective mathematics engagement within their mathematical learning situations: descriptive factors related to students and schools (e.g., gender, language, immigration status, economic disadvantage status, cultural characteristic of country, etc.) and instructional variables. However, there have not been many studies on the current status of students' affective mathematics engagement and its development through academic interventions. Investigating the complexity and inter-relatedness of these dimensions of students' affective mathematics engagement would provide better understanding of possible influences on positive affective mathematics engagement.

Purpose of the Study

The primary purpose of this dissertation was to explore how students' affective mathematics engagement revealed itself in mathematical learning situations. For this dissertation, I investigated how students' affective mathematics engagement differed by diverse factors (gender, language, immigration status, school characteristics, country/culture, and implementation of science, technology, engineering, and mathematics project based learning (STEM PBL)). I used the *Trends in International Mathematics and Science Study* (TIMSS) 2015 dataset to explore how affective mathematics engagement was influenced by student- and school-factors. I compared a sample of Korean students to a sample of United States (U.S.) students to understand how culture might intertwine and complicate the understanding of intrinsic and extrinsic motivators, and this impact on students' affective mathematics engagement. Finally, I compared two conditions to examine how students' affect changed based on participation in STEM PBL instruction or in traditionally taught mathematical instruction.

The findings from these articles are expected to provide potentially useful understanding of students' affective mathematics engagement and how we can improve students' positive affective engagement in mathematical learning situations. Thus, the research findings from my three-article dissertation will contribute to understanding how students' feelings about learning mathematics relate to their persistent in mathematics and STEM education.

Research Questions

During the writing of my dissertation, I focused on investigating students' affective mathematics engagement from multiple perspectives. The following three questions frame the three articles for my dissertation:

1. How much of the variation in affective mathematics engagement is within and between schools? What student- and school-level factors are significantly associated with affective mathematics engagement among 8th grade students?
2. Do intrinsic and extrinsic motivators impact affective mathematics engagement? Do students differ on affective mathematics engagement and motivation by countries (Korea vs U.S.)?
3. Do students differ on affective mathematics engagement by involvement in STEM PBL and non-STEM PBL instructions? How does student affective mathematics

engagement in mathematical attitude, emotion, self-acknowledgement, and value vary by participation in STEM PBL and non-STEM PBL instructions?

Literature Review

The affective mathematics engagement of students refers to a level of emotional response. It is characterized by situational feelings during an activity or task that is intended to teach mathematical concepts (Eccles & Wigfield, 2002; Finn & Zimmer, 2012; Wang & Degol, 2014). The foundation of affective mathematics engagement is mathematical affect. According to Plass, Homer, and Kinzer (2014), mathematical affect includes motivation, interest, goal orientation, self-efficacy, and self-esteem, as well as emotional design, which includes representation and interaction. Mathematical affect is a non-situational state represented by collective and general feelings toward mathematical concepts and learning (McLeod, 1988). Therefore, mathematical affect is stable and long-term (Goldin, 2002; Linnenbrink, 2007). Affective mathematics engagement is impacted by this general mathematical affect. On the basis of mathematical affect, situations in the learning process influenced the students' affective mathematics engagement. Therefore, affective mathematics engagement is situational, sensitive to time and environment, unstable, and a short-term state (Lee, Capraro, & Bicer, 2019). For example, students who usually have a negative mathematical affect may experience a positive affective mathematics engagement in particular mathematics learning situations. Although affective mathematics engagement is a situational and unstable state, consistent experiences of positive affective mathematics engagement can strongly influence students' overall mathematical affect (Linnenbrink, 2007) and, in turn, their mathematical achievement (Dotterer & Lowe, 2011). Therefore, improving students' positive affective mathematics engagement is considered a critical educational factor in their successful academic performance.

There has been considerable research on affective mathematics engagement, which has had significant implications for mathematics education. However, despite the effect of affective engagement in mathematics education, the affective mathematics engagement constructs remain ambiguous (Di Martino & Zan, 2001). One reason for this is most studies have mainly focused on the implementation of experimental research design, rather than on the development of a theoretical construct or concept (McLeod, 1992; Udo-Akang, 2012). Therefore, more explicit affective mathematics engagement constructs need to be developed in order to improve both the quality of research and the status of affective engagement as an academic discipline in mathematics education.

The constructs of affective mathematics engagement in education have been developed over the decades, and can be traced back to the appearance of the concepts of affect and engagement in mathematics education. Increased research in the field of affective engagement has led to a heightened awareness of the role of affective mathematics engagement in students' mathematics learning context. Correspondingly, the affective mathematics engagement domain has generally been viewed as divided into belief, attitude, and emotion. This was particularly intended to overcome the problem of a lack of clear and agreed upon definitions (McLeod, 1992). Debillis and Goldin (2006) later added value to affective mathematics engagement, and therefore defined it as including belief, attitude, emotion, and value. Most affective mathematics engagement studies over the past decades (e.g., Eagly, Mladinic, & Otto, 1991) have considered these four components as the primary constructs of affective mathematics engagement. However, the theoretical foundation underlying these constructs remained unclear. Although they were important for affective mathematics engagement, researchers have noted the lack of constructs for integrating the diverse range of performances that fit into affective mathematics engagement

(Rotundo & Sackett, 2002). In particular, the affective mathematics engagement constructs (attitude, emotion, beliefs, and value) originated from the constructs of mathematical affect. Therefore, certain aspects of the affective mathematics engagement constructs did not show the specific characteristic of affective mathematic engagement, which differed from those of mathematical affect. Clear constructs of affective mathematics engagement were necessary if it was to become a powerful theoretical instrument.

For example, the presence of belief as a construct in affective engagement suggests a lack of theoretical foundation on the part of many researchers (e.g., Bruce & Flynn, 2013; Champagne, Klopfer, & Gunstone, 1982; Kember, 2009; Pajares, 1992). Belief has been considered as a subscale of the constructs of both affect and affective engagement in mathematics education (Strike & Posner, 1985). However, belief should not be overemphasized in specific situations of mathematics learning (Pajares, 1992) because it is difficult to change (Skogen, 2012). This acceptance in mathematics education mitigated the importance of using these estimates in constructs with explicit intent to analyze affective mathematics engagement quantitatively over a relatively short period (Bruce & Flynn, 2013). Because affective engagement itself is situational and relatively easy to be changed in a short-term period (Goldin, 2002; Linnenbrink, 2007), belief is not a suitable construct of affective mathematics engagement.

The lack of a theoretical foundation and the consequent difficulty in interpreting related studies in affective mathematics engagement have not received sufficient attention in cognitive research within mathematics education (McLeod, 1992). Many researchers (e.g., Mandler, 1989; McLeod, 1988, 1992; Zan, Brown, Evans, & Hannula, 2006) have started to suggest that the most important component of research into affective mathematics engagement is the understanding of the interrelation between students' affective and cognitive domains in mathematics learning. The feelings of students toward mathematics include the appraisal of their cognitions in mathematics learning situations (Malmivuori, 2001). This interrelation between the affective and the cognitive domains during the mathematics learning situation has led a growing number of researchers to suggest that students' feelings toward cognition can be added as a key component of the affective mathematics engagement constructs (Debellis & Goldin, 2006; Mandler, 1989; McLeod, 1988, 1992; Zan et al., 2006). Therefore, Lee et al. (2019) removed belief and added mathematical self-acknowledgement as a key component of their affective mathematics engagement constructs. Consequently, the most current constructs of affective mathematics engagement include the aspects of attitude, emotion, value, and self-acknowledgement. They can be defined as follows: 1) attitude is the tendency toward certain sets of emotional feelings in particular mathematical contexts; 2) emotion is a rapidly changing state of feeling during a mathematics activity; 3) value is characterized as personal truth or commitment toward mathematics learning; and 4) self-acknowledgement is the individual's feeling regarding mathematical cognitive concept and learning. More detailed explanations of each construct are demonstrated in Chapter III and Chapter IV.

Affective mathematics engagement has been considered an important component of the school experiences of students due to its relationship to their mathematical academic performance (Dotterer & Lowe, 2011). The affective mathematics engagement of students in the learning process has been measured, and this effort was directly related to students' understanding of mathematical knowledge and skill (Goldin, Epstein, Schorr, & Warner, 2011). The impact of the students' affective mathematics engagement on their mathematical achievement was found to be mediated by their cognitive and social mathematical engagement. Affective mathematical engagement was found to be associated with other forms of engagement, such as social and cognitive mathematics engagement during mathematical learning situations (Osterman, 2000). The affective, social, and cognitive engagements impacted each other, which, in turn, affected the students' mathematical achievements (Voelkl, 2012). In addition, affective mathematical engagement is related to general mathematical affect, and other psychological and behavioral outcomes (e.g., confidence, effort to solve problems, active communication with peers, etc.) (Maddox & Prinz, 2003; Osterman, 2000; Voelkl & Frone, 2004). Therefore, constant positive affective mathematics engagement in mathematics learning situations may eventually influence the students' positive academic performance in mathematics.

The lack of affective mathematics engagement on the part of students has been common and is currently prevalent in mathematics classrooms. Educators have observed that far too many students are bored, unmotivated, uninvolved and disengaged from the academic and social aspects of school (Appleton, Christenson, & Furlong, 2008). Many students experience boredom or are otherwise turned off in the classroom, and this is especially true of mathematics. They often feel the mathematics they learn is disconnected from their everyday reality (Langer-Osuna, 2015). Gaining mathematical knowledge without positive affective mathematical engagement was found to be one of the greatest threats to students' mathematical learning outcomes (Hannula, 2002). Moreover, the lack of affective mathematics engagement on the part of students was found to have negative consequences in terms of both their academic mathematical achievement and other outcomes such as confidence and self-esteem (Borman & Overman, 2004; Uekawa, Borman, & Lee, 2007). Academic and affective growth would be observed in all students if the mathematics classrooms emphasized their affective mathematics engagement.

Method

The methodological approach of the three articles of this dissertation varies according to the research question for each study and type of data collected. Quantitative statistical analysis was mainly used in all three articles. In the Chapter II, hierarchical linear modeling (HLM) was utilized to analyze students' affective mathematics engagement and student- and school- level factors. In the Chapter III and Chapter IV, independent *t*-tests were utilized to analyze the differences between groups (Korea vs. U.S., and STEM vs. non-STEM). Effect sizes (e.g., Cohen's *d* or Measures of association strength) and confidence intervals are reported for practical significance. The Chapter III was also used structural equation modeling (SEM) to test the hypotheses about the theory of the impact of motivation on affective mathematics engagement.

Journal Selection

The journal was selected for publication of each manuscript by inclusion criteria as follows: (1) journals which include articles cited in the literature review of this dissertation, (2) the aptness of the scope and expected reader, which were described in the web page of each journal, and (3) impact factors (SCImago Journal Rank [SJR] and Source Normalized Impact per Paper [SNIP]) and prestige of the editorial board. The impact factors (SJR and SNIP) were found on the primary web sites; Scopus database of abstracts and citations for scholarly journal articles and Journal Citation Reports Social Sciences Citation Index (JCR-SSCI). Acceptance rates, review type, and length of manuscript from Cabell's Directory of Publishing Opportunities were referenced to choose the journals (see Table 1).

Table 1 Proposed Articles and Journals.

Chapter	Citation	Proposed Journal Information
Chapter II. School and student factors and their influence on mathematical affect	Lee, Y., Capraro, R. M., Capraro, M. M., Bicer, A. (2019, Submitted). School and student factors and their influence on mathematical affect. Paper submitted to *Mathematics Educational Research Journal.*	Mathematics Education Research Journal • Acceptance rate: 35% • Impact and ranking (SJR/SNIP): 0.570/0.893 • Editor in chief/Associate editors: Peter Grootenboer • Publisher: Springer • Type of review: Peer Review • Manuscript length: 9000 words
Chapter III. School and student factors and their influence on mathematical affect	Lee, Y., Capraro, R. M., Capraro, M. M., Bicer, A. (2019, Submitted). The comparison of students in U.S and Korea in terms of students' affective mathematics engagement. Paper submitted to *International Journal of Science and Mathematics Education.*	International Journal of Science and Mathematics Education • Acceptance rate: 30% • Impact and ranking (SJR/SNIP): 0.737/1.072 • Editor in chief/Associate editors: Huann-shyang Lin • Publisher: Springer • Type of review: Peer Review • Manuscript length: 30 pages
Chapter IV. The effectiveness of STEM PBL lessons on students' development of affective mathematics engagement (STEM PBL vs. non-STEM PBL)	Lee, Y., Capraro, R. M., Bicer, A. (2019). The effectiveness of STEM PBL lessons on students' development of affective mathematics engagement (STEM PBL vs. non-STEM PBL). *Canadian Journal of Science, Mathematics, and Technology Education*, 1-20. DOI: https://doi.org/10.1007/s42330-019-00050-0	Canadian Journal of Science, Mathematics, and Technology Education • Acceptance rate: 35% • Impact and ranking (SJR/SNIP): 0.346/0.702 • Editor in chief/Associate editors: John Wallace • Publisher: Springer • Type of review: Peer Review • Manuscript length: 6000 words

Note: SJR=*SCImago Journal Rank* in 2017. SNIP=*Source Normalized Impact per Paper* in 2017.

CHAPTER II

SCHOOL AND STUDENT FACTORS AND THEIR INFLUENCE ON AFFECTIVE MATHEMATICS ENGAGEMENT

Overview

This study examined the student-and school-level variability of the students' affective mathematics engagement. It was hypothesized that there is a school effect which contributes toward explaining differences of affective mathematics engagement, besides the student-level differences. For the sake of the nested structure of the data in Trends in International Mathematics and Science Study (TIMSS), I used the Hierarchical Linear Modeling (HLM) methodology. There were 10,221 students from 246 schools in the study. Besides the significant effect of students' demographic factors (i.e., gender, home language, and immigration status), the school economic disadvantage status was a significant factor which impacted students' affective mathematics engagement. The present study contributed to a better understanding of the variables at school-level which could positively impact students' affective mathematics engagement.

Introduction

Students' affective mathematics engagement has attracted the attention of educators and stakeholders in field of education. In particular, empirical research about affective mathematics engagement and the factors impacting it is expected to illustrate this significant educational topic for both students and educators. Students' affective mathematics engagement is an affective state by specific situation of a mathematical activity or task (Eccles & Wigfield, 2002; Wang & Degol, 2014). This situational feeling toward mathematics includes individual's comprehensive perspectives such as attitude, emotion, self-acknowledge, and value (Lee et al., 2019) and promotes students' activity level in mathematical learning situations and comprehensibility of mathematical concepts (Hidi & Baird 1986; Schiefele 1999). In turn, affective mathematics engagement impacts students' academic achievement (Dotterer & Lowe, 2011) and encourages them to pursue Science, Technology, Engineering and Mathematics (STEM)-related majors or careers through the improvement of interest toward mathematics (Grigg, Perera, McIlveen, & Svetleff, 2018). Therefore, fostering a positive affective mathematics engagement is one of the biggest factors to students' academic success.

However, a number of educators in mathematics education have recognized there was a lack of students' affective mathematics engagement in current mathematics classrooms. There were many affectively disengaged students who felt bored and uninvolved in mathematical learning situations (Appleton et al., 2008). One possible reason of students' affective disengagement in mathematics classrooms was the impact of students' and schools' demographic factors. The demographic factors of students (i.e., gender, home language, and immigration status) and schools (i.e., school mean economic disadvantage status) served as important factors to develop or decline students' affective mathematics engagement.

Gender Differences

The issue of gender differences in affective mathematics engagement continues to capture much attention within and beyond mathematics education, as researchers seek to address the greater number of male students than female students at the highest levels of affective mathematics engagement (Halpern, Benbow, Geary, Gur, Hyde, & Gernsbacher, 2007). One possible explanation for the underrepresentation of female students at the high end of affective mathematics engagement could be explained by cultural norms. Despite mounting evidence of gender similarities in mathematical academic achievement (Hyde, Lindberg, Linn, Ellis, & Williams, 2008), the stereotype threat that female students lack affective mathematics engagement compared to males has persisted. Mathematics-related disciplines and careers have been considered male-dominated fields (Buck, Clark, Leslie-Pelecky, Lu, & Cerda-Lizarraga, 2008). A number of researchers (e.g., Boedecker, Nite, Capraro, & Capraro, 2015; Bystydzienski & Bird, 2006; Ressler & Ressler, 2004) have shown male students as advantaged in mathematics and the stereotypes about female students in mathematics. Mathematics tended to be viewed as masculine and unexciting for female students (Boedecker et al., 2015). There was much research demonstrating stereotypes - female students being less capable with mathematics (Boedecker et al., 2015; Bystydzienski & Bird, 2006). Another stereotype about female students in mathematics is that female students tended to have lower mathematical affect (Correll, 2001; Dowker, Sarkar, & Looi, 2016; Eccles, 1994; Wai, Cacchio, Putellaz, & Makel, 2010). This low mathematical affect of female students manifested itself in female students being less affectively engaged in mathematics learning situations (Hyde, Fennema, Ryan, Frost, & Hopp, 1990) and interested in taking advanced mathematics related courses compared to male students (Boedecker et al., 2015).

Language and Immigration Status

The number of students from many countries, who have diverse backgrounds, has rapidly increased in the U.S. schools (Cochran-Smith et al., 2015). Consequently, around 9% of the students who enrolled in the public schools were identified as English Language Learners (ELL), and the population of these types of students has been increasing over the past several decades (U.S. Department of Education, 2016). The low-level of English proficient students limited their affective engagement in mathematical content and situations (Rillero, Koerner, Jimenez-Silva, Merritt, & Farr, 2017). When this affective mathematics engagement was not conveyed to the students, they could not develop their mathematical performance (Wright, 2015). The roles of the language the students were using in their homes and their immigration status in affective mathematics engagement in mathematics classes in their schools have been documented by many researchers (e.g., Areepattamannil & Freeman, 2008; Martin, Liem, Mok, & Xu, 2012). Students who spoke the English language more often at home tended to show more positive mathematical perspectives than students who spoke a foreign language at home (Martin et al., 2012; Mullis, Martin, Foy, & Arora, 2012). In addition, language issues are related to cultural issues. Most students who were not native English speakers were immigrants (Cho & Reich, 2008). These individuals have been less exposed to the culture in the U.S. If teachers or peers do not understand a student's culture and turn their faces away, the student’s affective mathematics engagement would be decreased (Gorgorió, Planas, & Vilella, 2002).

School Mean Economic Disadvantage Status

School mean economic disadvantage status in this study referred to how many students in a school came from economically disadvantaged homes. There has been a growing consensus that school mean economic disadvantage status is associated with students’ affective mathematics engagement. A number of researchers (e.g., Appleton et al., 2008; Pekrun & Linnenbrink-Garcia, 2012; Skinner & Pitzer, 2012) indicated the strong relationship between economic disadvantage status and students’ affective mathematics engagement. There was a variation in students’ affective mathematics engagement depending on their economic status. In particular, the number of students who were from economically disadvantaged homes was considered as the main issue in determining school support (Alexander, Entwisle, & Olson, 2001) which was related to students’ academic success. Low income of parents limited students’ learning circumstances and decreased students’ affective mathematics engagement (McGraw, Lubienski, & Strutchens, 2006; Tate, 1997). In addition, the differences between students in terms of economic disadvantage status impacted students’ mathematical performance and affective mathematics engagement during the time they were learning mathematics. For example, economically disadvantaged students also preferred to focus on drill-based or basic computational skills while economically non-disadvantaged students focused on problem solving and reasoning skills (Anyon, 1981). These types of mathematical performance differences between students depending on their economic disadvantage status eventually impacted the differences of their affective mathematics engagement (Appleton et al., 2008; Pekrun & Linnenbrink-Garcia, 2012; Skinner & Pitzer, 2012). The role of schools in minimizing this limitation of students needs to be considered so students could be supported to overcome the impact of their economic disadvantage on their learning.

The roles of schools and educational administration could have been an important issue (Chiu, Price, & Ovrahim, 2015) when they had a large portion of economically disadvantaged students who needed to have extra administrational and instructional supports (Alexander et al., 2001). For example, schools provided diverse opportunity to explore mathematics-related disciplines and careers regardless of students' economic disadvantage status. These experiences increased motivational beliefs, including self-efficacy, interest, values, and identity processes, impacting students' career aspirations and choices (e.g., Benbow, Lubinski, Shea, & Eftekhari-Sanjani, 2000; Jacobs, Davis-Kean, Bleeker, Eccles, & Malanchuk, 2005). In addition, schools providing mathematics activities using multi-media like a computer broadened students' experience, particularly those who did not have any opportunities to use them in their learning situations. However, schools included a large number of students who often represented that the economic statuses of these schools were also disadvantaged compared to those which had a large number of advantaged students. Providing opportunities for diverse mathematics activities and using technological material for the mathematics classroom were sometimes difficult to implement because of the economic issue (Palloff & Pratt, 2002). These economic statuses impacted students' affective mathematics engagement. Students from economically advantaged schools had a positive affective mathematics engagement and greater confidence than did their peers from economically disadvantaged schools (Perry & McConney, 2010).

In short, a myriad of student- and school-level factors are implicated in variability in students' affective mathematics engagement. However, the majority of the studies (e.g., Areepattamannil, Chiam, Lee, & Hong, 2015; Ma & Klinger, 2000; Tate, 1997) have only focused on the relationships between these factors and mathematical academic achievement. There has been a dearth of research on the relationships of student- and school-level factors in affective mathematics engagement among students. Owing to a lack of current research findings related to affective mathematics engagement, the field needs more research to understand the relationship of contextual factors and students' affective mathematics engagement. Such an exploration will provide a deeper understanding of the relative strengths and weaknesses of educational circumstances and help identify potential ways forward in developing the quality of the educational circumstances. The present study, therefore, aims to examine the student- and school-level factors related to students' affective mathematics engagement. The following research questions address the purpose of this study:

1. What are the effects of student-level factors (gender, home language, and immigration status) and school-level factor (school economic disadvantage status) on students' affective mathematics engagement?
2. Is there any evidence that the effects of student-level factors vary by school-level?

The present study used a quantitative analysis of school effects on students' affective mathematics engagement in U.S. public schools. The study aimed to examine student- and school-level variability of students' affective mathematics engagement and hypothesized that the effects of school contributed toward explaining differences of affective mathematics engagement. Different levels can be explained by salient characteristics with the relationships with other levels of hierarchy. In education, data are often nested in different levels such as classrooms, schools, and countries. Ignoring the structure of these nested data was likely to create a biased estimate or let researchers misunderstand the result (Raudenbush & Bryk 2002). Owing to the nested nature of the data, two-level hierarchical linear modeling (HLM) representing student- and school-level variables were hypothesized for the analysis of this study. Thus, the present study included student- and school-level factors and focused on students' affective mathematics engagement. The student-level factor in the analyses included students' demographic factors (i.e., gender, home language, and immigration status). School economic disadvantage status served as the school-level factor.

Method

Data Sources

Data for the study were drawn from TIMSS 2015 database. TIMSS, administered in participating countries every three years, is an international comparative survey of 4th and 8th grade students' academic achievement and affective domains in mathematics and science. It collects comprehensive educational information from students, teachers, and school stakeholders about cognitive and affective domains in mathematics and science, demographic and home contexts, and school characteristics including policies, curriculum, and instruction. In this study, I used the data from 8th grade students in the U.S. A total of 10,221 students (female = 5,091 (50.1%), male = 5,071 (49.9%), missing = 59) from 246 schools took part in TIMSS in 2015. The number of students per school in the U.S. sample varied between 3 and 73 (mean (M) = 41.59, standard deviation (SD) = 12.46).

Variables

Reflective indicators were selected from the original TIMSS 2015 questionnaires based on theory and operational definitions used in prior studies. Psychological items in mathematics were selected for exploratory factor analysis (EFA) using Statistical Package for the Social Sciences (SPSS) 25. The principal components analysis (PCA) with Varimax rotation was used to extract affective mathematics engagement factors for the current study. The results of the analysis showed that seven psychological items can be considered as variables of affective mathematics engagement. Following are the specific seven items of affective mathematics engagement used for this study: (1) I enjoy learning mathematics, (2) I like mathematics, (3) I look forward to mathematics class, (4) I usually do well in mathematics, (5) Mathematics is more difficult for me than for many of my classmates, (6) Mathematics is not one of my strengths, and (6) I learn things quickly in mathematics. The Cronbach's α reliability was .894. These items of affective mathematics engagement were well aligned with the items of affective engagement in science by Mo, Singh, and Chang (2013). Mo et al. (2013) demonstrated six items which overlapped with six of the items in this study: The present study included one more item, “I like mathematics.” Students were asked to indicate the extent of their agreement with each statement on a four-point Likert-type scale ranging from 1= “Disagree a lot” to 4= “Agree a lot”.

The student-level factors included students’ affective mathematics engagement and their background characteristics. The student background characteristics included gender (Question: “Are you a girl or a boy?”, Answer: 1 = “Boy” and 0= “Girl”), home language (Question: “How often do you speak English at home?”, Answer: 4 = “Always”, 3 = “Almost Always”, 2= “Sometimes”, and 1 = “Never”), and immigration status (Question: “Were you born in the U.S.?, Answer: 1= “Yes” and 0 = “No”). The school-level factor included school mean economic disadvantage status (Question: “Approximately what percentage of students in your school have the following backgrounds? Come from economically disadvantaged homes”, (Reversed) Answer: 4 = “0 to 10%”, 3 = “11 to 25%”, 2 = “26 to 50%” and 1 = “More than 50%”). The school mean economic disadvantage measured whether most students in the school came from economically disadvantaged homes. Gender and immigration status were dichotomously scaled items (boy/girl or yes/no). Items of home language and school mean economic disadvantage status were rated on a four-point Likert-type scale. Negatively phrased item (i.e., school mean economic disadvantage status) was inverted for item response theory (IRT) scaling, and higher values on these indices indicated more positive evaluation. The school-level variable was aggregated because some schools included multiple scores of economic disadvantage by teachers or classes. Thus, school mean economic disadvantage status became the school-level variable.

Data Analysis

To analyze the data, two-level HLM was conducted using SPSS 25. With the intention to examine the school-level variability of U.S. 8th grade students' affective mathematics engagement, the study hypothesized that school effects contributed toward explaining differences of affective mathematics engagement. Because of the nature of students who were nested in hierarchical social structures, they could not be fully independent. The students tend to show similarities different from people who are randomly selected from the population (Hox, 2002). The HLM was a useful analysis technique to deal with the nested data structures (Raudenbush & Bryk, 2002). Therefore, the HLM was built in sequence, using a series of models (McCoach, 2010). First, two-level HLM analyses started with an unconditional model that contained no predictor variables from any level. The unconditional model, which is also called null or intercept-only model, was run to estimate what portion of the total variance in outcome measures (i.e., students' affective mathematics engagement) was explained by within-school variance (i.e., variance attributable to student-level factors) and between-school variance (i.e., variance attributable to a school-level factor). This unconditional mixed model is similar to a model of random effects one-way analysis of variance (ANOVA) (Raudenbush & Bryk, 2002). However, only HLM can be used when the data are not completely balanced (i.e., sample size differed from school to school). The estimate of HLM included the mean of the means of affective mathematics engagement for each school, instead of the mean of all students in the study. Second, a Level-1 model that included all student-level variables was estimated. Lastly, a full Level-2 model that included both student- and school-level variables was estimated. The random intercepts and fixed slopes model were used for Level-1 and Level-2 models. The indices of model fitness were based on a Wald *z* value, which is the covariance parameter estimate divided by its standard error provided by SPSS 25.

The use of the hierarchical linear model involved a single cross-section of data with a two-level structure consisting of students (Level 1) nested within schools (Level 2). The Level 1 model added gender, home language, and immigration status as predictors. The Level 2 model included school economic disadvantage status. The HLM mixed model equations are provided below.

- Unconditional model: $(Affective\ Mathematics\ Engagement)_{ij} = \gamma_{00} + u_{oj} + e_{ij}$
- Level-1 model: $(Affective\ Mathematics\ Engagement)_{ij} = \gamma_{00} + \gamma_{10}(Gender)_{ij} + \gamma_{20}(HomeLanguage)_{ij} + \gamma_{30}(ImmigrationStatus)_{ij} + u_{oj} + e_{ij}$
- Full Level-2 model: $(Affective\ Mathematics\ Engagement)_{ij} = \gamma_{00} + \gamma_{01}(SchoolEconomicDisadvantage)_{ij} + \gamma_{10}(gender)_{ij} + \gamma_{20}(HomeLanguage)_{ij} + \gamma_{30}(ImmigrationStatus)_{ij} + u_{oj} + e_{ij}$

(i=student (1$\leq i \leq 10{,}221$), j=school (1$\leq j \leq 246$))

Intraclass correlation coefficient (ICC) was calculated to determine what percentage of the variance in affective mathematics engagement was attributable to school level. The formula for ICC (ρ) is:

$$\rho = \frac{\tau_{00}}{\tau_{00} + \sigma^2}$$

τ_{00} is a variance component at school level, and σ^2 is a variance component at student level.

To obtain information on the HLM models, two auxiliary statistics, variance explained and -2 restricted log likelihood (-2LL) were calculated. The variance (r^2) explained by the student-level predictor variables in the outcome variable is:

$$r^2 = \frac{(\sigma_{null}^2 - \sigma_{random}^2)}{\sigma_{null}^2}$$

σ_{null}^2 is a sigma value obtained in the previous step (unconditional model), and σ_{random}^2 is a sigma value obtained in the present step (student-level model or school-level model). The result of variance explained revealed how much the variance component at school level (τ_{00}) and the variance component at student level (σ^2) were further explained as more predictors were added (Raudenbush & Bryk, 2002). The -2LL was calculated to select the best-fit model for the collected data by examining whether the variable increased the model fitness.

Results

Unconditional Model

Table 2 presented the detailed results of fixed and random effects of all four models (unconditional, gender, home language, and immigration status). The results of the unconditional model indicated the average mean for students' affective mathematics engagement as 15.779 (t = 136.195, p < .001). The estimates of the variance components at student level was $\sigma^2 = 29.214$ and at school level, ($\tau_{00} = 2.480$, $Wald\ z = 68.489$,

p < .001). This result indicated that mean affective mathematics engagement score among schools was 15.779, and that there was more variation within schools than among the different schools. These results showed that there was statistical justification for running HLM. In addition, the ICC for this unconditional model is equal to $\rho_{uc} = .078$. The ranges of ICC in educational research with a cross-sectional design are considered between .05 and .20 in general (Kwok et al., 2008; Snijders & Bosker, 1999). The estimated ICC value indicated that 7.8% of the variability in the students' affective mathematics engagement scores was due to the organizational unit (i.e., school mean economic disadvantage). Because variance existed at both student- and school-levels of the data structure, independent variables were individually added at each level.

Student- and School-Level Factors Predicting Affective Mathematics Engagement

Level-1 model

For the student-level model, I added three student-level fixed factors: gender, home language, and immigration status. A regression coefficient was estimated, and its significance confirmed the relationship between student level predictor variables and the outcome variable (affective mathematics engagement). The results of the present analysis supported the relationship between affective mathematics engagement and gender ($r_{10} = .696, p < .001$), home language ($r_{20} = .222, p < .05$), and immigration status ($r_{30} = .691, p < .05$). That is, students' gender, home language, and immigration status were statistically significantly related to their affective mathematics engagement. In particular, male students, students who spoke English at home, and students who were born in the U.S. scored statistically significantly higher on affective mathematics engagement. To calculate a measure of effect size, the variance ($r^2_{within1}$) explained by the student-level predictor variables in the outcome variable was $r^2_{within1} = .007$, and the variance ($r^2_{between1}$) in affective mathematics engagement explained between schools was: $r^2_{between1} = -.003$. This result indicated that gender, home language, and immigration status explained .7 percent of the variance in affective mathematics engagement.

Full level-2 model

For the student- and school-level model, I added a school-level fixed factor: the school mean economic disadvantage status. A regression coefficient was estimated, and its significance confirmed the relationship of student- and school-level predictor variables with the outcome variable (affective mathematics engagement). The results of the present analysis supported that affective mathematics engagement was explained by student-level variables (gender: $r_{10} = .739, p < .001$, home language: $r_{20} = .219, p < .05$, and immigration status: $r_{30} = .574, p < .05$) and the school-level variable (school mean economic disadvantage status: $r_{01} = .286, p < .05$). That is, gender, home language, and immigration status of students and economic disadvantage status of schools were statistically significantly related to students' affective mathematics engagement. In particular, the slope of student-level variables was positive, meaning that male students, students who spoke English at home, and students who were born in the U.S. scored statistically significantly higher on affective mathematics engagement. When controlling for other variables in the model, male students were associated with scoring .739 points higher than female students; students who were born in the U.S. were associated with scoring .574 points higher than student who were not born in the U.S.; and a unit increase in students who spoke English at home predicted an increase of affective mathematics engagement score of .219 points. In addition, schools that had fewer economically disadvantaged students scored statistically significantly higher on affective mathematics engagement. For every unit decrease and school mean economic disadvantaged status predicted an increase .286 points in affective mathematics engagement.

The variance ($r^2_{within2}$) in affective mathematics engagement within schools explained is $r^2_{within2}$=$.012$. This result indicated that gender, home language, and immigration status explained 1.2% of the variance in affective mathematics engagement. The variance ($r^2_{between2}$) in affective mathematics engagement between schools explained is $r^2_{between2}$=$.053$. This result indicated that school mean economic disadvantage status explained 5.3% of the variance in affective mathematics engagement. The -2LL value of this full level-2 model was smallest, which indicated the best-fit model.

Table 2 Results of Hierarchical Linear Modeling Analyses Predicting Students' Affective Mathematics Engagement.

	Unconditional model			Level-1 model			Full level-2 model		
	B	*SE*	*t/Wald z*	*B*	*SE*	*t/Wald z*	*B*	*SE*	*t/Wald z*
Fixed effects									
Intercept, (r_{00})	15.779**	.116	136.195**	13.957**	.374	37.356**	13.112**	.541	24.246**
Level 1									
Gender (r_{10})				.606**	.112	6.232**	.739**	.117	6.324**
Home language (r_{20})				.222*	.093	2.400*	.219*	.098	2.244*
Immigration status (r_{30})				.691*	.255	2.707*	.574*	.270	2.128*
Level 2									
School mean economic disadvantage (r_{01})							.286*	.113	2.540*
Random effects									
Intercept variance (u_{0j} or τ_{00})	2.480		8.311**	2.488		8.305**	2.347		7.814**
Level-1 variance (Students variation, e_{ij} or σ^2)	29.214		68.489**	28.996		68.126**	28.855		64.960**
Intraclass correlation coefficient (ICC) (ρ)	.078			.079			.075		
Variance in affective mathematics engagement between schools explained (%)	N/A			-.3			5.3		
Variance in affective mathematics engagement within schools explained (%)	N/A			.7			1.2		
-2 Restricted Log Likelihood (2LL)	60161.554			59497.436			54035.394		

Note. *p < .05, **p < .001.

Discussion

In the 21st century, the crucial role of investigation and encouragement of students' affective mathematics engagement has been highlighted in mathematics education. The improvement of students' affective mathematics engagement is highly related to their high achievement of academic performance (Organization for Economic Cooperation and Development [OECD], 2010; Perry & McConney, 2010) as well as their future major or career choices in STEM-related fields (Capraro & Slough, 2013; Chen & Usher, 2013; Lent, Paixão, Da Silva, & Leitão, 2010). In particular, the U.S. has been emphasizing the preparation of a STEM-proficient workforce and filling positions in the growing STEM-related job market (President's Council of Advisors on Science and Technology [PCAST], 2012). Therefore, the objective of the present study was to examine the relationships of student- and school-level factors to students' affective mathematics engagement among U.S. 8th grade students. Hierarchical linear modeling (HLM) was used to statistically analyze a data structure where students (level-1) were nested within schools (level-2). Of specific interest was the relationship between students' affective mathematics engagement and both student-level factors (gender, home language, and immigration status) and a school-level factor (school mean economic disadvantage status). The finding of the study indicated schools accounted for more of the variability in affective mathematics engagement than did the students within schools. A school-level variable explained about 5.3% of the total variance in affective mathematics engagement, and student-level variables explained 1.2%. All factors of student- and school-level were statistically significantly associated with affective mathematics engagement.

Student-Level Analysis

Gender, home language, and immigration status of students have significant positive effects on their affective mathematics engagement. Consistent with the findings of prior research (e.g., Boedeker et al., 2015; Buck et al., 2008; Bystydzienski & Bird, 2006; Halpern et al., 2007; Ressler & Ressler, 2004), the results of the present study revealed significant gender differences in affective mathematics engagement. Male students' affective mathematics engagement was more positive than female students. The gender differences in students' perspectives toward mathematics are shaped by socio-cultural factors (Spelke, 2005) and national indicators of gender egalitarianism (Guiso, Monte, Sapienza, & Zingales, 2008). According to prior research, students' affective mathematics engagement was found to be male dominated. The cultural stereotype has been considered one of the reasons implicated in male students' superiority in positive affective mathematics engagement (Dowker et al., 2016; Wai et al., 2010). For example, female students who endorse such stereotypes are less likely to have positive affective mathematics engagement (Hyde et al., 1990; Schmader, Johns, & Barquissau, 2004). In addition, many female students believed that mathematics did not involve creativity and chose not to pursue STEM-related careers (Bicer et al., 2017 Boedecker et al., 2015; Correll, 2001; Wai et al., 2010). Moreover, female high school students tended to show less interest in taking advanced STEM related courses as compared to male students (Boedecker et al., 2015; Chen, 2009; Correll, 2001; Eccles, 1994). There have been a number of educational attempts to encourage female students' affective mathematics engagement and to combat the widening of the gender differences over time (Nosek et al., 2009). However, the findings of this study suggest that there is still a need for social and educational efforts to bolster female students' affective mathematics engagement.

Speaking English at home was positively linked to students' affective mathematics engagement, a finding consistent with prior findings (e.g., Areepattamannil & Freeman, 2008; Martin et al., 2012; Mullis et al., 2012; Rillero et al., 2017). In the U.S., the population of students who are represented as ELL has been increasing (U.S. Department of Education, 2016). Low-level of English proficiency limited students' understanding about the content and situation in mathematics classroom (Rillero et al., 2017) and mediated affective mathematics engagement. When the content and situation were not conveyed to the students, they could not affectively engage in mathematics classrooms (Lee et al., 2019; Wright, 2015). Given the statistically significant relationship between students' language proficiency and their affective mathematics engagement, instructional interventions aimed at enhancing academic language proficiency may be required for students who fail to develop sufficient proficiency in academic English for their academic success in mathematics learning (Areepattamannil et al., 2015; Slama, 2012).

Students' immigration status was another factor associated with their affective mathematics engagement. In particular, U.S. born students had more positive affective mathematics engagement than that of students who were not born in the U.S. This immigration status brought to the fore the cultural issue. Most students who were not born in the U.S. were either immigrants or children of immigrants, and many of them belonged to ethnic minorities and spoke English as a second language (Cho & Reich, 2008). Similar to the findings of this study, students who speak English as a second language are likely to have low affective mathematics engagement (Maldonado, Mosqueda, Capraro, & Capraro, 2018). In addition, students who were not born in the U.S. have less experience with U.S. culture. For example, the East Asian cultural norm is that students do not question the teacher; therefore, East Asian culture (e.g., Korea, Japan, China) indoctrinated students might be afraid of speaking in front of their peers during the mathematics class (Roebers, 1999). It is because, in most East Asian countries, students are taught by listening to what others say than by speaking what they want to say. If teachers fail to recognize East Asian cultural differences or for that matter cultural differences of others, then students' mathematical performance would suffer (Gorgorió et al., 2002; Roebers, 1999). In this case, direct instruction encouraging students' verbal participation in mathematics activities might be helpful (Gorgorió et al., 2002; Rillero et al., 2017).

School-Level Analysis

Of the school-level factors, mean economic disadvantage was linked to students' affective mathematics engagement. This finding concurs with prior research (e.g., McGraw et al., 2006; Perry & McConney, 2010; Tate, 1997) that students who attend economically advantaged schools tend to do well on standardized measures of affective mathematics engagement compared with their peers who attend economically disadvantaged schools. These results suggest there may be negative consequences of school economic segregation in terms of students' learning opportunities and atmosphere in mathematics classrooms. Because the school economic status is highly related to how many economically disadvantaged/advantaged students they have (Perry & McConney, 2010), the students who attend economically advantaged schools are likely to be exposed to greater instructional advantages and more learning opportunities. Greater instructional advantages tend to positively influence students' affective mathematics engagement (Bicer et al., 2018; Lee, Capraro, & Viruru, 2018; Lee et al., 2019). In addition, students' economic status is related to the social and emotional atmosphere of mathematics classrooms (Brackett, Reyes, Rivers, Elbertson, & Salovey, 2001; Griffiths, Sharkey, & Furlong, 2009; Reyes, Brackett, Rivers, White, & Salovey, 2012). Students may exhibit more affective mathematics engagement in socially and emotionally healthy classroom environments that are characterized by a sense of enjoyment, interest, satisfaction, connectedness, and belongingness. Therefore, educational policies targeted at improving education in low economic schools, and make use of instructional equity can have a positive influence on academic and affective success (OECD, 2010; Perry & McConney, 2010). In addition, reducing the differences in the educational context at school-level may minimize the school economic segregation (Palardy, 2013). Students' positive affective mathematics engagement starts from the socially and emotionally healthy learning environment.

The results of this study should be treated with caution for three reasons. First, the results of this study should not be interpreted as causal inferences. Because of a cross-sectional nature of TIMSS data, there are limited by the fact that the reported significant relationships are correlational and they are carried out at one-time point (Levin, 2006). Therefore, the results can be different in the sequence of events or if another timeframe is chosen. Second, there is a possibility of aggregation bias. The school-level variable, which is economic disadvantage has been aggregated at level-2; therefore, the aggregated means used in the imputation also constrained variation. In the aggregate, different characteristics within school-level defined the characteristic as a unique school that affected each student in the school. In this aggregated model, within-school variation was ignored, and students were treated as homogenous entities (Gill, 2003). However, students who are sampled within a particular school are more similar to each other than to students who are randomly selected from other schools. For example, students in a particular school tend to come from a community that is more homogeneous in terms of educational exposure, physical environment, and even economic status than the students as a whole (Cai, 2008). Further, sharing the experience in the same learning environment may lead to increased homogeneity over time (Cai, 2008; Hox, 2002). Third, the student-level factors, school-level factor, and affective mathematics engagement responses were collected via self-report. Students' self-referent thinking processes may influence their evaluation (Preckel, Goetz, & Frenzel, 2010). Because of the sensitivity of self-reporting towards students' internal processes of the task, the self-report has challenged the reliability and validity of measures (Fulmer & Frijters, 2009). However, this perceived challenge of self-report would therefore be of special importance when it comes to the students' perceptions or subsequent behaviors

(Pajares, 1996). This makes self-report measures good or even better than other competing or alternative measures (Fulmer & Frijters, 2009; Krannich et al., 2019).

CHAPTER III

CULTURAL AFFORDANCE AND AFFECTIVE MATHEMATICS ENGAGEMENT IN KOREA AND U.S.

Overview

Investigating the relationship between students' intrinsic and extrinsic motivation and their effects on affective mathematics engagement in the cultural context is critical for determining which types of motivation promote affective mathematics engagement and the relationship with cultural affordance. This investigation is comprised of two sequential and dependent studies. Phase 1 unpacked the effects of intrinsic and extrinsic motivation on affective mathematics engagement. A structural equation modeling (SEM) analysis revealed that affective mathematics engagement variables were directly related to motivation variables. In the hypothesized model, attitude and emotion were better explained by extrinsic motivation than intrinsic motivation, while self-acknowledgement and value were better explained by intrinsic motivation than extrinsic motivation. The results form phase1 indicated that the hypothesized theoretical model fit the data. From phase 1, intrinsic and extrinsic motivation, attitude, emotion, self-acknowledgement, and value were also used as variables for comparing Korean and U.S students' motivation and affective mathematics engagement for phase 2. The results of phase 2 indicated that the Korean sample had greater extrinsic motivation (Hedges' g = .583), attitude (Hedges' g = .283), and emotion (Hedges' g = .637) than U.S. sample. However, the U.S. sample had greater intrinsic motivation (Hedges' g = 3.645), self-acknowledgement

(Hedges' $g = 1.372$), and value (Hedges' $g = .844$) than the Korean sample. The key outcome for this research was that it is impossible to disentangle the complex cultural affordances from the complex emotional and cognitive structures.

Introduction

Affective mathematics engagement is a key outcome used for assessing the effectiveness of an educational system in a given country. Recently, educational researchers have expressed an increased interest in affective mathematics engagement as a means to identify factors to improve students' mathematical academic achievement; this is because of the high correlation of students' mathematical academic achievement and their affective domains (Hammouri, 2004). Teaching and learning in mathematics was formulated and maintained on the basis of affective mathematics engagement (Fredricks, Blumenfeld, & Paris, 2004). In particular, effective learning encompassed curriculum or teaching methods and also students' affective mathematics engagement (Fredricks et al., 2004; Greenwood, Horton, & Utley, 2002). This affective mathematics engagement among students was heavily impacted by their cultural context, which was referred to as cultural affordance (Kitayama & Markus, 1999). This study investigated the relationship between cultural affordance and affective mathematics engagement.

Theoretical Framework

Affective Mathematics Engagement

Attitude

Research concerning attitude has perhaps the longest history within the field of affective mathematics engagement (Hannula, 2006; Zan et al., 2006). However, numerous researchers (e.g., Hannula, 2006; Zan & Di Martino, 2003) have posited that attitude is an ambiguous construct with a vague definition. The definition of attitude required substantial refining (Ma & Kishor, 1997). In response to the critics and clarifications of attitude, numerous researchers have developed a definition and construct of attitude (e.g., Di Martino & Zan, 2001; Hannula 2002; Zan & Di Martino, 2003).

Attitude has been defined as an emotional disposition in particular contexts (Debellis & Goldin, 2006). The construct of attitude was initially developed within the context of social psychology as an individual's behavior in a certain context. One's attitude is organized through experience and is directly exerted on all objects and situations in mathematical learning (Pickens, 2005). Therefore, attitude has an explicit relationship with behavioral engagement (Hannula, 2006) and cognitive engagement (Majeed, Darmawan, & Lynch, 2013). Students who possessed positive attitudes regarding mathematics might exhibit positive behavioral engagement, such as actively seeking solutions to mathematics problems, or cognitive engagement, such as through mental processes and openness (Goldin, 2002; Majeed et al., 2013).

Emotion

Emotion is defined as a rapidly changing feeling during an activity (Debellis & Goldin, 2006). Students' interpretations and appraisals of specific situations are the basis of their emotions (Op't Eynde & Turner, 2006). Students vary in terms of personal factors such as age, gender, and culture and situational factors such as mathematical activities, teachers, and peers. These personal and situational factors continuously develop and influence students' emotion. Emotion is contextualized based on students' personal and situational factors and can therefore be unstable. In the same context, emotion is regarded as functional. Emotion is critical in human coping, adaptation (Buck, 1999), and decision-making (De Bellis & Goldin, 2006).

Self-acknowledgement

Self-acknowledgment refers to affect toward cognition in a mathematical situation. It is defined as an individual's affective posture to acknowledge sufficiency or insufficiency of mathematical cognition (DeBellis & Goldin, 2006; Furinghetti & Morselli, 2007). A student's self-acknowledgment is the outcome of consciously or subconsciously activating an individual's affective evaluation regarding cognition, their cognitive learning situation, or themselves as they learn mathematics (Malmivuori, 2001). Self-acknowledgement occurs between facts and expectations during the learning process and causes students to recognize their feelings regarding their understanding so that they may or may not pursue action (Mandler, 1984). For example, in a problem-solving situation in which students built a cognitive structure by constructing a new schema or developing a previously constructed schema (Goldin, 2000), this process of building cognitive structures interacts with students' affective mathematics engagement, which is the construction of self-acknowledgement. Students develop their own feelings regarding cognition and cognitive processes in a mathematical situation by employing affective self-states (Malmivuori, 2006). Students considered whether they could understand the problems, whether they were competent or incompetent problem solvers, whether they expected success or failure in solving problems, and their feelings about the problems and knowledge such as puzzlement, bewilderment, frustration, pleasure, elation, and satisfaction (Goldin, 2000). Because of strong relationships between self-acknowledgement and understanding of cognition, the development of self-acknowledgement can influence students' academic success.

Value

Value refers to personal truth or commitment towards mathematics, including ethics and morals (Debellis & Goldin, 2006). From the macroscopic perspective, value is inherently present and is pivotal in establishing a student's sense of personal and social identity regarding mathematics (Bishop, 2008). Because of the importance of value in mathematics learning, the OECD demonstrated the importance of value for students' affective mathematics engagement below:

> Mathematical literacy is an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgements and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned and reflective citizen (OECD, 2003, p. 24).

From the microscopic perspective, value exerts a crucial impact on affective engagement in mathematics classrooms. Students' mathematics value encompasses a large portion of affective engagement and disengagement in mathematics activity (Bishop, 2008; Deci & Ryan, 1985; Wigfield & Eccles, 2000). Therefore, to keep maintaining positive affective mathematics engagement, students need to be encouraged to have positive value during mathematical learning process.

Motivation

Motivation encompasses two components: intrinsic motivation and extrinsic motivation. These two types of motivations are formed by social and cultural factors at the appropriate level of generality (Vallerand, 1997). The motivation formed through cultural affordance is positive activation to affective mathematics engagement through directed attention and impulses to action. Affective mathematics engagement is the most direct link to motivation, being manifested either in positive and negative feelings depending upon how students learning situation aligns with their motivation (Hannula, 2006). In the process of salient affective-cognitive mathematical learning, students constantly engaged further with mathematical learning tasks through motivation. Motivation relates to the desire to engage with the tasks and is a key variable of students' affective state in their mathematical learning situation.

Intrinsic motivation

Students' experience in their learning process impacts their intrinsic motivation. Intrinsic motivation involves performing behavior for one to experience satisfaction and enjoyment gained during tasks (Wigfield & Eccles, 2000). Intrinsic motivation is related to exploring and understanding mathematical concepts and having an intrinsic curiosity regarding mathematical learning and knowledge (Harter, 1981). Students' intrinsic motivation is developed when they attempt to create new connections between mathematical concepts or accomplish mathematical tasks (Vallerand, 1997). Therefore, experiences of accomplishment in terms of mathematical learning processes positively impact the construction of intrinsic motivation. Thus, students who have been exposed to opportunities for accomplishment in their mathematics learning process are likely to have high intrinsic motivation. In particular, intrinsically motivated students were previously surrounded by an atmosphere in which they could freely investigate given tasks without competition or mastery (Matsumoto & Sanders 1988). The intrinsically motivated students in this environment were motivated to engage in their mathematical learning situation with their internal feeling of enjoyment and satisfaction (Ryan & Deci, 2000).

When students' tasks were based on intrinsic motivation, positive psychological consequences resulted (Deci & Ryan, 1985; Wigfield & Eccles, 2000). Intrinsically motivated students worked on the mathematics task for the pleasure they experienced while striving to create a product. In addition, this type of student may express that while working on their homework, they were working so arduously on their homework because they wanted to improve their mathematical skills. These students positively and affectively engaged in a mathematics learning process because they were interested in it and enjoyed the mathematical knowledge itself (Eccles & Wigfield, 2002). Being intrinsically motivated, students may perceive pleasant experiences such as feeling free and relaxed and less pressure and tension regarding their mathematical learning. This positive affective mathematics engagement allows them to focus on the mathematical learning process and the value of mathematical learning (Matsumoto & Sanders 1988; Vallerand, 1997), creating a cycle reinforcing intrinsic motivation and mathematical learning.

Extrinsic motivation

Extrinsic motivation refers to performing behavior to achieve a separable outcome, such as receiving rewards or avoiding punishment (Ryan & Deci, 2000; Eccles & Wigfield, 2002; Walker, Greene, & Mansell, 2006). For example, extrinsically motivated students may express that they study hard for mathematics tests because their parents will be upset if they receive low scores. This consideration accounts for the ultimate state not for its own sake (Wigfield & Eccles, 2000). Cultural affordance often induced students' extrinsic motivation. Overall, some cultural affordances are more strongly associated or even predisposed to be extrinsically motivated in various contexts. And eventually, students experiencing these cultural affordances were extrinsically motivated to affectively engage in mathematical learning situations in their mathematics classrooms. Because extrinsic motivation was associated with outcomes assessed, it was sensitive to certain circumstances (Senko & Harackiewicz, 2005). For example, students who have been exposed to the culture of competitive settings in which students were rewarded for performance (e.g., high test scores, entering a good university, getting a good job) based on their efforts (e.g., learning mathematics) are likely to have high extrinsic motivation as well. Therefore, extrinsic motivation induces situational affective consequences such as a high level of attention and positive attitude or emotion toward a particular mathematical task at a specific time (Vallerand, 1997). Extrinsic motivation is consideration for the usefulness of affective mathematics engagement in the task.

Educational Culture Differences between East Asian and Western Countries

East Asian cultures, such as Korean, Japanese, and Chinese cultures, may be described as interdependent. Concepts related to interdependence such as social harmony, duty to groups, adjustment and fitting in, and sympathy have historically been salient in East Asian countries (Kitayama, Mesquita, & Karasawa, 2006). The impact of cultural affordance on educational cultures in these countries is related to students having the same educational opportunities. These Eastern countries employ a national standardized curriculum and examination (Byun, Schofer, & Kim, 2012). Mathematical formal instruction has been preferred to adopting a whole-class teaching approach (Leung, 2002). Because of the standardized educational system, extrinsic motivation has assumed a more important position with respect to the success of students' mathematical learning (Leung, 2001). For example, the examination has traditionally been regarded as a legitimate source of motivation for student learning in East Asian countries. East Asian education systems are characterized by highly competitive examinations. This is already a well-known phenomenon (Leung, 2001, 2002) because it is considered the only means to enter a postsecondary-level school, which is also related to students' future success. Because of the importance of the examination, mathematics instruction has been oriented to encourage a focus on effort in competitive settings. East Asian countries have emphasized effort-based learning, regardless of the individual student's interest in mathematical tasks (Hess & Azuma, 1991; Kang, Scharmann, Kang, & Noh, 2010; Schiefele, 1991). In East Asian cultures, enjoyment of mathematics is derived from having exerted concerted effort and achieving a deep knowledge of the subject matter (Holloway, 1988). In addition, East Asian countries generally regard humility as a virtue in society, and this is evident in mathematics classrooms. For example, students who were indoctrinated in East Asian cultures may be afraid to speak in front of their peers during mathematics class (Roebers, 1999). This is because students from these countries have been socialized since their youth to not be boastful.

In contrast, Western culture can be described as more independent and individualistic. Ideas related to independence such as personal achievement, pursuit of goals, free choice, and personal rights are highlighted in Western countries such as the U.S., Canada, and United Kingdom (U.K.) (Kitayama et al., 2006; Oyserman, Coon, & Kemmelmeier, 2002). These Western cultural affordances have produced educational cultures in these countries which prioritize interest-based learning (Hess & Azuma, 1991; Kang et al., 2010; Schiefele, 1991). Educators in Western countries assert that the most effective means of motivating students to learn mathematics is by increasing students' interest in what they are studying in the mathematics classroom (Kitayama et al., 2006; Schiefele, 1991; Leung, 2001). In fact, these students' interest in mathematics is positively correlated with their affective mathematics engagement (Schiefele, 1991). Likewise, intrinsic motivation has been valued more highly to ensure the success of students' mathematical learning (Leung, 2001). Extrinsic motivation is even regarded as harmful to learning in Western countries (Leung, 2002). In this motivational paradigm, it was assumed that an individual with intrinsic motivation was capable of changing features of the external learning environment (Kitayama, Markus, Matsumoto, & Norasakkunkit, 1997). Table 3 demonstrated educational culture differences between East Asian and Western countries by authors.

Table 3 Educational Culture Differences between East Asian and Western Countries by Authors.

Authors	East Asian Countries	Western Countries
Kitayama, Mesquita, & Karasawa (2006)	• Interdependent • Socially engaging	• Independent • Socially disengaging
Kitayama, Markus, Matsumoto, & Norasakkunkit (1997)	• Self-criticism • Interdependence • Collective process	• Self-enhancement • Independence • Individual process
Leung (2002)	• Product (content) • Rote learning • Studying hard • Extrinsic motivation • Whole-class teaching • Competence of teachers: Subject matter	• Process • Meaningful learning • Pleasurable learning • Intrinsic motivation • Individualized learning • Competence of teachers: Pedagogy

Students' affective mathematics engagement has a deeper cultural milieu. Students' cultural environments can evoke highly different sets of affective engagement in their mathematical learning process (Kitayama et al., 2006; Leung, 2006). Therefore, it is important to investigate students' affective mathematics engagement to understand whether their actual learning processes are successful. In addition, comparing different statuses of affective mathematics engagement from different cultures can help educators illuminate fruitful implications in many countries. The present study investigated how intrinsic and extrinsic motivation, which were intertwined and complicated by cultural milieu, impacted students' affective mathematics engagement. This has enabled us to associate the employed operational measure of motivation with the conceptual definition in the literature regarding the perceived reasons (intrinsic or extrinsic motivation) for affective mathematics engagement. For this investigation, I compared two different cultural affordances to explore the differences in students' affective mathematics engagement depending upon culture: East Asian culture and Western culture. Phase 1 was situated within the U.S. sample and provided theoretical support for the measurement of intrinsic and extrinsic motivation used for phase 2. For phase 2, two countries were selected to represent East Asian culture and Western culture: samples from Korea and the U.S. The research questions were the following:

Phase 1: Do intrinsic and extrinsic motivators impact affective mathematics engagement?

Phase 2: Do students differ in terms of (intrinsic and extrinsic) motivation in affective mathematics engagement (attitude, emotion, self-acknowledgement, and value) by country (Korea as opposed to U.S.)?

Phase 1

For phase 1, I tested the relationships between intrinsic and extrinsic motivation and affective mathematics engagement using cross-sectional design. Structural equation modeling (SEM) was used to analyze the data. The SEM provides more appropriate models which were theory based and more reasonable statistical assumptions (Blanthorne, Jones-Farmer, & Almer, 2006). This allows researchers to manifest inconsistencies with the measurement model by analyzing the model with overall fit, construct reliability, discriminant validity, or loads on a latent construct (Kline, 2005). In line with the theoretical assumptions, intrinsic and extrinsic motivation were classified as endogenous variables, while attitude, emotion, self-acknowledgement, and value were classified as exogenous variables.

Methodology

Participants

For phase 1, the sample size was 127. The theoretical model includes six measured variables and estimated nine paths. Sufficient sample size for SEM analysis was suggested 10 to 20 participants per estimated parameter (Kline, 2005). Based on this, a minimum of 10 × 9 = 90 participants was needed to test the model in this study. Therefore, my sample size was sufficient to provide robust results. This sample included two students in 7th grade, 13 in 8th grade, 11 in 9th grade, 15 in 10th grade, 74 in 11th grade, and 11 in 12th grade (missing = 1). The sample included 80 female students and 45 male students (missing = 2). In terms of ethnicity, the participants included 24 African-American, 18 Asian, 49 Caucasian, and 31 Hispanic students, with the remaining one student from the other ethnic background (missing = 4). These students were randomly selected with equally likely possibility of selection from a total population of 606 (gender, grades, and ethnicities).

Instruments

Two instruments were used for this study. To measure motivation, the Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich, Smith, Garcia, and McKeachie (1991) was administered. The instrument consisted of eight items within the two frameworks: four items for intrinsic motivation (Cronbach's α = .74) and four items for extrinsic motivation (Cronbach's α = .62). The items of the MSLQ are scored on a seven-point Likert-type scale, from 1 (not at all true of me) to 7 (very true of me).

The second instrument for this study was to measure affective mathematics engagement, the Measurement of Affective Mathematics Engagement (MAME) by Lee et al. (2019) was administered (see Appendix A). The instrument consisted of 37 items within the four frameworks: seven items for attitude, 11 items for emotion, seven items for self-acknowledgement, and 12 items for value. The Cronbach's α was .91, and the construct validity was .89. Students were asked to indicate the extent of their agreement with each statement on a five-point Likert-type scale, from "This statement greatly represents how I felt in class today" to "This statement does not represent how I felt in class today" (scored from 5 to 1).

Analysis

Stata 15.1 was used for the analyses in this study. To test the theoretical model (see Figure 1), the structural equation modeling (SEM) technique was employed to estimate the fit of the hypothesized model that determined how students' motivation influenced their affective mathematics engagement. This tested whether endogenous variables (intrinsic motivation and extrinsic motivation) statistically significantly predicted the exogenous variables (attitude, emotion, self-acknowledgement, and value) based on the data from this study. Intrinsic motivation and extrinsic motivation were connected with a two-headed arrow. There were no missing data for SEM analysis, and measured variables were mean-centered. I used six measured variables and estimated nine paths for the theoretical model.

All fit indices were accounted for to determine whether the theoretical model fit the given data. Fit indices which were used for this study included the Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). Values greater than 0.90 for CFI are regarded as indicative of adequate model fit, although values approaching 0.95 are preferable. Values smaller than 0.08 for the RMSEA support respectively good model fit. Traditional fit indices (CFI, RMSEA) perform well under weighted least squares mean and variance adjusted (WLSMV) estimation (Beauducel & Herzberg, 2006). SRMR index is based on covariance residuals, which indicate the degree of difference that exists between the measured data and the model (Bentler, 1995). Values smaller than .08 for SRMR are regarded as a good fit of model (Hooper, Coughlan, & Mullen, 2008).

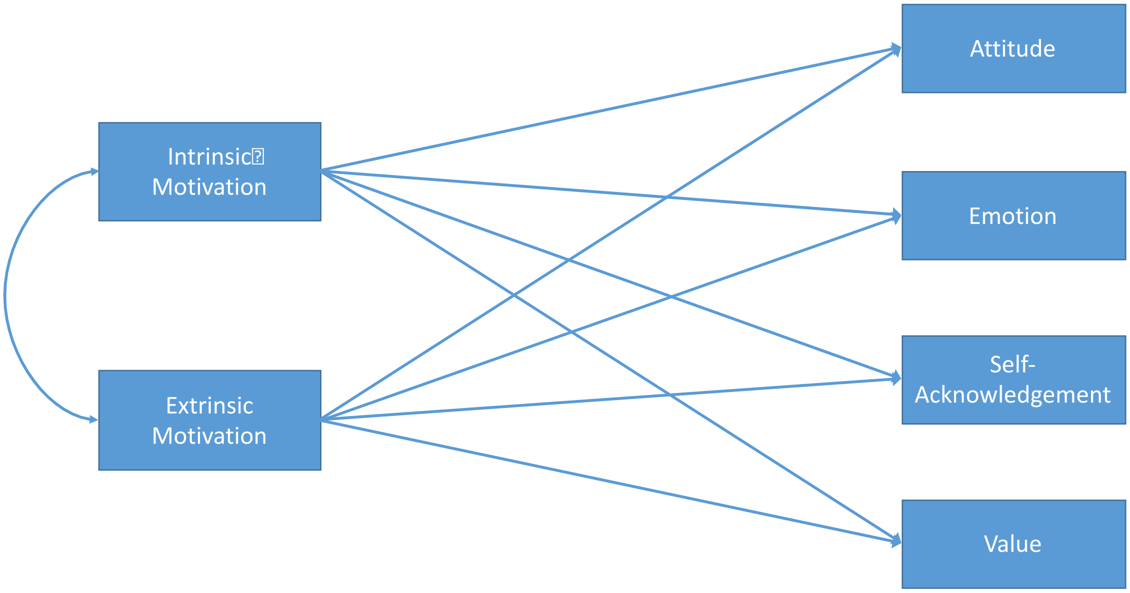

Figure 1 Theoretical model with measured variables and parameters.

Results

Preliminary analysis

In this study, students' motivation was categorized as either intrinsic motivation or extrinsic motivation. Students' affective mathematics engagement was classified into four components: attitude, emotion, self-acknowledgement, and value. Initially, descriptive statistics were conducted to determine means (*M*s) and standard deviations (*SD*s) of all of these six components (see Table 4). The results indicated that students' extrinsic motivation (*M* = 19.441, *SD* = 7.269) was higher than intrinsic motivation (*M* = 17.913, *SD* = 7.195). The comparison between the component of affective mathematics engagement should be conducted cautiously because the number of items of each component differed. Therefore, Table 4 indicates the ranges. The range encompasses the actual minimum and maximum scores for each component. This is reported because the scales of components and the number of items within each component differ. The range assists the reader in interpreting the reported means.

Table 4 Descriptive Statistics of Measured Variables.

Variables	***M***	***SD***	***Min***	***Max***	***95% CIs***
Intrinsic motivation	17.913	7.195	3	36	[16.650, 19.177]
Extrinsic motivation	19.441	7.269	4	36	[18.164, 20.717]
Attitude	24.480	6.051	7	63	[23.418, 25.543]
Emotion	32.677	9.018	12	99	[31.093, 34.261]
Self-acknowledgement	23.850	7.884	9	63	[22.466, 25.239]
Value	39.126	14.124	7	108	[36.466, 41.606]

Table 5 presents the correlations among the variables. Motivation components (intrinsic and extrinsic motivation) were statistically significantly and positively correlated to affective mathematics engagement components (attitude, emotion, self-acknowledgement, and value). The bivariate correlations can indicate the effect sizes associated with the key variables (Cohen 1988; King, McInerney, Ganotice, & Villarosa, 2015). The correlations between these variables were moderate or high, ranging from .582 to .821, $p < .001$. In particular, motivational subscales were mostly related to affective mathematics engagement subscales. These correlations appeared to adhere to the pattern expected based on theoretical expectations.

Table 5 Correlation Matric of All Components (Phase 1).

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
(1) Intrinsic Motivation	1					
(2) Extrinsic Motivation	.746**	1				
(3) Attitude	.608**	.655**	1			
(4) Emotion	.582**	.632**	.821**	1		
(5) Self-acknowledgement	.754**	.694**	.712**	.722**	1	
(6) Value	.762**	.753**	.600**	.709**	.778**	1

Note. **$p < .001$.

Structural equation modeling

The goodness-of-fit indices for the hypothesized model indicated a good fit with the data. According to *t*-rule, the number of estimated parameters (= 15) for this SEM analysis smaller than half the number of measured variables multiplied by the number of measured variables plus 1 $\left(\frac{n(n+1)}{2} = \frac{6\times7}{2} = 21\right)$. This model was identified (Bollen, 1989). The chi-square test results were $\chi^2 = 1.922$, $df = 1$, $p = .166$, which indicated a good fit. The value of RMSEA was .085, which indicated a relatively moderate fit of model that was exceptionally close to being a good fit. Both CFI (= .998) and SRMR (= .018) values suggested a good fit. The explained variance (R^2 = 1 - ‘error variance’) of attitude was R^2 = .461, emotion was R^2 = .427, self-acknowledgement was R^2 = .608, and value was R^2 = .657 (by intrinsic and extrinsic motivation). Intrinsic and extrinsic motivation were allowed to be freely correlated. Error terms for affective mathematics engagement were allowed to be correlated with each other due to the high modification index found. When the modification indices were run, all of the modification indices were less than 3.841, which suggested no changes in the covariance of error terms. Therefore, the model fit the data, and there were no specific sources indicating a lack of fit in this model.

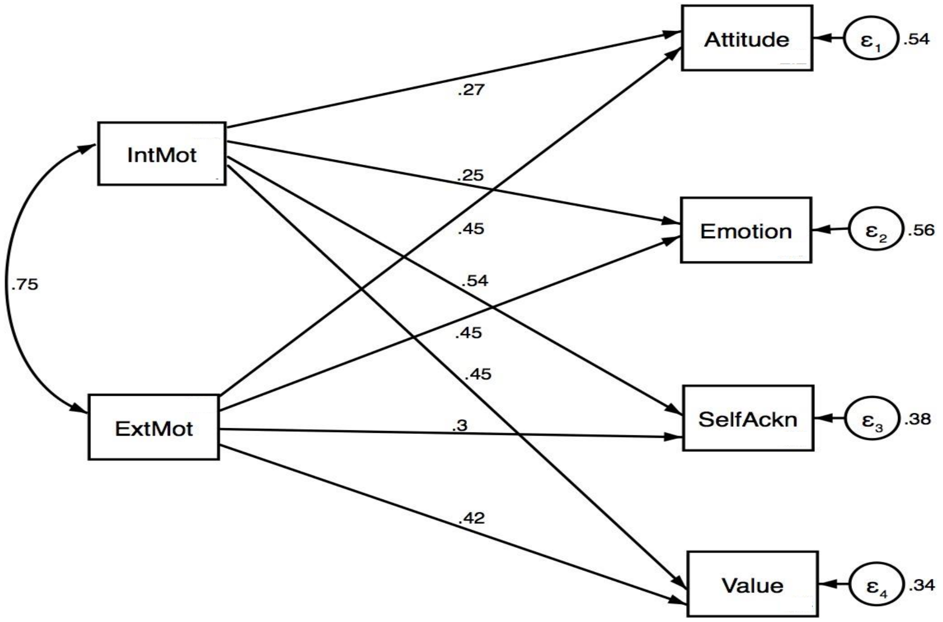

Figure 2 Standardized parameter values of the model. Motivation and affective engagement model results. Note. IntMot=Intrinsic motivation; ExtMot=Extrinsic motivation; SelfAckn=Self-Acknowledgement. All paths are statistically significant (*p* < .05).

Figure 2 illustrates the results of the reciprocal effects SEM. The standardized robust maximum likelihood parameter was estimated. The error variance (i.e., residual variance component) indicates the degree of unexplained variance. All loading (path coefficients) estimates were statistically significant, supporting the relationships between the measured variables. There were statistically significant relationships between endogenous variables (intrinsic and extrinsic motivation) and exogenous variables (attitude, emotion, self-acknowledgement, and value) ($p < .05$), and each path was positively estimated, as indicated in Figure 2. In particular, attitude and emotion were explained more effectively by extrinsic motivation (attitude: $\beta = .454$, $p < .001$, emotion: $\beta = .446$, $p < .001$) than intrinsic motivation (attitude: $\beta = .269$, $p < .05$, emotion: $\beta = .246$, $p < .05$), while self-acknowledgement and value were better explained by intrinsic motivation (self-acknowledgement: $\beta = .532$, $p < .001$, value: $\beta = .450$, $p < .001$) than extrinsic motivation (self-acknowledgement: $\beta = .298$, $p < .001$, value: $\beta = .417$, $p < .001$). For example, on average, one standard deviation increase in intrinsic motivation would result in a .532 standard deviation increase in self-acknowledgement; conversely, on average, one standard deviation increase in extrinsic motivation would result in only a .298 standard deviation increase in self-acknowledgement. The results of this analysis demonstrate a strong relationship between motivation and affective mathematics engagement. The hypothesis was confirmed by these results: Motivation positively predicted affective mathematics engagement. In particular, intrinsic motivation and extrinsic motivation statistically positively predicted attitude, emotion, self-acknowledgement, and value. Table 6 presents the estimation, significance, and relationships to variables of each path in the hypothesized model.

Table 6 Standardized Parameter Estimates, Standard Errors, *Z*-values, and *P*-values.

Variables		**Standardized Coefficient**	***SE***	***z***	***p***
Attitude on	Intrinsic Motivation	.269	.094	2.79	.005
	Extrinsic Motivation	.454	.093	4.86	<.001
Emotion on	Intrinsic Motivation	.249	.100	2.50	.012
	Extrinsic Motivation	.446	.096	4.62	<.001
Self-acknowledgement on	Intrinsic Motivation	.532	.079	6.77	<.001
	Extrinsic Motivation	.298	.082	3.62	<.001
Value on	Intrinsic Motivation	.450	.075	5.99	<.001
	Extrinsic Motivation	.417	.076	5.51	<.001

Another model was tested to investigate if there was a better model fit between motivation and affective mathematics engagement. This model included motivation (combination of intrinsic and extrinsic motivation) as one endogenous variable and four components of affective mathematics engagement (attitude, emotion, self-acknowledgement, and value). The results of model fit test did not indicate a good model fit. The CFI value was .884, and the SRMR value was .082, which indicated moderate fit. However, the chi-square test results were $\chi^2 = 56.320$, $df = 6$, $p < .001$, and the value of RMSEA was .267, which indicated that the data did not fit the model. This result supports the theoretical separation of intrinsic motivation and extrinsic motivation.

Discussion of Phase1

In phase 1, I examined the effects of motivation on affective mathematics engagement, particularly the paths through intrinsic motivation and extrinsic motivation to attitude, emotion, self-acknowledgement, and value. The results from the SEM analysis suggest that affective mathematics engagement variables were directly correlated with motivation variables. In the hypothesized model, attitude and emotion were more thoroughly explained by extrinsic motivation than intrinsic motivation, while self-acknowledgement and value were better explained by intrinsic motivation than extrinsic motivation. This suggests that students' motivation is associated with affective mathematics engagement. In line with the hypotheses, students with high motivation are also more likely to report being affectively engaged in mathematics.

In particular, distinguishing between intrinsic motivation and extrinsic motivation for this study provides a deeper and more detailed understanding and implication about the relationships between students' motivation and affective mathematics engagement. In fact, model fit using motivation (combination of intrinsic and extrinsic motivation) as one endogenous variable and four components of affective mathematics engagement did not indicate a good model fit. This result supports the theoretical separation of intrinsic motivation and extrinsic motivation.

The positive relationship between students' intrinsic motivation and their learning engagement has been supported by several researchers (e.g., Cokley, Bernard, Cunningham, & Motoike, 2001; Fan & Williams, 2010; Moneta & Siu, 2002). Students with high intrinsic motivation are likely to notice the importance of learning and understanding mathematical concepts, which encourages them to deeply engage in their learning process. For example, students who believe that the mathematical concept they are learning is important for personal reasons might be more focused on the mathematical learning situation they are engaging in. The intrinsically motivated students enjoyed mathematics activities and learning itself, so they are likely to have high engagement in terms of self-acknowledgement, which encompasses feelings about mathematical cognition (DeBellis & Goldin, 2006; Furinghetti & Morselli, 2007) and value, which refers to students' capacity to identify and understand the role that mathematics played (Bishop, 2008). Therefore, students' positive experience in mathematical learning process based on intrinsic motivation encourages them to improve their affective mathematics engagement.

Some researchers implicitly assume that extrinsic motivation cannot positively influence students' affective mathematics engagement (e.g., Jang, 2008; Joussemet, Koestner, Lekes, & Landry, 2005). The results of the present study and prior research supporting these results (e.g., Lee et al., 2018; Saeed & Zyngier, 2012) have indicated that extrinsic motivation fosters positive affective mathematics engagement. In particular, extrinsically motivated students care about receiving rewards or avoiding punishment based on their engagement (Eccles & Wigfield, 2002; Walker et al., 2006); therefore, they are likely to mediate attitude and emotion regarding mathematics during their learning process. This is because they understand that if they can fully engage by harboring positive attitudes and emotions toward mathematical learning situations; they understand that this may enable them to academically achieve in their mathematics classroom and eventually in their future careers. For example, some items about attitude in the affective mathematics engagement survey are related to the relationship with peers or teachers during mathematics activity. Students with high extrinsic motivation might demonstrate that they attempted to have a good relationship with others or avoid a conflict with others when they were communicating during mathematics classes. This might be because their negative attitude could impact their reputation, reward, or punishment.

In summary, intrinsic motivation and extrinsic motivation are important variables that can increase students' affective mathematics engagement. This suggests that educators and stakeholders must focus on students' development of mathematical motivation. If students formulate positive motivation in society, home, and schools, then their positive affective mathematics engagement also will be increased. This positive affective mathematics engagement can influence students' academic performance, achievement, and eventually their future major and career choices.

The results from this study suggest that in countries where students are likely to experience intrinsic motivation, students may also experience greater self-acknowledge and value. However, in countries where students are more likely to experience extrinsic motivation, they may experience greater attitude and emotion toward mathematics. According to the literature review, students in East Asian countries exhibited relatively higher extrinsic motivation than intrinsic motivation, and students in Western countries displayed relatively higher intrinsic motivation than extrinsic motivation (e.g., Kitayama et al., 1997, 2006; Leung, 2001, 2006; Schiefele, 1991). Therefore, students in East

Asian countries may exhibit relatively higher attitude and emotion, and students in Western countries may express relatively higher self-acknowledgement and value. Phase 2 explores whether these hypotheses could be supported through empirical study.

Phase 2

The results of phase 1 indicated the strong relationship between motivation and affective mathematics engagement. Based on those results, in this phase, I explored the country-differences in terms of students' motivation and affective mathematics engagement. In particular, two countries were selected which represent two different cultures: Korea represents a sample of an East Asian country, and the U.S. represents a sample of a Western country.

Methodology

Participants

The sample consisted of 33 students in Korea and 30 students in the U.S (see Table 7 for demographics). The sample for students in Korea were collected from a high school (10th and 11th grade) in Seoul, Korea, whereas the sample for the students in the U.S. were selected by random sampling from 606 students who were from several schools in Texas. Gender distribution of the participants was composted of 18 male and 15 female students from Korea and 9 male and 21 female students from the U.S. respectively. In terms of ethnicity, the participants in Korea were all Asians, while the participants in the U.S. included 1 African-American, 19 Caucasian, 7 Hispanic, and no Asian students (missing = 1). East Asian countries have been viewed as ethnically homogenous societies (Kim, 2009). Therefore, the sample of Korea which was only consisting of Asian students in this study seemed reasonable.

Table 7 Demographics for Students Participating in the Phase.

		Korea	U.S.
Gender			
	Female	18	9
	Male	15	21
Grade			
	8th	-	2
	9th	-	6
	10th	13	5
	11th	20	5
	12th	-	10
	Missing	-	2
Ethnicity			
	African-American	-	1
	Asian	33	-
	Caucasian	-	19
	Hispanic	-	7
	Missing	-	1
Total		33 (100%)	30 (100%)

Instruments

Students' motivation and affective mathematics engagement were measured with the same instruments as those used in phase 1. Participants were asked to answer the MSLQ on a seven-point Likert scale (1= "not at all true of me" to 7= "very true of me") for assessing their motivation; the MAME (see Appendix A) used a five-point Likert scale (1= "This statement does not represent how I felt in class today", 5= "This statement greatly represents how I felt in class today"). Note that all of the questionnaires used for this study were originally developed in English. These were translated into Korean for the participants in Korea. The back-translation method ensured the standardization of questions. Participants were asked to assess their affective engagement in mathematics in the middle of the semester. The survey required 10 to 15 minutes to complete.

Analysis

SPSS 24 was used for statistical analyses. To determine the mean differences in students' affective mathematics engagement between Korea and the U.S., independent *t*-tests were used. Descriptive statistics including Hedges' *g* effect sizes were reported. Because Hedges' *g* was chosen because it provides a more conservative estimate of the effect; however, that correction becomes smaller as the sample size increases (Fritz, Morris, & Richler, 2012).

Results

Descriptive statistics of the performance of students in Korea and the U.S were presented in Table 8. Both include means, standard deviations (*SD*), and 95% confidence intervals (CIs) (lower and upper limits). In addition, the range of scores, which were the actual minimum and maximum scores for each framework, were reported because the number of items within each subscale differs.

Table 8 Descriptive Statistics, and t-value in Subscales of Motivation and Affective Mathematics Engagement.

Framework	Korea			U.S.			Range		*t*-value (*$p<.05$, **$p<.001$)
	Mean	***SD***	***95% CIs***	***Mean***	***SD***	***95% CIs***	***Min***	***Max***	
Intrinsic Motivation	11.121	3.594	[9.895, 12.347]	24.200	3.488	[22.952, 25.448]	5	28	-14.628**
Extrinsic Motivation	21.667	4.392	[20.169, 23.165]	18.767	5.437	[16.821, 20.713]	7	28	2.338*
Attitude	25.733	3.991	[24.411, 27.135]	24.576	4.078	[23.117, 26.035]	16	34	1.137
Emotion	34.800	6.494	[32.584, 37.016]	30.333	7.330	[27.710, 32.956]	11	51	2.550*
Self-Acknowledgement	22.091	4.397	[20.591, 23.591]	29.800	6.494	[27.276, 32.124]	14	36	-6.779**
Value	35.455	8.584	[32.526, 38.384]	42.567	8.024	[39.696, 45.438]	16	59	-3.223**

Independent *t*-tests were conducted using scores of subscales of students' motivation and affective mathematics engagement in Korea and the U.S. to examine whether there were statistically significant mean differences between students in these two countries. Results from the analysis revealed that the difference between Korea and the U.S in terms of intrinsic motivation was statistically significant (t = -14.628, df = 61, $p < .001$). The mean of students in the U.S. was higher than the mean of students in Korea, indicating that students in the U.S. had more intrinsic motivation than those in Korea. The Hedges' g effect size for this difference was 3.645. Furthermore, the difference in extrinsic motivation between Korea and the U.S was also statistically significant (t = 2.338, df = 61, $p < .001$). The mean of students in Korea was higher than the mean among students in the U.S, indicating that students in Korea possessed more extrinsic motivation than those in the U.S. The Hedges' g effect size for this difference was .583. The results of these analyses suggest that the students in Korea harbored more extrinsic motivation, while the students in the U.S. had more intrinsic motivation. Figure 3 represents the means and 95% CIs of intrinsic and extrinsic motivation in Korea and the U.S.

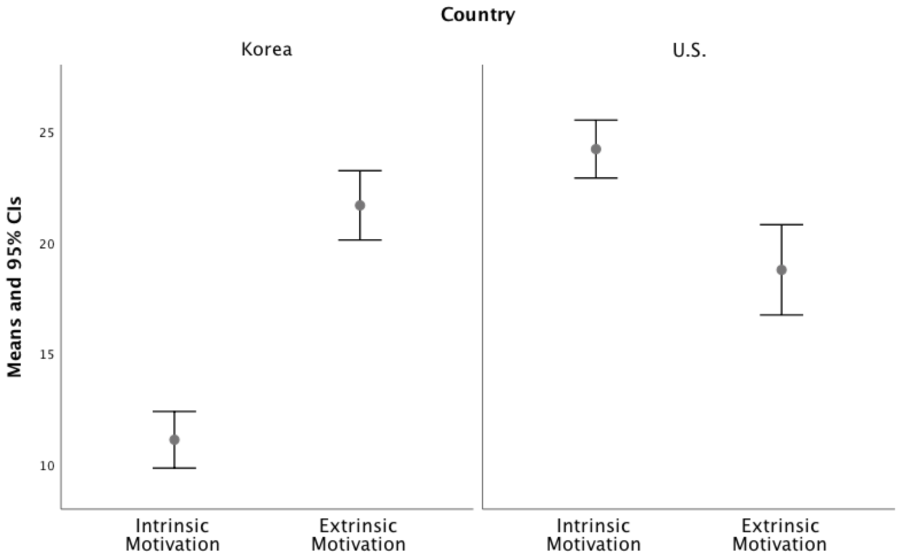

Figure 3 Intrinsic motivation and extrinsic motivation in Korea and the U.S.

Affective mathematics engagement was disaggregated by frameworks such as attitude, emotion, self-acknowledgement, and value (see Figure 4). The means of the students in Korea were higher than the means among the students in the U.S. on attitude (t = 1.137, df = 61), but this was not statistically significant (p = .260). The mean of the students in Korea was statistically significantly higher than the mean of the students in the U.S. regarding emotion (t = 2.550, df = 61, p < .05). The Hedges' g effect sizes were .283 for attitude and .637 for emotion. The means for self-acknowledgement (t = -6.779, df = 61, p < .001) and value (t = -3.223, df = 61, p < .001) were higher for the students in the U.S. than for students in Korea. The Hedges' g effect sizes were 1.372 for self-acknowledgment and .844 for value.

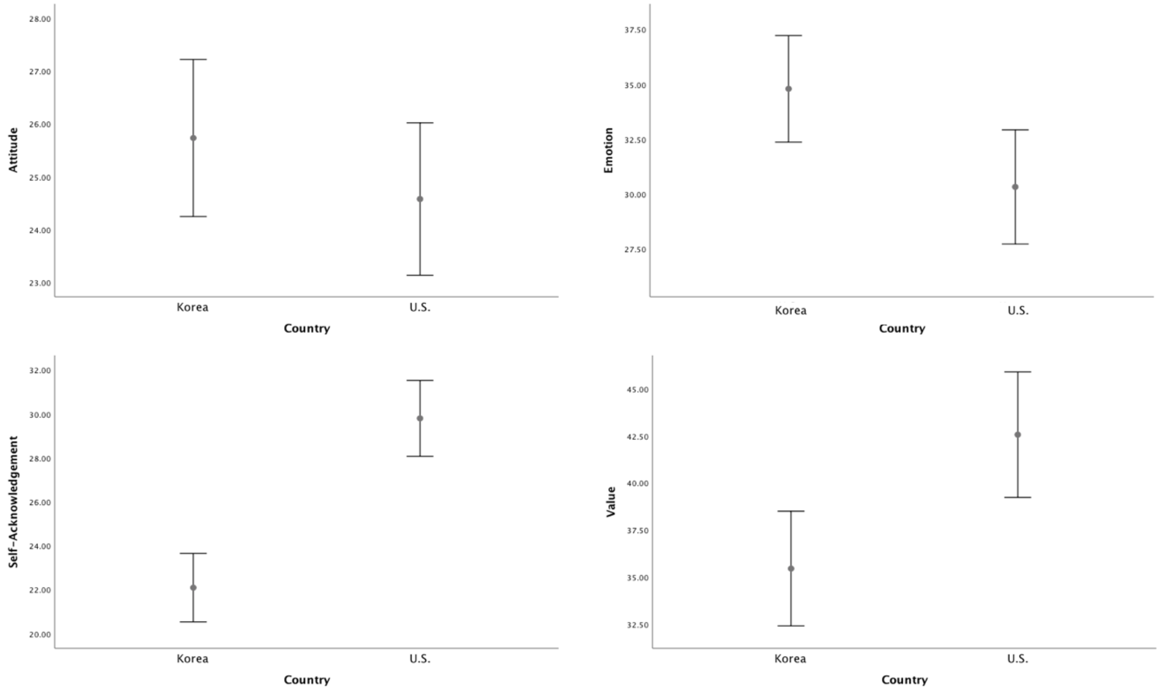

Figure 4 Means and 95% confidence intervals of attitude, emotion, self-acknowledgement, and value in Korea and the U.S.

Discussion of Phase 2

In phase 2, the differences in students' motivation to learn mathematics and affective mathematics engagement by countries (Korea vs U.S.) were calculated. The results of this study revealed that students in Korea exhibited more extrinsic motivation in mathematics than those in the U.S., while the students in the U.S. displayed more intrinsic motivation in mathematics than those in Korea. In addition, students in Korea demonstrated more positive mathematical attitude and emotion than students in the U.S., while students in the U.S. exhibited more positive mathematical self-acknowledgement and value than students in Korea.

Country differences in terms of intrinsic and extrinsic motivation and their relationships with affective mathematics engagement are supported in much of the literature. The standardized educational system in Korea causes teachers to prefer to implement traditional instruction (Byun et al., 2012; Leung, 2002). These characteristics of the Korean education system encourage students' motivation to focus on their academic outcomes, such as test scores, college entrance exams, and extrinsic rewards. The success of learning in mathematics has assumed a more important position, which was represented in extrinsic motivation. The traditional instruction is intended to provide highly structured, teacher-centered instruction (Ewing, 2011). Therefore, students may focus more on the outcome of their learning process rather than the process itself and may have felt less pressure during their learning process (Lee et al., 2019). Therefore, students in non-STEM PBL instruction (i.e., traditional instruction) may experience less stress during their learning process, which has been demonstrated to result in relatively positive attitude and emotion.

Based on to the higher extrinsic motivation of students in Korea, they are more encouraged by the rewards for their success in mathematical learning rather than the interest or enjoyment of mathematical learning itself. They are even likely to suppress their intrinsic motivation to learn mathematics (Lin, McKeachie, & Kim, 2003). For example, although the students enjoyed mathematics classes and implementing collaborative mathematics learning, they attempted to avoid engagement if they believe that the activity requires more time to learn mathematical concepts through traditional instruction. The traditional instruction has typically been shown to be more effective for learning mathematical concepts that are necessary for passing a test or demonstrating rote knowledge. Extrinsically motivated students may say "I cannot afford to get interested in this course because I have to get a good grade." (Lin et al., 2003). In this case, it is possible that affective mathematics engagement indicated from the students is pseudo engagement.

Students in the U.S. place a greater value on intrinsic motivation. Teaching and learning in mathematics classes in the U.S. are more student-centric than traditional, teacher-centered instruction; therefore, students can enjoy their mathematical learning. It was assumed that this interest-based learning is a crucial for students' success in their mathematical learning (Hess & Azuma, 1991; Kang et al., 2010; Kitayama et al., 2006; Schiefele, 1991; Leung, 2001). Focusing on the learning process itself and student-centered instruction encourages students to focus on the mathematical learning process. By focusing on their own interest and being intrinsically motivated, students may enjoy the exploration of mathematical concepts. Therefore, intrinsic motivation may cause students to increase their mathematical self-acknowledgement and value.

The mean difference between Korea and the U.S. in terms of mathematics attitudes was not statistically significant. One possible reason is a measurement error. The Cronbach's α reliability of the items of attitude is .57, which is relatively not large. When reliability decreases, the measurement error increases (Wells & Wollack, 2003). And this makes statistical significance of a study (p-value) increases (Jacobson, Roberts, Berns, & McGlinchey, 1999). Although the t-test result showed non-statistically significance, there was an apparent difference between the two countries in terms of attitude through Figure 4 and the result of Hedges' g (= .283), even though the difference is small.

Conclusion

Cultural differences account for important variation in students' perceptions of motivation and affective mathematics engagement. The findings of phase 1 and phase 2 provide supporting evidence that the instructional environment present in East Asian culture and Western culture have influenced both motivation and affective mathematics engagement. The results of phase 1 indicate that intrinsic motivation effectively explains students' self-acknowledgement and value, and the results of phase 2 support these findings because students in the U.S. show higher intrinsic motivation, exhibit higher self-acknowledgement, and value as compared to students in Korea. In addition, the results of phase 1 indicate that extrinsic motivation effectively explains students' attitudes and emotions, and the results of phase 2 support this by analyzing why students in Korea who have higher extrinsic motivation display higher attitude and emotion relative to the students in the U.S. Students in Korea were influenced by extrinsic motivation factors.

According to the results of the present study, it is clear that motivation and affective mathematics engagement are not isolated but dynamically interrelated within the student. This conceptual clarity through the assessment of students' motivation and affective mathematics engagement allowed an enhanced understanding of students' learning situations rather than investigating single components. While the components of motivation and affective mathematics engagement have been studied independently, it is unknown how these components combine or interact in determining students' academic performance. In particular, applying both theoretical (phase 1) and empirical (phase 2) studies, it becomes possible to determine when motivation will produce affective mathematics engagement consequences. This study also allows comparison between the impact of intrinsic and extrinsic motivation based on cultural affordance on various types of affective mathematics engagement (attitude, emotion, self-acknowledgement, and value).

The results of this study suggest the importance of considering relationships when generalizing about the effects of different motivations on affective mathematics engagement. Although motivation is based on cultural backgrounds, it is activated by cues in the current environment (Lin et al., 2003). Therefore, the important educational questions for future study is how we can overcome educational paradigms situated in countries. For example, by sharing educational learning context across countries, this provides opportunities for students in Korea to be exposed to intrinsic motivation through student-centered instruction. And this may positively impact students' positive self-acknowledgement and value toward mathematical learning. Students in the U.S. may benefit from increased emphasis on mathematical proficiency. These findings provide the context for unpacking the different learning opportunities, students' learning experience across to international learning environment.

CHAPTER IV

AFFECTIVE MATHEMATICS ENGAGEMENT: A COMPARISON OF STEM PBL VERSUS NON-STEM PBL INSTRUCTION*

Overview

The integration of Science, Technology, Engineering, and Mathematics Project-Based Learning (STEM PBL) into educational curriculum has received much attention because of its strength in improving students' affective engagement. We designed the present study to investigate the effectiveness of STEM PBL lessons on 9th grade students' development of affective mathematics engagement. The affective mathematics engagement of two groups of participants (STEM PBL and non-STEM PBL) were compared (N = 147). The results showed group differences in STEM PBL vs. non-STEM PBL lessons was statistically significant (t = 5.587, p < .001, d = *.960*). In particular, STEM PBL students had greater positive affective mathematics engagement in terms of mathematical self-acknowledgement and value as compared to the non-STEM PBL students. The results of the study indicate that highly situated and integrated instruction has a positive impact on students' perceptions of their affective mathematics engagement.

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Introduction

The interdisciplinary fusion of STEM disciplines has received a great deal of attention in the 21st century. The aim to supply a STEM proficient workforce to fill positions in the growing STEM-related job market has become a critical objective of the U.S. in ensuring its role as a global economic and scientific leader (PCAST, 2010). The U.S. has been focusing on developing a strong research base in STEM education to identify strategies and practices that could lead to improved STEM-related learning outcomes among U.S. students (Banning & Folkestad, 2012). Because success in STEM-related subjects typically nurtures motivation to pursue STEM-related careers, traditional instruction[1] is receiving less emphasis in U.S. classrooms while newer methods that require integrated knowledge in applied settings are being emphasized (Guthrie, Wigfield, & VonSecker, 2000). One such approach is STEM Project-Based Learning (STEM PBL), which is emerging as an effective strategy for teaching and learning that improves students' affective engagement (Liu, Hsieh, Cho, & Schallert, 2006).

In particular, it is important to focus on secondary education because students' affective engagement in STEM disciplines serves as a necessary prerequisite in pursuing

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[1] In the present study, we considered traditional instruction to be instruction that consists of a typical lesson progression of "explanation plus output practices that move learners from mechanical to communicative drills" (VanPatten, 1993, p. 54). We provide additional details about traditional instruction under the subheading titled 'STEM PBL vs. non-STEM PBL'.

a STEM major (Dawis, 2002). In many mathematics classrooms, the instructional content has transformed from that with a mathematics focus to that based on a STEM-oriented instructional model (English, 2015). Because more schools are becoming increasingly STEM-focused and adopting STEM instructional strategies (e.g., Bicer et al., 2015; Honey, Pearson, & Schweingruber, 2014) it is important to understand how these strategies influence affective mathematics engagement. Therefore, the purpose of the present study was to compare the impact of STEM PBL instruction versus traditional mathematics instruction (non-STEM PBL) on 9th grade students' affective mathematics engagement. This exploration could provide insights that influence the content and instructional approaches used in future mathematics classrooms as the emphasis on STEM continues to grow.

Affective Mathematics Engagement

Students' affective mathematics engagement has frequently been referred to as the situational affective state students enter during teaching-learning mathematics activities (Wang & Degol, 2014). The concept of affective engagement is based on that of affect, which is the socio-emotional, non-situational state represented by the collective range of feelings related to learning (McLeod, 1988). In other words, affective engagement is a situational state, bound by time and environment, related to an individual's overall non-situational affect toward a subject. For instance, a student who says, "I don't like math", may be expressing negative affect toward mathematics. However, the same student may experience positive affective mathematics engagement while completing a particular mathematics learning activity. Furthermore, students' affective engagement can considerably influence their overall affect toward a discipline (Linnenbrink, 2007). Given the nuanced nature of the relationship between students' affect toward mathematics and their affective mathematics engagement, it is critical to examine the underlying socio-emotional variables that can influence both.

Researchers have linked students' affect in mathematics education with socio-emotional variables that have been shown to influence student academic performance. For instance, in the 1960s and 1970s, studies regarding mathematical affect focused on anxiety and attitude toward mathematics (Zan et al., 2006). In the 1970s and 1980s, the concept of mathematics belief gained traction, and this interest in belief was influenced by the theories of cognitive science (Chen & Leung, 2015). In the new millennium, Debillis and Glodin (2006) defined these components of affect: (1) attitude is tendency toward certain sets of emotional feelings in particular contexts, (2) emotion is a rapidly changing state of feeling during an activity, (3) value, including ethics and morals, is characterized as personal truth or commitment, and 4) belief is the attribution of external truth and validity toward concepts or cognitive configurations. Many researchers have considered these four components as the primary factors of both mathematical affect and affective mathematics engagement.

However, while the four components align well with mathematical affect, affective mathematics engagement is a situational state rather than a non-situational state. Therefore, the presence of belief, which is relatively stable and difficult to change in a short-term and situational status (Champagne et al., 1982; Kember, 2009; Pajares, 1992; Skogen, 2012), suggests a lack of theoretical foundation for affective mathematics engagement. In addition, a growing number of researchers have suggested that affect toward cognition (e.g., mathematical self-acknowledgement) should be added as one of the key components of the affective mathematics engagement framework (Debellis & Goldin, 2006; Mandler, 1989; McLeod, 1988, 1991; Zan et al., 2006). Therefore, in the present study, we constructed an affective mathematics engagement framework in which we removed belief and included mathematical self-acknowledgement (see Figure 5).

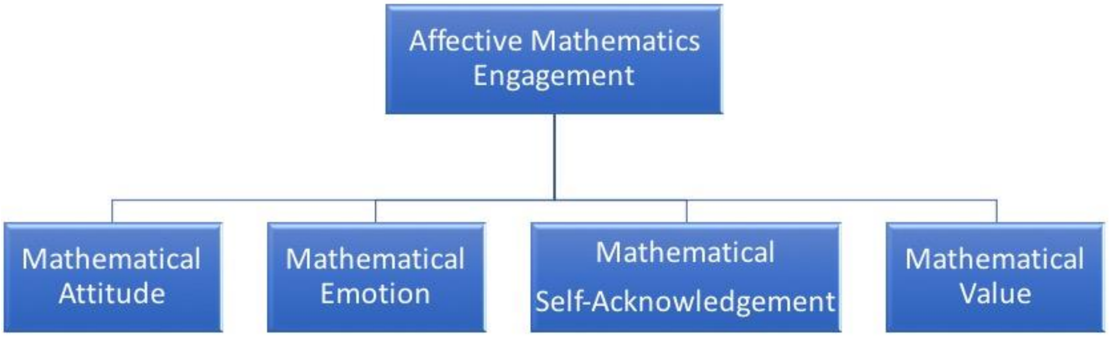

Figure 5 A theoretical framework of mathematical affective mathematics engagement.

Rationale for omitting belief

Belief has long been considered part of the affective engagement theoretical framework (Strike & Posner, 1985), and the importance of belief cannot be overemphasized in the learning of mathematics (Pajares, 1992). In fact, belief structures are often considered important predictors of academic success and failure (Hart, 1989). When belief is aligned with expected learning outcomes, typically, the outcomes become more positive. This convergent alignment of beliefs and academic success has been supported in the literature of mathematics education (McLeod, 1991). However, belief is often considered unlikely to change (Champagne et al., 1982; Kember, 2009; Pajares, 1992). In contrast, affective mathematics engagement itself is unstable, short-term, and situational (Goldin, 2002; Linnenbrink, 2007). Therefore, students' affective mathematics can be estimated within a relatively short period. Because estimates of a robust trait (i.e., long-term and stable status, [Cattell & Scheier, 1961]) show little change over typically short experiences (1- to 3-month interventions), robust estimates can be considered traits. Estimates of belief structures across various subjects and samples show nearly unequivocal acceptance that belief is difficult to change (Skogen, 2012). The common understanding or acceptance within mathematics education that beliefs are stable and not highly susceptible to small changes in lesson format, design, or enactment, serves as a justification for eliminating the beliefs from the framework of the present study (Bruce & Flynn, 2013).

In fact, Goldin and his colleagues, who identified and defined the four components of affect, viewed beliefs as inherently stable (c.f., Debellis & Goldin, 2006; Goldin et al., 2011). They mentioned that “beliefs are characteristically woven into their [engagement structures'] fabric and influence their activation" (p. 547). Goldin et al. (2011) saw belief as a stable affective characteristic that influences the other intertwined strands of affective mathematics engagement. Because the purpose for this study was to measure variables anticipated to be highly susceptible to changes due to instruction, we did not retain the belief structure. The problem we encountered was that there was a factor previously omitted but both easily measured and highly susceptible to instruction: mathematical self-acknowledgement.

Rationale for including mathematical self-acknowledgement

Cognition is a sensory process that involves recognition, memory, feature identification, categorization, and psychological judgement (Zajonc, 1980, 1984). Many researchers (e.g., Haddock & Zanna, 1999; Jimerson, Campos, & Greif, 2003) have separated the concept of affective mathematics engagement and mathematical cognition, but these are highly correlated. That is, studies have shown that affective mathematics engagement and mathematical cognition influenced each other's process; affective reactions were considered expressions or manifestations of cognitive processes (Zajonc, 1980). Furthermore, affective mathematics engagement could not emerge without prior cognitive mediation (Lazarus, 1982). Additional findings have indicated that cognitive processing promoted students' openness to affective cues (Fuendeling, 1998) and that affective mathematics engagement led students to make more associations among ideas that could traverse diverse mental categorizations (Isen, 1987) and stimuli (Schwartz & Bohner, 1996). Activities that engaged students' cognitive process led to affective manifestations, and vice versa. Therefore, we added mathematical self-acknowledgment, which in the present study refers to a student's affect toward cognition, as a factor of affective mathematics engagement. Adding mathematical self-acknowledgement to our framework allows us to carefully analyze the items from the Rutgers Instrument for Mathematics Engagement (Goldin et al., 2011) that best align with this particular affective mathematics engagement component.

Mathematical self-acknowledgement has been defined as an individual's affective posture toward acknowledging his or her sufficiency/insufficiency of mathematical cognition (DeBellis & Goldin, 1997, 2006; Furinghetti & Morselli, 2007). One develops self-acknowledgement through a process of self-questioning in which he or she asks questions of “being” and “feeling” (Pajares & Schunk, 2002) related to a particular cognitive component; this process then influences his or her sense of competence related to the cognitive component (Bong & Skaalvik, 2003). For example, items that are typically used to assess students’ mathematical self-acknowledgement include “I am interested in [mathematical concept]”, and “[mathematical concept] is easy for me”. Self-acknowledgement is also formed in part through students’ experiences within a situational state and is influenced especially by environmental and societal reinforcements (Shavelson, Hubner, & Stanton, 1976). Mathematical self-acknowledgement leads students to recognize their feelings toward their mathematical understanding during the learning process, and this recognition of their own understanding influences their reaction. “One’s perceptions of himself are thought to influence the ways in which he acts, and his acts in turn influence the ways in which he perceives himself” (Shavelson et al., 1976, p. 411). Students’ academic performance can be impacted by the actions they take based on their self-perceptions, and self-acknowledgement influences both students’ self-perceptions and their actions (DeBellis & Goldin, 2006). Educational researchers have begun to recognize the importance of investigating self-acknowledgement in mathematics education due to its demonstrated benefits on student cognitive and academic development, but research related to self-acknowledgement is still very limited and therefore prevents one from being able to draw any firm construct.

The sociocultural context of learning has been suggested as an important component of affective mathematics engagement research (Goldin et al., 2011; Hart & Allexsaht-Snider, 1996; Zan et al., 2006). Results from prior studies have shown that students' social interactions were strongly linked to affect, leading to deeper engagement in learning situations (Goldin et al., 2011; Hannula, 2012). This enhanced engagement is due to the opportunity that students have to share emotions and attitudes across cultures and communicate their ideas (Greenwald & Banaji, 1995) and values within peer groups (Goldin, 2002). The social context allowed students to interact affectively, which has been credited with influencing their engagement. Teaching strategies in which student affective engagement is prioritized, such as PBL, could influence student academic performance as well (Shallcross, Spink, Stephenson, & Warwick, 2002).

STEM PBL vs. Non-STEM PBL

A new instructional model, STEM PBL, has been gaining interest among mathematics educators. The instructional model of STEM PBL is inherently student-centered. Implementation of this model allows teachers to utilize student-directed inquiry to help students understand and apply concepts. Conceptual understanding in this model is developed through the completion of ill-defined tasks in which students develop a product that has real-life applications (Johnson, & Lamb, 2007). Although the task itself is ill-defined, the outcome is well-defined (Bicer & Capraro, 2017; Capraro & Slough, 2013; Han, Rosli, Capraro, & Capraro, 2016; Slough & Milam, 2013). Lessons created using this instructional model require students to solve several problems, which when considered in their entirety, showcase student mastery of several concepts of various STEM subjects (Capraro & Slough, 2013). Furthermore, the activities enable students to demonstrate their understanding of how to apply STEM-related concepts in real-world problems (Han et al., 2016). Results from multiple studies have indicated the benefits of incorporating STEM PBL activities in classrooms. Researchers have shown that students in STEM PBL autonomously investigated problems when completing ill-defined tasks (Slough & Milam, 2013), collaborated with peers to identify problems (Ozel, 2013), displayed rigorous subject matter engagement (Capraro & Slough, 2013), and demonstrated extensive understanding of the material (Ozel, 2013). Such engagement in lesson content has been shown to have a positive influence on student mathematics achievement (Han, Capraro, & Capraro, 2015; Han et al., 2016; Navruz, Erdogan, Bicer, Capraro, & Capraro, 2014). In these studies, the impact of STEM PBL was multi-dimensional, affecting various academic skills that collectively improved student mathematics achievement.

STEM PBL, A special case of inquiry

The STEM PBL instructional model consists of inquiry-based tasks that help students develop understanding of important technological, social, and core curriculum content (Nastu, 2009). STEM PBL has also been considered as a unique case of inquiry-based learning (Slough & Milam, 2013, p. 13). Both inquiry-based learning and STEM PBL give students the opportunity to expose their own thinking through feedback, revision, and reflection with themselves, teachers, and other students (Slough & Milam, 2013). For instance, students in inquiry-based learning have been encouraged to develop content knowledge in their learning process by solving problems (Artigue & Blomhøj, 2013). However, the implementation of inquiry-based learning may vary to an extent within each STEM discipline. In one study, students engaged in inquiry-based learning embedded within a science education context and were encouraged to conduct a self-designed inquiry to find answers to their own scientifically oriented questions (van Uum, Verhoeff, & Peeters, 2016). The idea behind this self-guided inquiry is that students could develop their scientific knowledge through the process of "collecting evidence to test possible explanations and the ideas behind them in a scientific manner" (Artigue & Blomhøj, 2013, p. 801). In inquiry-based learning within mathematics education, students learn mathematical knowledge through exploring concepts and ideas while completing tasks and solving problems (Jaworski, 2008). The process of inquiry within mathematics education consists of elaborating questions, analyzing the data, reasoning, defining, and modeling mathematical understanding (Artigue & Blomhøj, 2013).

However, unlike inquiry-based learning, a foundational component of STEM PBL is ill-defined tasks, which involve students producing an artifact or product that is a solution to a real-life problem (Sahin, 2013). For this reason, STEM PBL has been called a "special case of inquiry" (Sahin, 2013, p. 59; Slough & Milam, 2013, p. 19). The inquiry-based aspect of STEM PBL maintains a critical balance between an emphasis on developing students' conceptual and procedural understanding when they solve ill-defined tasks.

Conceptual and procedural understanding in STEM PBL

The interplay between conceptual and procedural understanding become most evident during the STEM PBL activities. Conceptual understanding has been defined as “implicit or explicit understanding of the principles that govern a domain and of the interrelations between units of knowledge in a domain” (Rittle-Johnson, Siegler, & Alibali, 2001, pp. 346-347). In comparison, procedural understanding has been defined as “the skill in carrying out procedures flexibly, accurately, efficiently, and appropriately. It includes, but is not limited to, algorithms (the step-by-step routines needed to perform arithmetic operations” (Sireci et al., 2016, p. 9). Findings have indicated that the use of STEM PBL activities provides students with pedagogical context guidance throughout the learning process and helps them develop both conceptual and procedural understanding. For example, while completing an ill-defined task in mathematics, students explore diverse mathematical concepts and knowledge to identify appropriate solutions for the task; this process fosters their conceptual understanding of mathematics. Furthermore, the task prompts students to use their existing conceptual knowledge to guide their application of and improve their procedural knowledge. Proficient conceptual knowledge will increase the likelihood that the students will select an appropriate procedure to solve the problem, complete the ill-defined task, and achieve the well-defined outcome, thus enhancing their procedural understanding (Kollöffel & de Jong, 2013). In turn, reflecting on procedural understanding can help students become aware of what conceptual knowledge plays a key role in solving certain problems (Kollöffel & de Jong, 2013; Rittle-Johnson et al., 2001). Both conceptual and procedural understanding, which are developed through STEM PBL activities, are critical components that influence the competence and expertise of students in STEM-related disciplines (Kollöffel & de Jong, 2013; Streveler, Litzinger, Miller, & Steif, 2008).

Distinguishing STEM PBL lessons from other lessons is often easily achieved by determining whether a lesson has an ill-defined task and a well-defined outcome. Using an ill-defined task in STEM PBL lessons as opposed to a well-defined task in non-STEM PBL lessons is an early observable distinguishing characteristic at the onset of the activity (Capraro & Slough, 2013). Students in STEM PBL lessons encounter complex, flexible, and unstructured problems before instruction rather than after, as compared to non-STEM PBL lessons. Ill-defined tasks embrace learning by stimulating students to explore problems that they may confront in everyday life (Gallagher, Stepien, Sher, & Workman, 1995). The ill-defined task is a task that is under-described to allow students to use various strategies and approaches for addressing the task. In addition, STEM PBL lessons require teachers to arrange their classes in a way that all students must develop a product/solution. This well-defined outcome governs what the product or evidence of learning looks like and how the objectives are met. The alignment between the ill-defined task and well-defined outcome naturally supports authentic assessment techniques. There are three components of a well-defined outcome that teachers should take into account while arranging their classes (Sahin, 2013): (1) clear expectation about how students deliver their products at the end; (2) specification of constraints before students start working on their products, which leads students to make a product within the boundaries; (3) guidelines on how to assess what students learn as both a group and individually. These two characteristics, ill-defined task and well-defined outcome, clearly distinguish STEM PBL instruction from traditional instruction (Bicer, Capraro, & Capraro, 2013).

For the present study, the non-STEM PBL group received traditional instruction. Findings from previous research have indicated that students in non-STEM lessons demonstrated greater difficulty in developing a balanced understanding of both conceptual and procedural understanding when compared to the students in STEM PBL lessons (Kollöffel & de Jong, 2013). In general, the teachers who taught using traditional instruction controlled all classroom activities, and their students were mainly expected to develop conceptual understanding of problems. Further, students in the non-STEM PBL lessons had both less responsibility for their own learning and less control of the learning processes (Slough & Milam, 2013). This teacher-centered instruction discourages students from becoming autonomous learners. Furthermore, it has been found that non-STEM PBL lessons do not afford opportunities for students to actively engage in lessons, and lack of engagement may limit students' development of problem-solving skills (Tretten & Zachariou, 1995). This traditional instruction has been connected with several disadvantages for students in terms of their mathematical affect and affective mathematics engagement in science and mathematics (Johnson & Dasgupta, 2005). On the other hand, active learning and group work through STEM PBL activities have been shown to lead students to interact with instructors and each other (McKeaschie, 1999) and to work cooperatively to demonstrate mastery of objectives (National Council of Teachers of Mathematics [NCTM], 1991; National Research Council [NRC], 1996).

Two of the primary goals for STEM PBL are the development of affective mathematics engagement and the growth of student initiative in the learning process (Barron et al., 1998). The STEM PBL lessons could enhance students’ motivation for learning, as well as their interest, achievement, and persistence in learning (Honey et al., 2014). In particular, research has shown that students’ engagement with learning during STEM PBL activities positively impacted their affect toward whichever STEM content was the focus (Ketelhut, Nelson, Clarke, & Dede, 2010; Liu et al., 2006). In turn, students’ affective mathematics engagement influenced their post-secondary education choices (Watt, Eccles, & Durik, 2006) as well as their career choices (Capraro & Slough, 2013; Chen & Usher, 2013; Lent et al., 2010) with more students choosing post-secondary STEM opportunities. However, when students had little affective mathematics engagement for STEM subjects, they typically avoided careers that required a strong background in those subjects (Lent et al., 2005). Therefore, documenting students’ affective mathematics engagement during STEM PBL activities could play a pivotal role in understanding how STEM PBL instruction influences their affective mathematics engagement. We used the following two research questions to guide the present study:

1. Did students differ on affective mathematics engagement by involvement in STEM PBL versus non-STEM PBL lessons for mathematics learning?
2. How did student affective mathematics engagement in mathematical attitude, emotion, self-acknowledgement, and value vary by participation in STEM PBL and non-STEM PBL lessons?

Methodology

Participants

The participants were a diverse group of 9th grade students enrolled in separate urban, low socio-economic, Title I schools. The students (*N*=147) were divided into two groups that received different interventions. Fifty-one students (34.7%) were engaged in STEM PBL lessons, and the other 96 students (65.3%) were taught in a more traditional manner without STEM PBL lessons (see Table 9 for demographics).

Table 9 Demographics for Students Participating in the Study.

		STEM PBL lessons	non-STEM PBL lessons
Gender			
	Female	30 (58.8%)	51 (53.1%)
	Male	21 (41.2%)	45 (46.9%)
Ethnicity			
	Asian	6 (11.8%)	8 (8.3%)
	African- American	11 (21.6%)	27 (28.1%)
	Caucasian	14 (27.5%)	24 (38.5%)
	Hispanic	20 (39.2%)	37 (25.0%)
At-risk			
	Yes	10 (19.6%)	20 (20.8%)
	No	41 (80.4%)	76 (79.2%)

Intervention

The present study, we used a nonrandomized quasi-experimental design that had both a single treatment and control group. The design for this study could be represented as:

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NR     X      O
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NR            O
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The letter X indicated a treatment, and the letter O, the affective mathematics engagement measurement. The letters NR indicated that the group on that line was formed by nonrandom assignment. Two groups divided by a dashed line indicated that they were not common to each other (Shadish, Cook, & Campbell, 2002).

Students who participated in STEM PBL activities learned about rational numbers during the 9-week period. During this time, students received 32.25 hours of STEM PBL instruction. Primary components of the STEM PBL instruction included interdisciplinary content, collaborative knowledge construction, application of concepts, fostering learning through explicitly connecting knowledge across subjects, and fostering problem solving (Asghar, Ellington, Rice, Johnson, & Prime, 2012; Barron et al., 1998; Berry, Chalmers, & Chandra, 2012; Krajcik & Blumenfeld, 2006; Lou, Liu, Shih, & Tseng, 2011). The STEM PBL lesson covered Texas Essential Knowledge and Skills (TEKS, 2019) for Mathematics. In particular, the TEKS indicated that "Students use concepts, algorithms, and properties of rational numbers to explore mathematical relationships and to describe increasingly complex situations. Students use concepts of proportionality to explore, develop and communicate mathematical relationships" ("§111.26. Grade 6, Adopted 2012. (a) Introduction", para. 3).

The focus of the instruction was on the mathematics within a context that included science, technology, and engineering. The project was for students to measure seven different round objects, finding the circumference, diameter, and radius using a tape measure, compass, and/or protractor. Once students had measured the objects, they were to explore relationships among the measurements and express those relationships as fractions. Then students were expected to use that information to design and then build, using materials supplied by the teacher, to create a single case that would be able to hold and secure round objects. Students again used measurements and fractional parts to build the container. They were expected to use their computer tablets to begin and update their engineering design notebook, which included drawings from the task, annotated sketches with measurements, notes about attachment points, and lists of the materials used for attaching parts together. Once there was an admissible design, students used notebook paper to create and build a prototype. They made refinements based on their experiences with building the prototype and to refine their drawn design. Students were then expected to show their work for securing each of their objects in their own respective compartments within the single case and with all remainders expressed as fractional parts of an inch. Objects had to be secure regardless of their size and protected from being jostled or dropped in the case so the compartments had to be sized to each object. This required students to make choices among the materials provided and also ruled out notebook paper because it would not provide sufficient protection for the objects. Based on what students learned in their science class about properties of materials they were expected to select both suitable materials and designs that would protect the objects. Then, students developed their written procedures for building their case and the group was allowed to build and decorate their case. Then students developed a 30-second YouTube advertisement in which they described their case and identified the classes of objects that would fit in their case. During the STEM PBL activities, the students were encouraged to actively engage in group work, hands-on activities, completion of projects, and presentation of their learning, so that they could develop both conceptual and procedural understanding.

Students taught using non-STEM PBL lessons also learned about rational numbers (same content and objectives) and began their lessons 2 weeks later than those students who received the STEM PBL lessons. In total, they received 33.5 hours of traditional mathematics (non-STEM PBL) instruction. In non-STEM PBL lessons, students were exposed to the traditional format of learning, which was primarily lecture-based learning. Typical lesson development and delivery for the non-STEM PBL class was consistent across teachers and included the following: (1) bell work (a 5 minute warm-up of previous mathematics skills necessary for the lesson), (2) a description of the objective, (3) two or three demonstration problems completed by the teacher in front of the entire group, (4) individual practice on 2 to 3 problems where students were invited to either explain how they solved the problem or worked the problem on the board, and 5) finally, for the majority of class time students completed additional problems independently with the teacher circulating to answer individual questions.

Students in each group (STEM PBL and non-STEM PBL) were taught by different teachers. The teachers were offered free professional development (PD) and a stipend for their participation. The students in the STEM PBL group (*n* = 51) were taught by a teacher who worked in a STEM focused secondary-level school. In addition to participating in classroom observations and coaching, the teacher had completed 135 hours of PD over the course of three-year period prior to teaching participants in the present study including face-to-face, online, and summer intensive sessions. The PD focused on how to connect mathematics content knowledge and real-world situation and how to provide STEM PBL to students in mathematical teaching and learning instructions.

The students in the non-STEM PBL lessons (*n* = 96) were taught by a teacher who had received a stipend to participate in PD related to mathematics content knowledge dealing with rational numbers and algebra without a pedagogical component PD in rational numbers and algebra. The non-STEM PBL teacher had participated in 110 hours of PD, both face-to-face and online, over a two-year period prior to teaching participants in the present study. The PD focused on mathematical objectives that were typically low in the state of Texas. The focus was on utilizing mathematical content knowledge, sequencing the content, improving techniques for questioning, uncovering misconceptions, and using assessments for formative feedback.

Assessment

To measure affective mathematics engagement, the Measurement of Affective Mathematics Engagement (MAME) was administered (see Appendix A). I formulated subscales, which were affective mathematics engagement items based on the Rutgers Instrument for Mathematics Engagement (RUMESI) by Goldin et al. (2011). The formulated subscales were aligned to the theoretical framework of the present study, meaning that the items fell into categories corresponding to one of the four affective mathematics engagement components: mathematical attitude, mathematical emotion, mathematical self-acknowledgement, and mathematical value. For this study, nine structures were subsumed under the four-theoretical framework categories:

Mathematical Attitude included *Get the Job Done (GTJD)* and *Pseudo Engagement (PE)*; **Mathematical Emotion** included *Stay Out of Trouble (SOOT)* and *Don't Disrespect Me (DDM)*; **Mathematical Self-Acknowledgement** included *Check This Out (CTO)* and *I'm Really into This (IRIT)*; **Mathematical Value** included *Let Me Teach you (LMTY)* and *Look How Smart I Am (LHSIA).* Table 10 contains the description of the affective mathematics engagement framework subscales.

Table 10 Affective Mathematics Engagement Framework Objectives Subscales and Descriptions.

Framework	Subscales	Descriptions
Attitude	Get the Job Done (GTJD)	• Reaction to finishing an assigned mathematical task correctly following given instruction
	Pseudo Engagement (PE)	• Pretending to engage in the task while avoiding genuine participation
Emotion	Stay Out of Trouble (SOOT)	• Feeling a need or desire to avoid conflict with others, or negative affect
	Don't Disrespect Me (DDM)	• Perceiving challenges to one's mathematical identity
Self-Acknowledgement	Check This Out (CTO)	• Desire of reward for conveying/displaying understanding or achievement
	I'm Really into This (IRIT)	• Concentrating to achieve mathematical understanding or solve problems, or experiencing fascination for mathematics
Value	Let Me Teach You (LMTY)	• Awareness of an importance of helping others by sharing an idea or mathematical knowledge
	Look How Smart I Am (LHSIA)	• The belief that one is impressing others with mathematical knowledge or ability

A factor analysis was conducted using the 37 original items, and results of the analysis indicated four frameworks: 7 items for mathematical attitude (Cronbach's α =

.86), 11 items for mathematical emotion (Cronbach’s $\alpha = .83$), 7 items for mathematical self-acknowledgement (Cronbach’s $\alpha = .79$), and 12 items for mathematical value (Cronbach’s $\alpha = .89$) (see Appendix A for all items). To understand whether our instrument adapted from the RUMESI (Goldin et al., 2011) measured our intended variables, we estimated construct validity, which was determined to be .89.

Students were administered the survey instrument before and after each intervention period. The pre-test was provided right before starting the first day of the classroom instruction, and the post-test was provided immediately following the last day of the classroom instruction. Each administration was completed within 10-15 minutes. Students were asked to indicate the extent of their agreement with each statement, on a five-point scale from “This statement greatly represents how I felt in class today” to “This statement does not represent how I felt in class today” (scored from 5 to 1). The directions for the instrument were to think about your prior mathematics lesson and complete the items based on how you remember feeling.

The research in the present study was conducted and reported in a manner aligned with the American Educational Research Association guidelines (Duran et al., 2006) and the best reporting practices of the American Psychological Association (APA, 2010). The SPSS 24 was used for statistical analyses. To determine the mean differences of students’ affective mathematics engagement between STEM PBL and non-STEM PBL lessons, an independent *t*-test was used. Descriptive statistics including 95% Confidence Intervals (*CI*) and Cohen’s *d* effect sizes were reported.

Results

Descriptive statistics of the pre- and post-test performances are presented in Table 11. Both pre- and post-test performance data include means, standard deviations (*SD*), and range of scores (minimum and maximum). In addition, post-test comparisons include 95% confidence intervals (lower and upper limits), followed by the results for the research question. The total mean scores of the pre-test performance in terms of both STEM PBL and non-STEM PBL lessons were similar, but the total mean scores of the post-test performance had a gap between both lessons. In terms of the STEM PBL group, the total mean score of post-test performance (103.06) was higher than the total mean score of pre-test performance (91.80). In particular, the mean scores of mathematical self-acknowledgement and mathematical value for the STEM PBL group increased while the mean scores of mathematical attitude and mathematical emotion decreased. By comparison, the total score of post-test performance (91.66) was slightly lower than the total mean score of the pre-test performances (91.85) in terms of students who participated in non-STEM PBL lessons. The mean scores of mathematical attitude, mathematical self-acknowledgement, and mathematical value for the non-STEM PBL group increased while the mean score of mathematical emotion decreased. The growth of scores from pre- to post-test in STEM PBL lessons was higher than the growth in non-STEM PBL lessons.

Table 11 Mean, *SD*, 95% CI, and Range in Affective Mathematics Engagement Frameworks and Subscales.

Framework	STEM PBL lessons			non-STEM PBL lessons			Range	
	M	*SD*	95% CI	*M*	*SD*	95% CI	Min	Max
	Pre-Test Performances							
Attitude	20.63	4.67		21.07	4.52		7	35
Emotion	41.33	5.19		40.28	4.96		11	45
Self-Acknowledgement	10.11	3.66		10.14	3.88		7	33
Value	19.73	4.22		20.36	4.01		12	55
Total	91.80			91.85			59	131
Post-Test Comparisons								
Attitude	16.86	6.67	[14.99, 18.74]	22.44	6.70	[21.08, 23.79]	7	35
Emotion	23.73	6.92	[21.78, 25.67]	33.73	6.80	[32.35, 35.11]	11	45
Self-Acknowledgement	23.35	5.48	[21.81, 24.89]	13.66	5.18	[12.61, 14.71]	7	33
Value	39.12	7.67	[36.96, 41.27]	21.83	5.11	[20.80, 22.87]	12	55
Total	103.06		[99.61, 106.51]	91.66		[89.32, 93.99]	59	131

Note. The range is the actual minimum and maximum scores for each framework. This is reported because the number of items within each subscale differs; therefore, the range assists the reader in their interpretation of the reported means.

An independent *t*-test was conducted using the combined affective mathematics engagement scores from the STEM PBL and non-STEM PBL group to examine whether there were statistically significant mean differences between students in terms of STEM PBL and non-STEM PBL. Results from the analysis revealed that the difference between students' affective mathematics engagement by STEM PBL group and non-STEM PBL group was statistically significant ($t = 5.587$, $df = 145$, $p < .001$, see Figure 6). The mean of the STEM PBL group was higher than the mean of the non-STEM PBL group, indicating that students who received the STEM PBL lessons had more affective mathematics engagement than those who received the non-STEM PBL lessons. The Cohen's *d* effect size for this difference was 0.96, and the 95% confidence interval associated with this effect size was [0.61, 1.32].

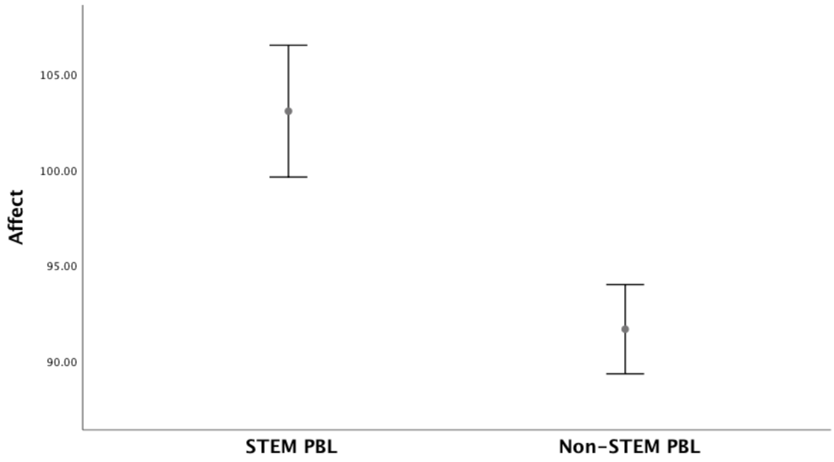

Figure 6 Affective mathematics engagement of composite scores of mathematical attitude, emotion, self-acknowledgement, and value by STEM PBL and Non-STEM PBL lessons.

Results were disaggregated by frameworks such as mathematical attitude, emotion, self-acknowledgement, and value (see Figure 7). The means of the STEM PBL group were higher than the means of the non-STEM PBL group on mathematical self-acknowledgement and value, which indicated that STEM PBL lessons had a greater influence on students' affective mathematics engagement toward mathematical self-acknowledgement and value. The Cohen's *d* effect sizes and 95% confidence intervals for these differences were 1.83, [1.43, 2.23] for mathematical self-acknowledgement and 2.83, [2.35, 3.29] for mathematical value. In comparison, the means for mathematical attitude and emotion were higher for the non-STEM PBL group than for the STEM PBL group. This indicated that non-STEM PBL lessons had a greater impact on students' mathematical attitude and emotion. The Cohen's *d* effect sizes and 95% confidence intervals for these differences were 0.83, [0.48, 1.18] for mathematical attitude and 1.46, [1.08, 1.84] for mathematical emotion. These standardized differences represent a large practical significance for educational research. Results showed that the mean differences of students' mathematical attitude, emotion, self-acknowledgement, and value were all statistically significant (*p* < .01).

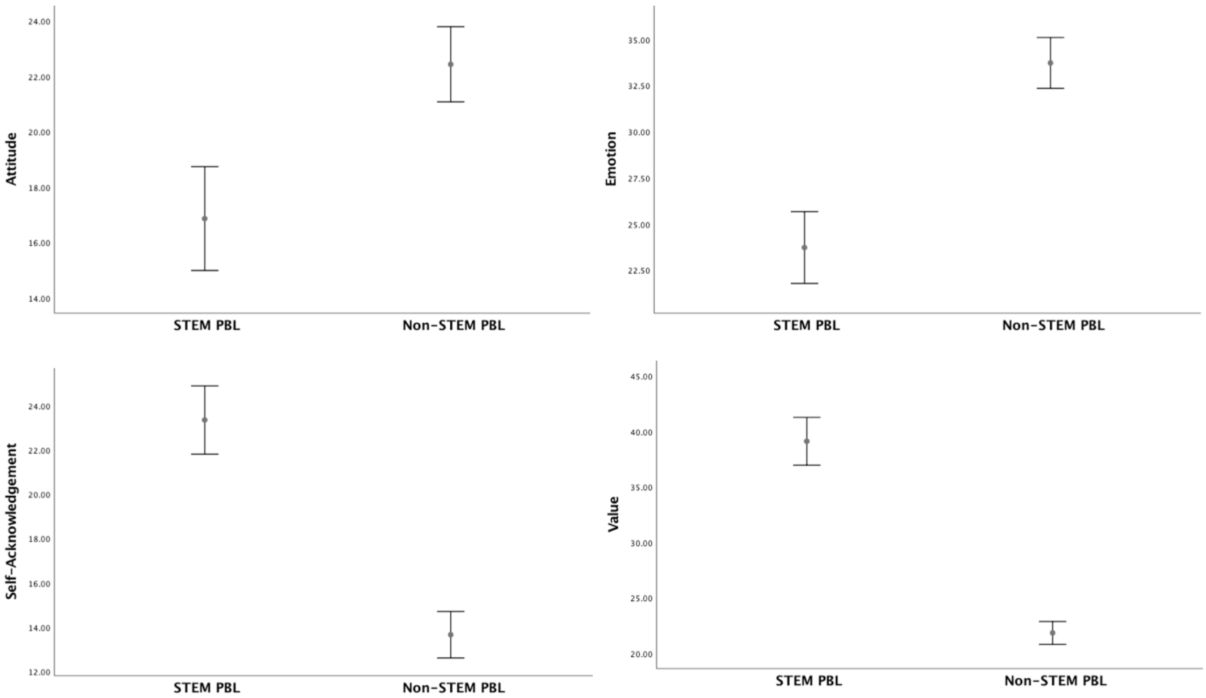

Figure 7 Affective mathematics engagement toward each framework in STEM PBL and non-STEM PBL.

Discussion

Students' affective mathematics engagement has been widely considered a predictor of successful educational experiences, and STEM PBL has been theorized as an effective and innovative instructional strategy that has potential to improve students' affective mathematics engagement (Barron et al., 1998; Honey et al., 2014; Ketelhut et al., 2010). In this study, the impact of STEM PBL and non-STEM PBL lessons on students' affective mathematics engagement was compared. The findings for the present study revealed that students in STEM PBL lessons demonstrated more affective mathematics engagement than those in non-STEM PBL lessons.

Many studies have indicated that STEM instruction has been useful for improving content learning. In fact, researchers in most of these studies have used large scale assessments that included state high-stakes tests that were used to examine a broad set of content knowledge across subjects as evidence of learning (e.g., Chun-Ming., Hwang, & Huang, 2012; Freeman et al., 2014; Hmelo-Silver, Duncan, & Chinn, 2007; Marx et al., 2004; Schneider, Krajcik, Marx, & Soloway, 2002). While most of the studies indicated increases in student mathematical learning, researchers in these previous studies did not account for the underlying mechanisms responsible for the increases in performance. One might argue that it is the social aspects of instruction or perhaps the increased communication or additional experiences with problem solving that are responsible for the improvement in test scores. In the current study, we suggest one plausible explanation, namely, students simply like the lessons more and are more engaged with the content they are expected to learn. Because of the nature of STEM PBL instruction, students may have to rely more heavily on prior knowledge of the subject or may have to make new connections to knowledge from another subject that previously was just an isolated fact. This process, in turn, may lead students to increase their mathematical self-acknowledgement and value. In particular, the means of the STEM PBL in terms of students' mathematical self-acknowledgement and value were statistically significantly higher (*p* < .01) than those of the students' experiencing the non-STEM PBL.

Based on the theoretical framework, one can expect that during STEM PBL lessons students may exhibit the following behaviors and tendencies: a desire to communicate their excitement about something they learned (CTO); focused engagement and concentration for achieving mathematical understanding, problem solving, and/or experiencing fascination for the mathematics they are learning (IRIT); actively helping others by sharing an idea or their mathematical knowledge (LMTY); and an interest in impressing on others that they have developed mathematical knowledge or ability (LHSIA). Because the setting for STEM PBL is more student centric than traditional, lecture-based instruction and has an emphasis on collaborative work, the environment encourages and facilitates discussion and the exchanging of ideas and knowledge; therefore, through STEM PBL, students have the potential to improve their mathematical self-acknowledgement and value related to affective mathematics engagement.

Due to the nature of the STEM PBL environment, which supports collaborative and cooperative teaching and learning practices, students in STEM PBL may believe in the importance of helping others and express the desire to impress their peers and teachers. In part, STEM PBL lessons may foster students' affective mathematics engagement because they nurture students' autonomous investigation of the situation on the basis on an ill-defined task (Slough & Milam, 2013) and require students to collaborate with their peers to identify problems (Ozel, 2013). Learning is a process of acquiring and retaining affective mathematics engagement and mathematical understanding (Akinsola & Olowojaiye, 2008; Farrant, 1994). If students are not assisted or encouraged to positively perceive most of the concepts and ideas they are learning in mathematics classes, their performance will be affected. It depends entirely on the teacher to help students develop positive affective mathematics engagement.

Students in the non-STEM PBL group demonstrated more favorable mathematical attitude and emotion than students did in the STEM PBL group. The means of the non-STEM PBL students' mathematical attitude and emotion were statistically significantly higher ($p < .01$) than that of the STEM PBL students. Traditional instruction straightforwardly provides clear instruction related to mathematical concept. Teachers who use traditional instruction guide students toward developing new mathematical knowledge and basic academic skills (Jones & Southern, 2003). This direct way of teaching and learning is a proven example of an effective instructional method for students' mathematical academic development (Ewing, 2011; Stone, 2002). Since the traditional instruction is intended to provide a highly structured form of teaching (Ewing, 2011), students may have felt less pressure to self-initiate steps or procedures during class or the learning process. Therefore, students receiving traditional instruction might experience less stress during their class, which has been shown to result in relatively positive attitudes and emotions. The results based on the theoretical framework support this interpretation. Based on the theoretical framework, the findings of the present study may indicate that students engaged in non-STEM PBL have different aspects of engagement activated. They may be more likely to express feelings aligned with the following categories: are preoccupied with completing the mathematical task correctly, following instructions as provided (GTJD); pretend to engage in the task while avoiding genuine participation (PE); feel the need or desire to avoid conflict with others or with the teacher (SOOT); and perceive challenges to their mathematical identity (DDM).

Despite decades of mathematics educational reform (NCTM, 1989), calls for building students' mathematical identity (Boaler & Greeno 2000), increasing opportunities for students to voice their thoughts and ideas (Lerman, 2001), and creating more inclusive classrooms (Gellert, 2004), most mathematics classes still fall short (e.g., Ryan, Gheen, & Midgley, 1998; Wagner, & Herbel-Eisenmann, 2009). Because traditional mathematics classrooms typically use more teacher centric instructional methods and lesson progression (Boaler, 2002), it is not uncommon for students in traditional classrooms to self-limit their questions, discussion, and responses to teacher questions. When students do not feel the need to self-limit their learning and instead operate in a collective mindset, they can exhibit characteristics closer aligned to mathematics-reformed ideas.

An important result emerging from the present study is that STEM PBL lessons foster the factors of mathematical self-acknowledgement and value to a greater extent than do non-STEM PBL lessons. This result supports previous findings that indicated that STEM PBL increases students' mathematical self-acknowledgement and value for mathematics (Lou et al., 2011). In addition, the results from the previous study indicated that non-STEM PBL students were passive with regard to interaction with others. For example, such students might appear to focus more on tasks, but are predisposed to avoid conflict and distraction, and to protect their mathematical identity.

Despite the findings from the present study, there are limitations worthy of discussion. The first is that we cannot control for variance in teacher implementation within this technique. When considered, it is possible that this sample size and its nested structure would provide insights into best-case scenarios for implementation; however, it does little to contribute to what can happen in the general teaching population. Despite this limitation, the results show clear differences between model STEM PBL and non-STEM PBL lessons in terms of students' affective mathematics engagement. Another condition limiting our study is the minimal examination given to lesson development and the teachers' pedagogical content knowledge. Students' affective mathematics engagement can be influenced by the teaching-learning context itself. Lesson content may differ depending on a teacher's approach, and this can potentially influence students' affective mathematics engagement. Further, studies need to be designed to examine the phenomena considering lesson content coverage and teacher pedagogical prowess.

Finally, the ethnic composition of the groups was not exactly the same. However, when considering participants' starting scores, there was no difference on the obtained scores that could be attributed to the ethnic composition of the samples. From U.S. national comparisons and other studies that seek to identify differences in mathematics performance by ethnicity, Asian students typically outperform all others, followed by Caucasians, Hispanics, and African Americans (Bicer & Capraro, 2017; Guglielmi, &

Brekke, 2017; Tate, 1997). When considering the sample from this study, the non-STEM PBL group had 2 more Asian students than the STEM PBL group, a relatively small number given the total sample size. With regard to African Americans, there were more than twice as many in the non-STEM PBL group than there were in the STEM PBL group, but when considering the total sample, that difference (6%) does not represent a substantial proportion. That small difference would exert little influence on the obtained scores.

There were 11% more Caucasians in the non-STEM PBL group than in the STEM group; this could be considered somewhat problematic. However, pre-test scores for the groups were similar, and no comparisons were made between ethnic groups. There were 14.2% more Hispanics in the STEM PBL-group than in the non-STEM PBL group. Some might consider this more problematic because of the potential for native language to function as a barrier to learning, especially for a pedagogy that relies heavily on peer communication and collaboration. Given these differences and typical performance by ethnicity in the U.S., one might expect that the non-STEM PBL group would be slightly favored given they had a greater proportion of Caucasian students and a substantially smaller proportion of Hispanic students. However, this was not evidenced from the results. Furthermore, the results for both gender and at-risk proportions showed only small differences between groups, which suggests that these two factors are unlikely contributors to changes on the observed variable scores. The mean scores of the pre-test performance in terms of both STEM PBL and non-STEM PBL lessons were similar, so we did not discuss these findings in extensive detail.

In general, the results clearly show the differences between STEM PBL and non-STEM PBL in terms of students' affective mathematics engagement. STEM PBL activities foster the development of affective mathematics engagement. There are only a few studies in which the impact of STEM PBL on students' affective mathematics engagement has been investigated. Therefore, this study could be a starting point to understand students' mathematical attitude, emotion, self-acknowledgement, and value that are fostered during STEM PBL instruction.

CHAPTER V

CONCLUSIONS

The main focus for this dissertation was to explore how students' affective engagement reveals itself in mathematical learning situations. The general findings revealed that the students' affective mathematics engagement was impacted by diverse factors, such as gender, home language, immigration status, school mean economic disadvantage status, cultural affordance by their countries, and educational intervention (i.e., STEM PBL).

The findings indicate the importance of demographic factors for the students and the schools. Student-level factors, such as gender, home language, and immigration status, were associated with affective mathematics engagement. In particular, students who were male, spoke English at their home, or were born in the U.S. experienced more positive affective mathematical engagement, in comparison to their peers who were female, did not speak English at home, or were not born in the U.S. School mean economic disadvantage status, which refers to the average ratio of economically disadvantaged students in a school, was also a statistically significant factor in the students' affective mathematics engagement. Students in economically advantaged schools experienced more positive affective mathematics engagement than students in economically disadvantaged schools. In the light of this research, policies are needed that address the educational context at the school-level, and that focus on improving the schools' economic circumstances, eliminating economic segregation between schools, and enhancing the social and emotional health of the learning environments. Such efforts are intended to broaden the students' learning opportunities and increase their positive experiences, which may in turn enhance their affective mathematics engagement.

In addition, the cultural affordance of difference countries influences their students' motivation toward mathematics and their affective mathematics engagement. Students in Korea have a relatively high extrinsic motivation toward mathematics, and are therefore likely to experience mediated attitudes and emotions in mathematics classrooms, in comparison to students in the U.S. By contrast, students in the U.S. have a relatively high intrinsic motivation toward mathematics, and are therefore likely to have greater self-acknowledgement and value the mathematics learning. Given that cultural differences between countries are associated with educational differences, macroscopic changes at the country level are necessary in order to improve other aspects of motivation and affective mathematical engagement.

Affective mathematical engagement is impacted by a comprehensive set of factors that moderate both the students themselves and the situation around them. These factors may be difficult to change. However, there are many interventions that educators can implement in order to overcome the students' unchangeable limitations and improve their affective mathematics engagement. One effective example is the implementation of STEM PBL in mathematics instruction. Affective mathematics engagement is sensitive to the learning situation. The STEM PBL encourages students to fully participate in the mathematical learning situation so that they can actively foster their affective mathematics engagement through their experiences. The improvement of affective mathematic engagement can be expected to positively impact the students' overall academic performance in their mathematical learning.

The findings of this dissertation provide important educational implications for three primary reasons. Firstly, it is essential to improve students' affective mathematics engagement in order to foster their academic success. Affective mathematics engagement is closely related to the students' academic achievement and to their future majors and career choices (Lent et al., 2010; Watt et al., 2006). Transforming the instructional pedagogy is likely to have a profound influence on both motivation and affective mathematics engagement. Secondly, the results of this dissertation indicate the important relationship between the students' demographic factors and their affective mathematical engagement. The demographic factors cannot be changed, and these factors impact students' affective mathematics engagement, which in turn mediates their learning process. However, educational policies and practices that impact the students' demographic factors may help to overcome the segregation between students and schools. Thirdly, we can learn from the educational status of other countries. Every country has its own cultural characteristics, and it is these characteristics that impart both motivation and affective mathematics engagement. By investigating and learning from various countries' educational cases, we can gain an understanding of how other countries approach their systems of education. An understanding of the educational discrepancies between countries may provide solutions to the educational issues that we face.

Students’ affective mathematics engagement depends on how classrooms, schools, and society structure educational circumstances. In educational fields, understanding and minimizing of students’ differences have been considered important as the traditional boundaries of the social differences have broken down (Choi, 2010). Diversity of students’ demographic factors such as gender, ethnicity, culture, and language reside in the society. Acknowledgement of diversity in the society has affected the trend of education. The issue of current education focuses more on understanding students’ different backgrounds and how to achieve a healthy balance of students’ academic achievement in these differences (Choi, 2010). To develop students’ affective mathematics engagement, curriculum should include more understanding and respect toward social-demographic diversity. In addition, instructional supports, such as STEM PBL, to overcome the differences should be implemented. The fusion of consideration of students’ social-demographic factors and implementation of effective instructional methods in teaching and learning situations will almost certainly allow students to have more positive mathematics engagement. The encouraged active affective mathematics engagement would lead students’ academic success.

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APPENDIX A

MEASUREMENT OF AFFECTIVE MATHEMATICS ENGAGEMENT (MAME)

[Mathematical Attitude]

Get the Job Done (GTJD)

1. I wanted to make sure that all the required work was completed.
2. The most important thing for me was getting the answer to the problem.
3. I worked on getting the answer to the problem.
4. I tried to get members of my group to work to get the answer to the problem.
5. I wanted the teacher to think I am a good student.

Pseudo Engagement (PE)

6. I wanted to look like I was doing work even when I wasn’t.
7. I worried that I might get in trouble with the teacher.

[Mathematical Emotion]

Stay Out of Trouble (SOOT)

8. I was worried I might do something that would get me into trouble with one or more students.
9. I paid attention to the way others were reacting to me.
10. I hoped people would not pay attention to me.
11. I cared more about feeling OK than about solving the math problem.
12. I felt relieved when all the work was done.

Don’t Disrespect Me (DDM)

13. I was not going to let someone disrespect me and get away with it.
14. I argued strongly in support of my ideas.
15. I had an unpleasant disagreement.
16. I archived a good understanding of the math we worked on today.
17. My ideas were challenged by others.
18. Some person or some group of people tried to disrespect me.

[Mathematical Self-acknowledgement]

Check This Out (CTO)

19. I realized that if I worked hard at the problem I could figure it out.
20. As I made progress, I became more interested in understanding the math.
21. I felt proud about what I accomplished.
22. I felt that learning the math today would benefit me or pay off for me.

I’m Really into This (IRIT)

23. I concentrated deeply on today’s math problem.
24. I was so into my work that I tuned out things going on around me.
25. I was fascinated by the math today.

[Mathematical Value]

Let me Teach you (LMTY)

26. I wanted to teach another student something that I knew that this other student did not know.
27. I listened carefully to the ideas of someone I was trying to help.
28. I helped someone see how to do the math.
29. Others listened carefully to my ideas

Look How Smart I Am (LHSIA)

30. I wanted people to think that I’m smart.
31. I tried to impress people with my ideas about the problem.
32. People seemed impressed with the ideas I shared about the problem.
33. People saw how good I was at the math we did today.
34. I felt smart.
35. I wanted to show someone that my way was better.
36. I was a lot better at math than others today.
37. I argued strongly in support of my ideas.