A STUDY OF HOW SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) PROJECT-BASED LEARNING (PBL) CAN IMPROVE STUDENT ENGAGEMENT

A Thesis

by

ASHLEY MARRIE CRAFT

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Chair of Committee,	Robert M. Capraro
Co-Chair of Committee,	Mary Margret Capraro
Committee Members,	Luciana R. Barroso
Head of Department,	Michael de Miranda

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ABSTRACT

Schools and teachers are facing a difficult challenge of how to keep students engaged in mathematics and students' lack of engagement is common nationally. The research conducted for this study focused on the effects of STEM PBL on student engagement. The drive for the present study was to understand the effects STEM PBL instruction has on student engagement compared to non-STEM PBL instruction. There has been growing evidence that STEM PBL instruction increases student engagement and enhances the academic learning across demographic demarcations. In order to cognize how engagement is influenced by instructional methods an experimental design was used where three conditions were established and students were randomly assigned to one of the three conditions.

Confidence intervals were used to compare means across 8 engagement structures within the three conditions. These results suggest that student engagement as measured by engagement structures can be separated across teachers and that lesson type may influence student engagement as measured by the same instrument. Those 8 structures were then subjected to an exploratory factor analysis that produced two-second order factors allowing for a separation between academic and behavioral engagement. These results showed more specifically the influence of STEM PBL on students' academic engagement. Overall it is suggested that student engagement was greater with the STEM PBL instructional strategy than the other two.

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Professor Robert M. Capraro and Aggie STEM provided the data analyzed for Chapter II and III. The articles are co-authored by Professor Robert M. Capraro. The student completed all other work conducted for the thesis independently.

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1. INTRODUCTION

Student engagement is often absent in schools today. Increasing rigor while keeping students engaged in the classroom has become critical in the education of today's adolescence. Boosting participation, engagement, and achievement in science and mathematics has become a worldwide concern challenging educators and researchers to update the development of policy and practice in mathematics and science education (Ruthven & Reiss, 2009). Statistics have shown that U.S. education suffers from lack of rigorous K-12 education, especially in STEM areas (Sahin & Top, 2015) putting tremendous pressure on schools to increase rigor in the classroom (Harada, Kirio, & Yamamoto, 2008). It has been acknowledged by educators that far too many students are unenthusiastic, unconcerned, and disconnected from the academic and social characteristics of school (Appleton, Christenson, & Furlong, 2008). Researchers reveled that disengagement is an obvious factor in low student accomplishment (Stone, Alfreld, & Pearson, 2008). Student engagement refers to the level of connection, interaction, and learning students demonstrated in classroom projects and activities (Gourgey, Asiabanpour, & Fenimore, 2010) and is critical to academic achievement (Yonezawa, Jones, & Joselowsky, 2009). Therefore, academic engagement is a significant forecaster of academic achievement (Dotterer & Lowe, 2011). If teachers aim to construct engagement through replicable strategies, prospective academic success may become recognized academic fulfillment. It is necessary that educators find approaches of increasing rigor and student engagement concurrently.

The integration of STEM has steadily become more important in today's society and STEM PBL has been proven to increase student engagement. The focus on STEM education has been awakened based on the need to raise citizens who can supply the workforce and promote the economic and cultural competency of the information era of this nation (Soylu, 2016). Young children needed to be prepared to live in a technology rich, ever growing, 21st century (Wise Lindeman & McKendry Anderson, 2015). Active instruction, which is common in STEM PBL, has optimistically impacted academic attainment across ethnic and SES categories as well as students' non-academic performances, demonstrating a positive outlook towards learning, communication, and collaboration (Dominquez & Jamie, 2010). STEM PBL offers methods for engaging students in realistic learning experiences through the promotion of active engagement and student ownership while also being rigorous in content (Capraro, Capraro, & Morgan, 2013). Rigorous curriculum, instruction, and assessment, integrated technology and engineering in science and mathematics curriculum, and promotion of scientific inquiry and the engineering design process are all requirements of a high quality STEM education program (Kennedy & Odell, 2014). Students engaged in deeper levels of PBL understanding can create relevant and rigorous learning (Harada et al., 2008). Therefore, the combination of STEM curriculum with PBL can function as a conceivable resolution to increase rigor and engagement in the classroom.

Statement of the Problem

The research conducted for this study will focus on the effects of STEM PBL on student engagement. An educational challenge is how to keep students engaged in mathematics and students' lack of engagement is common nationally in schools today.

Declining interest is especially a concern for urban inner-city students who face challenges of poverty, cultural differences, and language. These students are at risk of everyday mathematical illiteracy and dropping out of the advanced mathematics courses offered in high school. Students who do not take these courses will not only face exclusion from STEM-related careers but also disengagement from higher mathematics which is also associated with dropping out of school (Levin & Belfield, 2009). Enhancing participation, engagement, and achievement in science and mathematics has become a pressing concern across the nation.

Purpose of the Study

The purpose of the present study was to understand the effects STEM PBL instruction has on student engagement compared to non-STEM PBL instruction. There has been growing evidence that STEM PBL instruction enhances the academic learning across demographic demarcations. STEM PBL has increasingly become more popular in education today as the demands for collaborative problem solvers increase in the job market. STEM PBL has the capability of reducing the mathematics and science achievement gaps faced by lower or average achievers, as well as underrepresented minority groups through increased student engagement; typically lower and average achievers seemed to benefit the most from STEM PBL (Han, Capraro, & Capraro, 2014). The main product expectations from using STEM PBL instruction is to train students for post-secondary education and the 21st century workforce by having them solve open-ended, multi-outcome problems (Kennedy & Odell, 2014). The research conducted during this thesis study will contribute to knowledge about the effectiveness of STEM PBL and STEM education literature.

Research Question

1. How is student engagement in a high fidelity (best case) STEM PBL activity and a non-STEM PBL activity differentially evoked depending upon (1) rigorous content, (2) meaningful opportunity for active engagement, and (3) mathematical discourse between all classroom stakeholders?

Journal Selections

For each purposed manuscript two potential journals have been selected. See Table 1.1 for the materials referenced for the selection of each journal.

Table 1.1

Proposed Articles and Journals

Proposed Articles	Proposed Journal #1	Proposed Journal #2
Article 1:	*International Journal of Science and Mathematics Education* • Acceptance rate: 30% • Impact and ranking (SJR/SNIP): 0.759/1.121 • Editor in chief/Associate editors: Huann-shyang Lin/ Larry D. Yore, Hsin-Kai Wu • Publisher: Springer • Type of review: Double-Blind Review • Manuscript length: Max. 30 pages	*Eurasia Journal of Mathematics Science and Technology Education* • Acceptance rate: 16-17% • Impact and ranking (SJR/SNIP): 0.14/1.61 • Editor in chief/Associate editors: Mehmet Fatih Taşar/ Stephen Ritchie • Publisher: Moment Publications • Type of review: Double-Blind Review • Manuscript length: N/A

Table 1.1 Continued

Proposed Articles	Proposed Journal #1	Proposed Journal #2
Article 2:	*International Journal of STEM Education* • Acceptance rate: NA • Impact and ranking (SJR/SNIP): NA • Editor in chief/Associate editor: Yeping Li/ Jeffrey Froyd • Publisher: Springer • Type of review: Double-Blind review • Manuscript length: N/A	*International Journal of Mathematical Education in Science and Technology* • Acceptance rate: 38% • Impact and ranking (SJR/SNIP): 0.295/0.687 • Editor in chief: M. C. Harrison • Publisher: Taylor & Francis • Type of review: Blind Review • Manuscript length: N/A

Article #1: How Science, Technology, Engineering, and Mathematics Project-Based Learning Can Improve Student Engagement

Student engagement is suffering in schools across the nation. The disengagement being experienced has consequences such as lower academic achievement and higher dropout rates. STEM PBL instruction has been proven to improve students' affective engagement. This article aims to explain and define student engagement and STEM PBL. It will reveal and support how student engagement was greater with the STEM PBL instructional strategy than non-STEM PBL strategies and that student engagement is profoundly influenced by characteristics of the lesson more than that of the teacher. Activities that utilize collaboration through STEM PBL (Capraro et al., 2013; 'Sahin et al., 2014) could be liable for the positive attitudes, engagement, and have the potential to support student learning from one another.

Methodology

To comprehend how affective engagement is influenced by instructional methods an experimental design was used. Three conditions were established and students were randomly assigned to one of the three conditions. Quantitative data were collected from the three conditions to assess student engagement through a student survey that measured positive feelings such as curiosity, respect, and pride and negative feelings such as discouragement, anger, and boredom. Two highly recognized teachers, teacher A and teacher B, were utilized to carry out the three conditions. These three conditions involved a STEM PBL lesson taught by teacher A, a non-STEM PBL lesson taught by teacher A, and a non-STEM PBL lesson taught by teacher b.

Participants

Participants in this study were students from two inner city Title 1 schools, where the majority of the student population were of low socioeconomic status. Data were collected on 147 of the two teachers' students, which was the only data for the students who were preselected for the study using stratified random sampling. Two of the sample groups contained 51 students and the third contained 45. Groups were then equalized across demographics, which narrowed each group to 20 students, 10 at risk and 10 not at risk. Decisions about removal from the not at risk students was based on balancing the number of students in each subgroup: gender and ethnicity.

Instrument and Data Analysis

The Rutgers University Mathematical Engagement Structures Inventory (RUMESI) instrument was adapted from Goldin, Epstein, Schorr, and Warner (2011) and allowed access to students' own personal experiences in a standardized way and was used to gather student feedback and measure their engagement. The instrument encompassed 8 structures that were applied to gage the different types of motivating desires and possible engagement features. The items in each of the 8 structures were scored and averaged to cultivate a mean structure score for each student and were then used to analyze the engagement level of each group. Using those mean scores data were then analyzed using 95% confidence intervals and Cohen's *d* effect sizes.

Article #2: Science, Technology, Engineering, and Mathematics Project-Based Learning: Merging Rigor and Relevance to Increase Student Engagement

Increasing rigor while keeping students engaged in the classroom has become fundamental in the education of the 21st century. This article aims to explain how rigor and relevance is directly related to student engagement. Increasing cognitive rigor of work engaged in has been shown to improve academic achievement and classroom engagement (Paige et al., 2013). STEM PBL provides the means to blend rigor and relevance by connecting relevant real-world situations and preserving high expectations of student achievement. STEM PBL more specifically improved student academic engagement, which potentially leads to improved academic achievement.

Methodology

An experimental design was used to compare the effects of STEM PBL on student engagement. Three focus groups were established and students were randomly assigned to one of the three groups. Quantitative data from the three focus groups was collected to assess student engagement within a STEM PBL classroom compared to a non STEM PBL classroom.

Participants

Participants in this study were students and teachers from an inner city school with a high population of students from a low socioeconomic background. The teachers who partook were provided professional development (PD) and a stipend for their participation. Two ideal teachers (teacher A and teacher B) were selected and data were collected from 147 of their students. The students were divided into three groups (1) STEM PBL lesson taught by teacher A, (2) non-STEM PBL lesson taught by teacher A, and (3) non-STEM PBL lesson taught by teacher b.

Instrument and Data Collection

The Rutgers University Mathematical Engagement Structures Inventory (RUMESI) instrument was adapted from Goldin et al. (2011) and was used to measure student engagement during the study. The instrument was administered at the end of a mathematics class and students were asked to respond to their overall feelings, or perceptions of class that day. An exploratory factor analysis (EFA) was performed on the data collected from the 37 items of the RUMESI and all items loaded into 8 components that were then named and classified as engagement structures that measure the different types of motivating desires and possible engagement characteristics. A score for each structure was then documented and calculated for each student and was used to analyze the engagement level of each group within the structures. To search for patterns of correlations (Henson, Capraro, & Capraro, 2004) among the 8 structures, a second level exploratory factor analysis EFA was performed. After inspecting the results the 8 structures measuring student engagement to search for patterns of correlations (Henson et al., 2004), a second level exploratory factor analysis EFA was performed using the extraction method principal component analysis (PCA) with Varimax rotation. The means of the regression factor scores were then used to produce confidence intervals to compare the effects of the factors on different groups. The value of Cohen's *d* and effect-size correlation, *r*, was calculated using the means and standard deviations for each possible combination of groups.

2. MANUSCRIPT #1

How Science, Technology, Engineering, and Mathematics Project-Based Learning Can Improve Student Engagement

The purpose of this study was to analyze the effects of STEM PBL on student engagement. Engagement is the key to academic success and can improve mathematics learning and STEM PBL has been shown to increase student engagement. Participants in this study were students from two inner city Title 1 schools, where 88% and 89% of the student population were of low socioeconomic status. Two exemplar teachers and 60 students constituted the two groups of students for this study. However, three groups where analyzed; a controlled STEM PBL math group taught by an exemplar STEM PBL trained teacher, a non-STEM PBL math group thought by the same teacher, and a non-PBL math lesson taught by an exemplar teacher who received professional development in algebra content. In this experimental study quantitative data was collected from the three conditions to assess student engagement. Confidence intervals were used to compare means across 8 engagement structures; results indicated that students in the STEM PBL lesson exhibited greater levels engagement, followed by the non-STEM PBL lesson taught by the same teacher and finally the typical lessons taught by the other teacher. The results suggest that student engagement as measured by engagement structures offered by Goldin and his team can be disentangled across teachers and that lesson type may influence student engagement as measured by the same instrument.

Keywords: mathematics achievement; project-based learning; STEM; student engagement

Introduction

Students' lack of engagement is common in schools today. Enhancing participation, engagement, and achievement in science and mathematics has become a worldwide concern challenging educators and researchers to update the development of policy and practice in math and science education (Ruthven & Reiss, 2009). It has been recognized by educators through observation that far too many students are bored, unmotivated, uninvolved and are disengaged from the academic and social aspects of school (Appleton, Christenson, & Furlong, 2008). Many students experience boredom or are otherwise turned off from the classroom; this is especially true in mathematics, which students often feel is entirely disconnected from their everyday reality (Langer-Osuna, 2015). Attempting to impart knowledge without student engagement in thinking that builds connections is one of the biggest threats to a student's learning outcomes (Wilder, 2015). The lack of student engagement has negative consequences related to students' academic achievement (Uekawa, Borman, & Lee, 2007). Therefore, academic engagement is an important predictor of academic success (Dotterer & Lowe, 2011). If teachers work to build engagement through replicable strategies potential academic success may become realized academic attainment.

STEM PBL has been shown to improve student engagement. Active instruction such as what is common in STEM PBL has positively impacted academic achievement across ethnic and SES categories students' non-academic performances, showing positive attitudes towards learning, communication, and collaboration (Dominquez & Jamie, 2010). It has been found that PBL students find the experience enjoyable, inspiring, and self-fulfilling, while lecture students were quite negative about their learning experience (Tseng, Chang, Lou, & Chen, 2013). Students learn better when they are engaged in meaningful activities (Fortus, Krajcik, Dershimer, Marx, & Mamlok-Naaman, 2005; Hancock & Betts, 2002) that produce authentic artifacts (Hung, Tan, & Koh, 2006). STEM PBL provides the means for engaging students in realistic learning experiences because it promotes active engagement and makes students more apt to take ownership of their education and future.

Literature Review

There has been growing evidence that STEM PBL instruction enhances the academic learning across demographic demarcations. For example, STEM PBL instruction was shown to enhance mathematics and science learning across content albeit with lower gains shown in probability and statistics concepts than in others (Han, Rosli, Capraro, & Capraro, 2016; Erdogan, Navruz, Younes, & Capraro, 2016). The achievement gains have typically favored underrepresented and language minority students (Han, Capraro, Capraro, 2016), in part because of inherent achievement disparity present at the start of those studies, whereas typically lower and average achievers seemed to benefit the most from STEM PBL (Han, Capraro, & Capraro, 2014). It impossible to discount that the discourse and group interactions could lead to improved language use and understanding could in part lead to the observed achievement gains (Bicer, Boedeker, Capraro, & Capraro, 2015). However, observed gains were not related to school types either inclusive STEM focused schools or charter schools specializing in STEM (Oner, & Capraro, 2016; Oner, & Capraro, & Capraro, 2016; Oner, Navruz, Bicer, Peterson, Capraro, & Capraro, 2014). The only exception was that when comparing STEM focused schools to their peers STEM achievement was related to the number of years since adopting a STEM emphasis and STEM focused curriculum (Bicer, Navruz, Capraro, Capraro, Oner, & Boedeker, 2015). STEM PBL has the capability of reducing the mathematics and science achievement gaps faced by lower or average achievers, as well as underrepresented minority groups, through increased student engagement, but like any pedagogical strategy takes training, time, and experience.

Engagement

Engagement can be defined as an emotional involvement and commitment. When students are emotionally involved or committed to something they are more likely to appreciate, comprehend, and understand the value in the commitment at hand (Goldin, Epstein, & Schorr, 2007). Engagement is an important component of students' school experience because of its direct relationship to achievement (Dotterer & Lowe, 2011). There is a positive relationship with academic gains in mathematics, independent of socioeconomic or minority status (Goldin, Epstein, Schorr, & Warner, 2011; Park, 2005). A student's engagement in academic work is measured by their investment in and effort directed towards learning, understanding, or mastering the knowledge, skills, or crafts intended (Park, 2005). Engaged students pay attention to classroom activities, are interested in content, and may experience heightened states of awareness, confidence, and performance (Uekawa et al., 2007). Engagement leads to greater attainment of knowledge resulting in better-prepared students for future careers and life in general (Newton & Newton, 2011). A high level of engagement for students is often predicated on the types of learning activities used and the teacher's level of knowledge. Increasing student engagement leads to improved mathematics achievement.

STEM PBL

Science, technology, engineering, and mathematics (STEM) Project-Based Learning (PBL) is an instructional strategy that is student centered, interdisciplinary, collaborative, and sometimes technology based. The STEM PBL instructional strategy makes heavy use of two learning theories enactivism (Maturana & Varela, 1987) and constructivism (Steffe, & Gale, 1995) that emphasizes the co-construction of knowledge and the importance of self in the learning process (Tseng et al., 2013). The Common Core State Standards (CCSS), the Next Generation Science Standards (NGSS), and the Texas Essential Knowledge and Skills (TEKS) are all conducive to enactments of STEM PBL instructional strategies. A STEM PBL classroom is typically student-centered and inquiry-based where students solve problems while actively engaging in and collaborating with others (Han, Capraro, & Capraro, 2015). Strategies include motivating curiosity, asking/generating questions, making discoveries, and rigorously testing discoveries or intuition in search of new solutions (Marks, 2013). Positive learning outcomes are associated with authentic inquiry-based learning experiences (Tomas, Jackson, & Carlisle, 2014). Students engaged in active learning have reported positive feelings about class and felt that they were learning something new without compromising the perceived difficulty of the tasks (Uekawa et al., 2007). Increasing student engagement is one goal of STEM PBL (Newman, 2015) that incorporates real-world problems into learning, allowing teachers to challenge student thinking and encourage students to embrace problems as opportunities (Abbott, 2016; Sahin & Top, 2015). Integrating interdisciplinary STEM teaching enhances the development of engineering design, problem solving, and higher-level thinking skills (Lin & Williams, 2013). The main outcome expectations for using STEM PBL instruction is to prepare students for post-secondary education and the 21st century workforce by having them solve open-ended, multi-outcome problems (Kennedy & Odell, 2014). The purpose of the present study was to understand the effects that STEM PBL instruction has on student engagement compared to non-STEM PBL instruction.

Methodology

In order to understand how affective engagement is influenced by instructional methods an experimental design was used. Three conditions were established and students were randomly assigned to one of the three conditions. The teachers were exemplary mathematics teachers who were used by each district as an exemplar. Both teachers had participated in three years each of professional development (90 or more hours per year). Both teachers taught multiple sections of Algebra and were the mathematics department chairs for their respective schools. Teacher B also was the mathematics coach and lead mathematics professional development specialist for her district. Teacher A was working in a designated STEM focused middle school. She participated in 380 hours of STEM PBL professional development and by year 3 co-taught the summer professional development with the research team to subsequent cohorts of teachers. Her instruction focused on bridging mathematics and real-world experiences. Her projects often bridged her introduction and assessment components of instructional units. The PBL projects were used to demonstrate content mastery and typically took from 5-9 class hours to complete. The assessments were used to help her to identify weaknesses for reteaching. She taught multiple sections of Algebra, however, not all classes included STEM PBL activities at the same time. Due to the complexity of the projects and the extra grading, the teacher rotated class participation in projects. For example, periods 1, 3, 5, might do the first project in week 5 and periods 2, 4, and 6 would do the next project in week 8. The content was held constant for this study, "Linear functions, equations, and inequalities. The student applies the mathematical process standards when using graphs of linear functions, key features, and related transformations to represent in multiple ways and solve, with and without technology, equations, inequalities, and systems of equations". Therefore, teacher A created an excellent condition to study mathematical affect based on two instructional conditions one with STEM PBL and one without STEM PBL. Teacher B taught in a non-STEM focused school. She participated in a large-scale study for 4 years to improve algebra teaching and learning where she partook in 419 hours of professional development. The professional development was primarily focused on content knowledge with some focus on tools GeoGebra, calculator, and manipulatives along with improving questioning techniques. Teacher B also provided, as the primary provider, 16 professional development sessions for other algebra teachers covering what she learned from participating in the research project. Her typical lesson development was characterized as bell work, topic introduction- in student language, demonstration, group practice, group practice with reporting out, and individual practice. Given the scope of her position she only taught 3 sections of Algebra, which were all the Algebra I classes offered at her school.

Both teachers were observed periodically to estimate fidelity to the professional development. A fidelity measure was developed for the STEM PBL (e.g. Stearns, Morgan, Capraro, & Capraro, 2012) and teacher A scored an average score 4.73 out of 5 across all indicators across all observations. Teacher B was observed using an instrument designed for the study. Her average score was 7.60 out of 8 points. The main difference between the two instruments is that the second instrument more heavily weighted content knowledge, mathematical accuracy, and the use of appropriate mathematical language because this was aligned with the intent of the professional development.

Quantitative data were collected from the three conditions to assess student engagement using the Rutgers University Mathematical Engagement Structures Inventory (RUMESI, Instrument available from developers Gerald A. Goldin et al., Rutgers University).

Participants

Participants in this study were students from two inner city Title 1 schools, where 88% and 89% of the student population were of low socioeconomic status. Teachers who participated were offered free professional development (PD), continuing education credit (used for teaching certificate renewal) and a stipend for their participation. Two exemplar teachers (teacher A and teacher B) were selected as the "Case Study Teachers", and data were collected on 147 of their students. While all students participated in the instruction and all students completed the instrument, only data for the students who were preselected for the study using stratified random sampling were provided to the research team. The students were classified by gender, at risk or not at risk, and ethnicity (Asian, African-American, Hispanic, or Caucasian). The students were divided into three groups that received different interventions.

Groups were balanced across demographics, which narrowed each group to 20 students, 10 at risk and 10 not at risk. Decisions about removal from the not at risk students was based on balancing the number of students in each subgroup, first by gender and then by ethnicity. Students from each category were randomly removed using a table of random numbers. Descriptive statistics were used to monitor changes to both gender and ethnic groups. The process was repeated until the number of students by ethnicity was balanced and the ratio of female to male within groups was equalized. The original and selected group frequencies for identifying variables can be found in Table 2.1.

Table 2.1

Demographics by Teacher and Instructional Method

		Teacher A		Teacher B
	Variable	Group 1	Group 2	Group 3
Original Sample	At Risk	10	10	10
	Not At Risk	41	41	35
	Female	30	27	24
	Male	21	24	21
	Asian	6	4	4
	African American	11	15	12
	Hispanic	20	18	19
	Caucasian	14	14	20
Selected Sample	At Risk	10	10	10
	Not At Risk	10	10	10
	Female	10	10	10
	Male	10	10	10
	Asian	5	4	4
	African American	5	5	5
	Hispanic	5	6	6
	Caucasian	5	5	5

Intervention

The intervention was administered in two settings. Teacher A was formally trained in STEM PBL (setting 1) and Teacher B received PD in algebra content without a pedagogical component (setting 2). Students were divided into three groups. Teacher A taught the students of Group 1 in a controlled STEM PBL lesson. Teacher A also taught the students of Group 2 but did not use STEM PBL with that group. Teacher B who was not trained and did not implement STEM PBL, but received content professional development taught the students of Group 3. Groups 2 and 3 received similar pedagogical lessons. The purpose for Group 2 was used in an attempt to isolate the teacher effect that could influence the effect of STEM PBL instruction. At the end of target lesson content with the interventions applied, students completed a survey to measure engagement.

Instrument

To address the research questions, the instrument used allowed access to students' own personal experiences in a standardized way. The Rutgers University Mathematical Engagement Structures Inventory (RUMESI) instrument was adapted from Goldin et al. (2011) used to collect student input and measure their engagement in the math course. RUMESI contains 37 items (see appendix) and takes about 10 – 15 minutes to complete. The instrument contained 8 structures that were implemented to measure the different types of motivating desires and possible engagement features. Those 8 engagement structures are:

1. I'm really into this (IRIT),
2. check this out (CTO),
3. let me teach you (LMTY),
4. look how smart I am (LHSIA),
5. get the job done (GTJD),
6. pseudo engagement (PE),
7. don't disrespect me (DDM), and
8. stay out of trouble (SOOT).

Each structure corresponds to a subscale items that measured positive emotions such as interest, respect, and pride and negative feelings such as discouragement, anger, and boredom adapted from Zuckerman (1960). Table 2.2 contains the descriptions of the structures (adapted from Goldin et al., 2011). The instrument was administered at the end of the math class and students were asked to respond to an overall feeling, or perception, of class that day. Students rated questions on a five-point Likert scale where 1 represented “this does not represent how I felt in class today” and 5 represented “this greatly represents how I felt in class today”. The items in each of the 8 structures were scored and averaged to develop a mean structure score for each child. Scores were then used to analyze the engagement level of each group.

Table 2.2

Engagement Structures

Structure	**Measurement Description**
I’m Really Into This (IRIT)	Measures the motivation to solve the problem for its own sake; leading to sense of flow and accomplishment.
Check This Out (CTO)	Measures the motivation to achieve a nonmathematical “payoff” which can lead to intrinsic interest in the task or heightened extrinsic interest.
Let Me Teach You (LMTY)	Measures motivation to share knowledge, receiving satisfaction from teaching, and helping others.
Look How Smart I Am (LHSIA)	Measures the motivation to impress others with the goal of achieving recognition that their own thinking is correct.
Get the Job Done (GTJD)	Measures the desire to fulfill an assigned task, receiving a sense of satisfaction from having fulfilled the commitment.
Pseudo Engagement (PE)	Measures the students desire to stay under the radar, which decreases engagement.
Don’t Disrespect Me (DDM)	Measures when a student felt that they were being disrespected, which distracted from engagement and desire to gain mathematical understanding.
Stay Out of Trouble (SOOT)	Analyzes the students desire to avoid trouble or negative attention.

Data were analyzed using 95% confidence intervals and Cohen's *d* effect sizes. Interpretation of confidence interval representations was completed as described in Capraro (2005; 2006) and Cumming and Finch (2005). This analytic method (CIs) provides for comparing variables without the inflation of TYPE I error when using multiple univariate tests (Thompson, 2002). For interpreting statistical significance (p <.05) exists when there is a less than a 25% overlap of confidence intervals. For research purposes effect size estimates for this study were considered important if a .25 difference was demonstrated in relation to Group 3 effects.

Results

The results represented by the confidence intervals in Figure 2.1 indicated weak effects for GTJD and SOOT. Therefore, there was little to no effect on students' feeling about the two variables between the groups. In Figure 2.2, for the variables IRIT, CTO, LMTY, and LHSIA there were strong effects in favor of STEM PBL instructional strategy over the other two instructional types. In Figure 2.3, there were strong effects for DDM and PE when comparing the STEM PBL instructional strategy to the other two instructional strategies. When comparing the STEM PBL instructional strategy and non-STEM PBL instruction by the same teacher there were noticeable important effects. The students in STEM PBL instruction had more positive feelings on LMT, CTO, IRIT, and LHSIA. This indicates that students experienced generally higher levels of positive affect than instruction by the same teacher when not using STEM PBL.

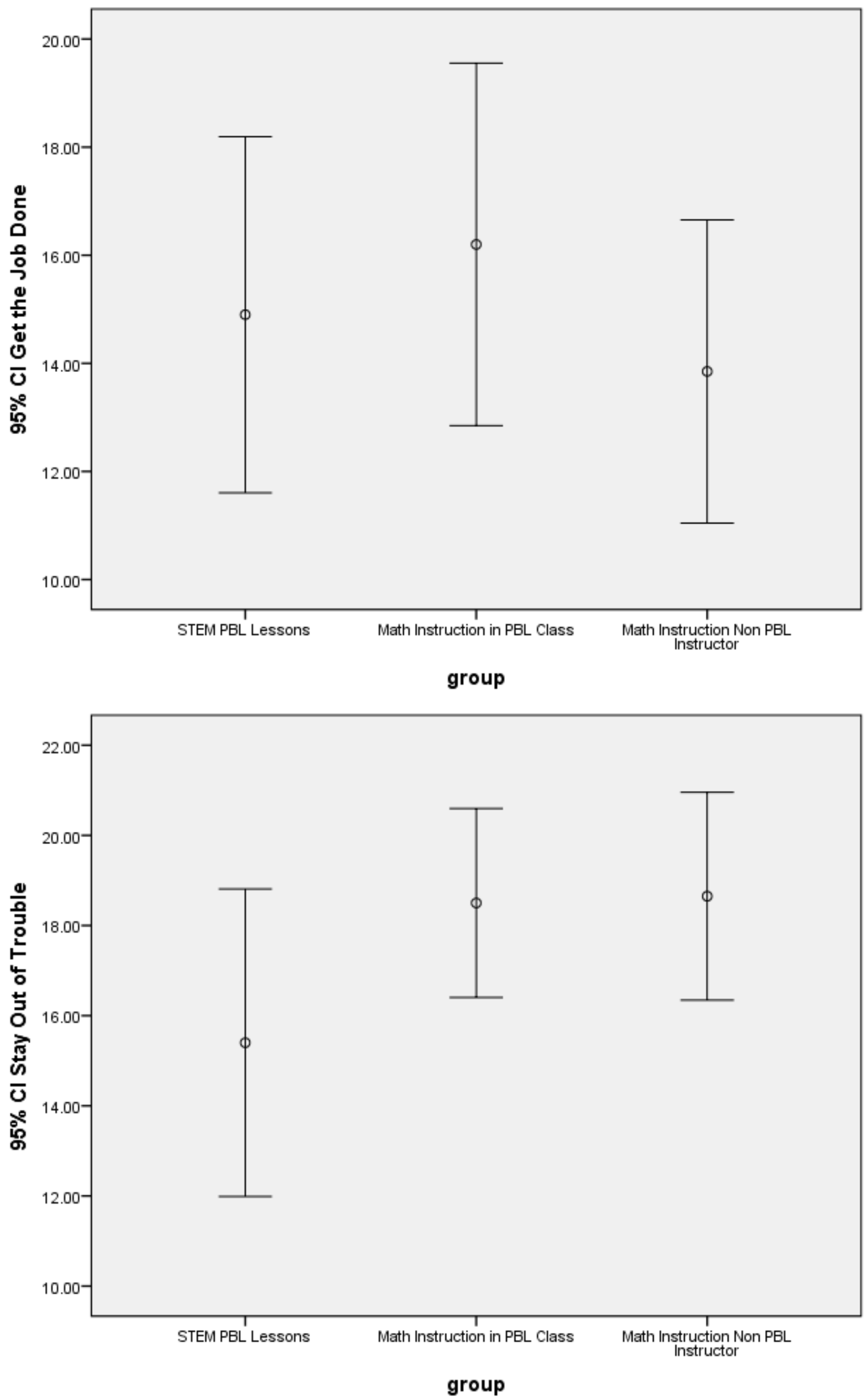
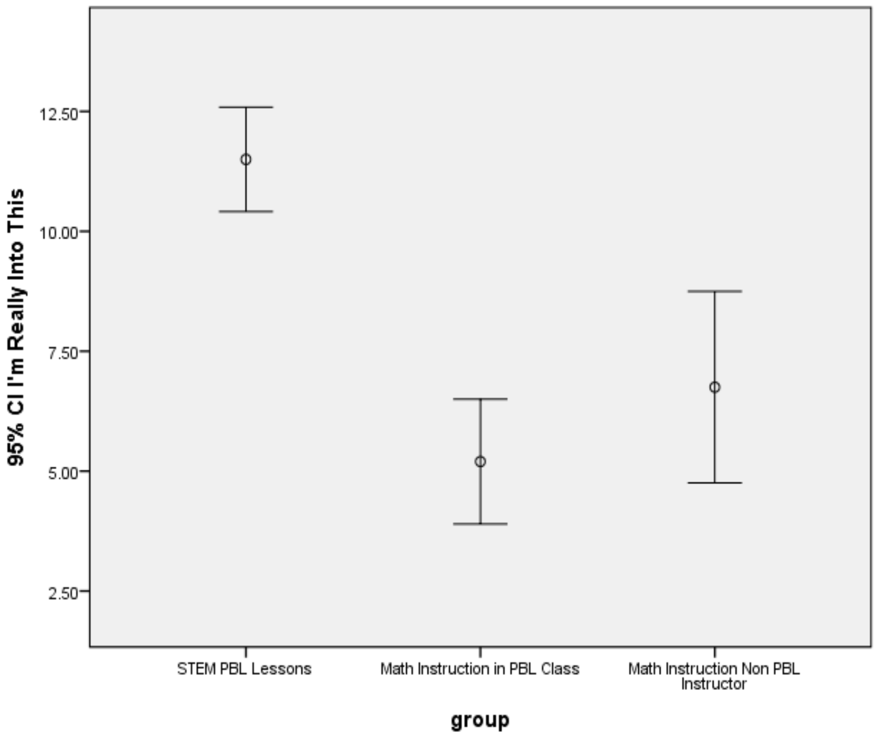


Figure 2.1. Comparison of engagement structures GTJD and SOOT in STEM PBL vs non-STEM PBL instruction.



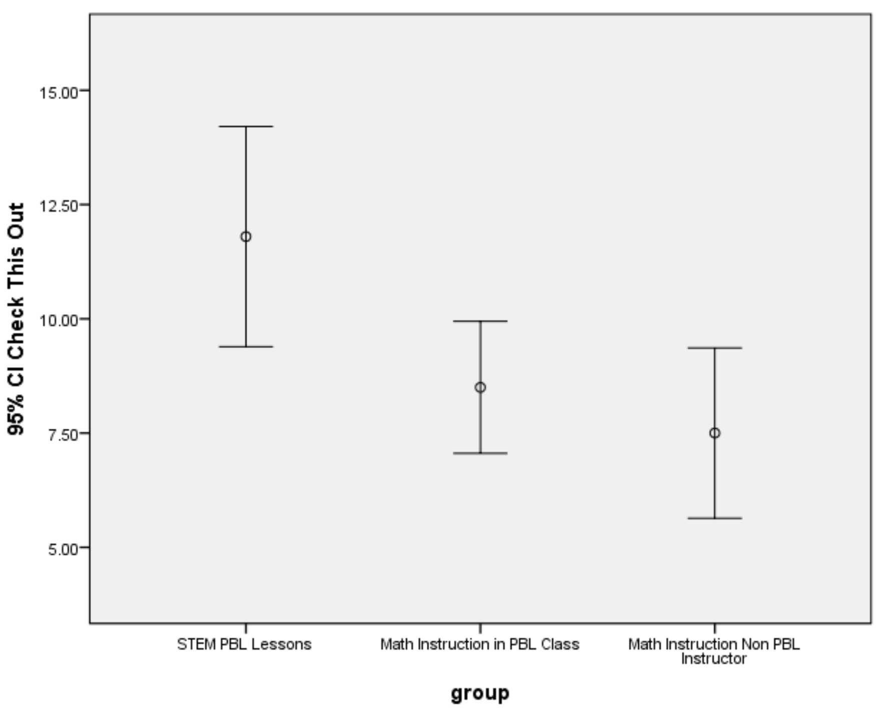
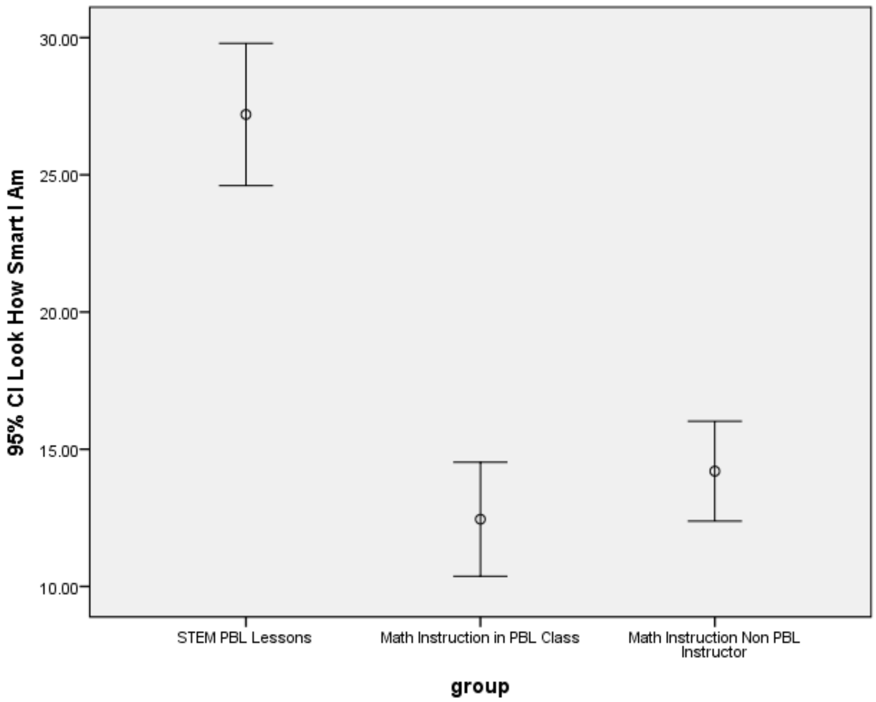


Figure 2.2. Comparison of engagement structures IRIT, CTO, LHSIA, and LMTY in STEM PBL vs non-STEM PBL instruction.



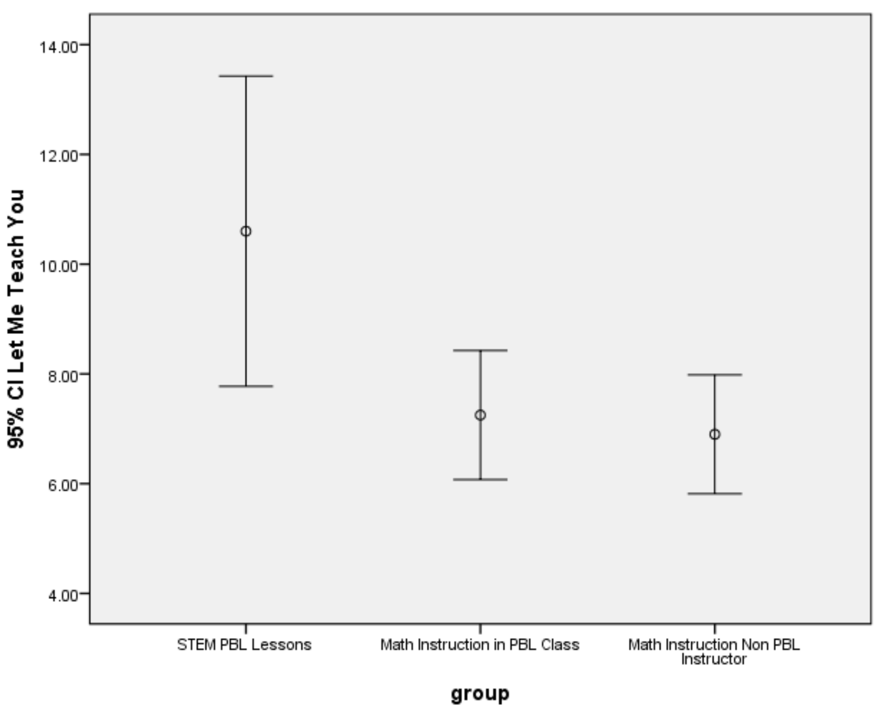


Figure 2.2. Continued.

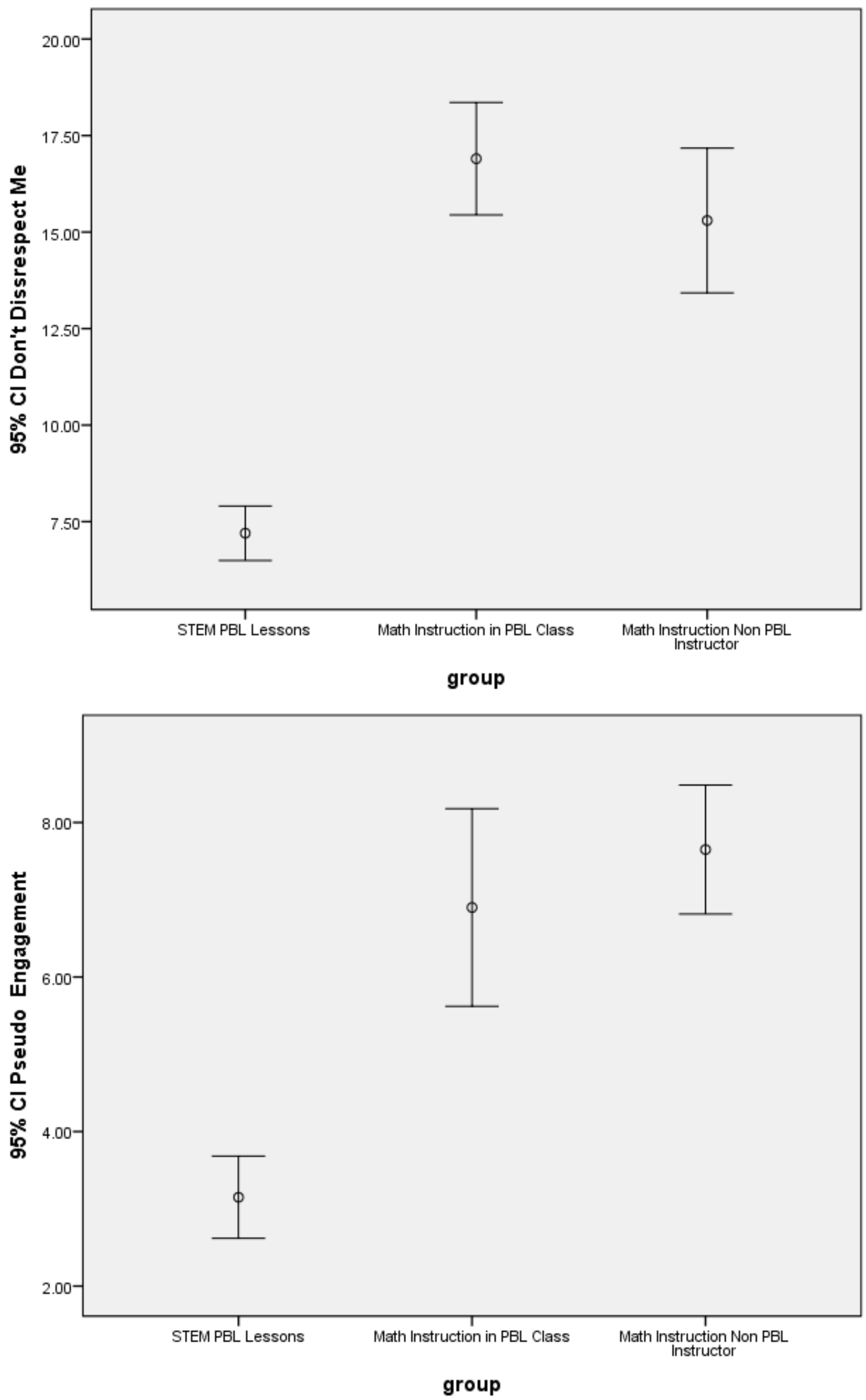


Figure 2.3. Comparison of engagement structures DDM and PE in STEM PBL vs non-STEM PBL instruction.

The means, standard deviations, and the *Cohen's d* effect sizes of each variable are presented in Table 2.3. The On the variables of SOOT, GTJD, PE and DDM the effect sizes indicated that students' scores were practically important but indicating their scores were much lower than the non-PBL instruction by the same teacher. There was a large effect size for LMTY, CTO, LHSIM and IRIT with the effects favoring the STEM PBL instructional strategy. The effects were similar when comparing the STEM PBL instructional strategy to the other non-STEM PBL instructional model taught by another teacher across all of the variables.

Table 2.3

Means, Standard Deviations, and Effect Sizes by Variable and Group

	Group 1		Group 2		Group 3		Groups 1 vs 2	Groups 1 vs 3
Variable	Mean	SD	Mean	SD	Mean	SD	Cohen's *d*	Cohen's *d*
LMTY	10.6	6.038	7.25	2.511	6.9	2.315	0.784	0.886
SOOT	15.4	7.287	18.5	4.478	18.65	4.923	-0.527	-0.532
GTJD	14.9	7.040	16.2	7.164	13.85	5.994	-0.183	0.161
PE	3.2	1.137	6.9	2.731	7.65	1.785	-1.939	-3.080
CTO	11.8	5.146	8.5	3.086	7.5	3.980	0.8017	0.942
DDM	7.2	1.508	16.9	3.110	15.3	4.001	-4.201	-2.941
IRIT	11.5	2.328	5.2	2.783	6.75	4.266	2.465	1.441
LHSIA	27.2	5.540	12.45	4.442	14.2	3.888	2.955	2.758

Discussion

The results indicate that student engagement, as measured by the instrument, was greater with the STEM PBL instructional strategy than the other two. The strong effects of STEM PBL on the IRIT, CTO, LMTY, and LHSIA structures shows evidence that

STEM PBL has a positive impact on student engagement. This finding is reasonable given that STEM PBL instruction is an inquiry-based strategy where students learn through hands on methods and build a product or model to demonstrate their learning. Students are more likely to feel higher levels of IRIT (I am Really Into This), CTO (Check This Out), LMTY (Let Me Teach You) and LHSIA (Look How Smart I AM). These four structures all deal with positive feeling about their learning experience. Students in the STEM PBL instructional group have lower scores on DDM, SOOT, GTJD, and PE versus the non STEM PBL groups. Students who engaged in STEM PBL did not have those engagement structures activated. Therefore, they did not feel anyone disrespected them, did not feel it necessary to fake their engagement (pseudo engagement), did not engage in the activity to stay out of trouble, or simply just to get the job done. While there was no statistically significant difference on GTJD and SOOT the obtained effects were strong and favored the STEM PBL instructional method.

The activities that make use of collaboration through STEM PBL (Sahin et al., 2014) could be responsible for the positive attitudes, engagement, and have the potential to help students learn from each other. Overall the instrument results showed that STEM PBL has a positive effect on student engagement and that the teacher alone does not account for the obtained effects nor does a traditional lesson. Teacher B, while having high fidelity to the content and delivery, the instruction was traditional and focused on demonstration, replication, and then private practice.

The findings in the present study supports the theory that student engagement is heavily influenced by characteristics of the lesson more so than the characteristics of the teacher.

A similar study showed that PBL students had significantly higher overall critical thinking compared with students who experienced lecture, and continued to have higher scores 2 years afterwards (Tseng et al., 2013). Previous research supports that school engagement is an important predictor of academic achievement (Dotterer & Lowe, 2011). Additional longitudinal research is needed to examine the potential long-term effects of STEM PBL on student engagement and examine its impact on mathematics achievement. Implementing STEM PBL in schools can have diverse impacts on student achievement and attitude (Han et al., 2015). Engaging students in STEM PBL promotes instructional strategies' that challenge students to innovate and invent (Kennedy & Odell, 2014) which supports how STEM PBL can not only improve student engagement but highlights the possibility of leading to improved mathematics achievement. Given the engagement effect is measureable and differentiable from the teacher effect it is possible to use the instrument to determine the utility of a pedagogical strategy for increasing engagement. While it would be far reaching to assume that higher levels of engagement would result in increased learning, the literature is clear that learning requires engagement as a prerequisite.

3. MANUSCRIPT #2

Science, Technology, Engineering, and Mathematics Project-Based Learning: Merging Rigor and Relevance to Increase Student Engagement

Increasing rigor and keeping students engaged in the classroom has become essential in the education of today's youth. Science, technology, engineering, and mathematics (STEM) project based learning (PBL) has increasingly become more popular in education today as the demands for collaborative problem solvers increase in the job market. STEM PBL is an instructional method that blends rigor and relevance by providing the means to connect relevant real world situations while maintaining high expectations of student achievement, and increasing engagement. In order to study the effects of STEM PBL on student engagement an experimental design was used. Quantitative data from the three focus groups was collected to assess student engagement within a STEM PBL classroom compared to a non-STEM PBL classroom. An exploratory factor analysis was preformed to more closely look at the 8 engagement structures and resulted in the creation of two higher order factors, (1) academic engagement (AE) and (2) behavioral engagement (BE). The results can be used to verify that there exists an improvement in student academic engagement between the intervention groups, comparing traditional math lessons verses STEM PBL lessons. The results showed that the academic rigor and relevance provided through STEM PBL lessons increases students' academic engagement.

Keywords: mathematics achievement; project-based learning; rigor; relevance; STEM; student engagement

Introduction and Literature Review

Increasing rigor while keeping students engaged in the classroom has become essential in the education of today's youth. Statistics have shown that U.S. education suffers from a lack of rigor in K-12 education, especially in STEM subjects (Sahin & Top, 2015). Today's schools are under tremendous pressure to increase rigor in the classroom (Harada, Kirio, & Yamamoto, 2008) but are losing sight of the importance of providing an education that combines challenge and engagement (Yonezawa, Jones, & Joselowsky, 2009). Researchers reveled that disengagement is a noticeable factor in low student achievement (Stone, Alfreld, & Pearson, 2008). Educators need to be reminded that student engagement is critical to academic success (Yonezawa et al., 2009) and refers to the level of connection, interaction, and learning students demonstrate in classroom projects and activities (Gourgey, Asiabanpour, & Fenimore, 2010). It is essential that educators find methods of increasing rigor and student engagement simultaneously.

STEM PBL activities are rigorous in content and provide students with meaningful opportunities to be actively engaged. "A STEM curriculum can serve as a natural progress to rigorous high school level science, technology, engineering, and mathematics classes" (Capraro & Nite, 2014, p. 1). Rigorous curriculum, instruction, and assessment, integrated technology and engineering in science and mathematics curriculum, and promotion of scientific inquiry and the engineering design process are all requirements of a high-quality STEM education program (Kennedy & Odell, 2014). Project based learning actively engages students in deeper levels of comprehension and is a potentially powerful means to produce relevant and rigorous learning (Bicer, Navruz, Capraro, & Capraro, 2014; Harada et al., 2008; Han, Capraro, & Capraro, 2014). Therefore, the combination of STEM curriculum with PBL can serve as a possible solution to increase rigor and engagement in the classroom.

Rigor

Science, technology, engineering, and mathematics (STEM) project based learning (PBL) activities can increases student engagement while providing rigorous content. Rigor is defined as the quality and intensity (American College Testing, I., 2007) of course work. Rigor can also be described as the extent to which classroom instructions challenge and demand students to use critical thinking skills (Paige, Sizemore, & Neace, 2013). It is important to create an environment where each student is supported and expected to learn at high levels. Providing support through scaffolding, while engaging students in more challenging work is essential to the definition of rigor (Blackburn & Williamson, 2009). The dimensions of rigor include active learning, meaningful content, higher-order thinking, and appropriate expectations (Draeger, Del Prado Hill, Hunter, & Mahler, 2013). A rigorous school environment is described as one where students are engaged in tasks that demand high levels of cognition and focus (Wolf, Crosson, & Resnick, 2005). It has been shown in studies that strong links between rigor and engagement are generated by combining academic rigor with the relevance of applying their knowledge to real-world situation (Siri, Zinner, & Lezin, 2011). Increasing cognitive rigor of students' work has been shown to be effective for improving academic achievement and classroom engagement (Paige et al., 2013).

STEM PBL is an instructional method that blends rigor and relevance to increase student engagement in the classroom.

Relevance

Relevance is an important link between increased academic rigor and student engagement. Relevant content can be referred to as content that relates to one's current interest, contributes to one's future goals, and is considered significant to one's identity (Corso, Bundick, Quaglia, & Haywood, 2013). Relevance can also be defined as having distinct meaning and purpose for the child by accentuating the connection of curriculum content and skill acquisition with life (William & Wilson, 2012). There is an impasse in current educational frameworks that construct academic rigor and relevance as incompatible with one another (Williams & Wilson, 2012) but the truth is that rigor is directly correlated to relevance (Blackburn & Williamson, 2009). Providing relevant and engaging instruction that relates content to real life has become more important than ever (Sahin & Top, 2015). Researchers have shown that students appreciate opportunities to work on real-life projects and believe that such collaborations will better prepare them for their future (Marchetti & Karpova, 2014). STEM PBL offers a balance of providing relevant context for learning and integrating rigorous content knowledge (Kennedy & Odell, 2014). Connecting with the real world allowed students to formulate and investigate questions and problems that are relevant to them (Hasni et al., 2016) increasing student engagement. STEM PBL provides the means to connect relevant real world situations while maintaining high expectations of student achievement, and increasing engagement.

Engagement

There are three specific types of engagement that can influence mathematical performance: affective, behavioral, and cognitive. Affective engagement is a measurement of students' sense of belonging, importance, and appreciation and is related to the positive or negative reactions to teachers, classmates, curriculum, and school (Fredricks & McColskey, 2012; Hospel & Galand, 2016; Goldin, Epstein, Schorr, & Warner, 2011). Positive affective engagement is believed to promote student involvement in school both academically and non-academically. Behavioral engagement is measured by effort, participation, and the ability to follow instructions. Behavioral engagement is comprised of students' observable actions or performance (Dotterer & Lowe, 2011; Fredricks & McColskey, 2012). Behavioral engagement is typically considered important for experiencing a positive academic experience. Cognitive engagement is a matter of students' level of mental effort in relation to their work; it refers to a students' investment in learning, and willingness to put forth the necessary effort to comprehend and master difficult skills (Fredricks & McColskey, 2012; Hospel & Galand, 2016). There have been several attempts to understand cognitive engagement but generally it is unobservable (cf. Gresalfi, & Barab, 2011). Innovative approaches have included methods such as "Cognitive Drive Bys" or "Cognitive Labs" (Winter, Kopriva, Chen, & Emick, 2006). Improving cognitive engagement may lead to improved learning, but the ability to directly influence it often requires proxy measures and the reliance on supposition. The influence of both emotional and cognitive engagement has been shown to have an important positive effect on science and mathematics achievement (Chang, Mo, & Singh, 2013). The use of emotional engagement as an indicator has been used as a measureable indicator of cognitive engagement. Typically, students only form some type of emotional response based on some experience cognitively interpreted.

STEM PBL

STEM PBL has increasingly become more popular in education today as the demands for collaborative problem solvers increase in the job market. Education plays a crucial role in preparing and equipping future generations to take charge and face the challenges of the 21st century (Wan Husin et al., 2016). Project-based teaching is nothing new and originates from the work of authors like Dewey and Kilpatrick (Hasni et al., 2016). Researchers have proven that project based models add rigor and relevance to any class setting (Jollands & Molyneaux, 2012) while also improving students' engagement and criticality in the learning process (Hanney & Savin-Baden, 2013) and heightening the quality of learning in the classroom (Galvan & Coronado, 2014). It understood from previous research that group work is highly correlated to students' enhanced sense of relevance for their everyday life and is related to higher levels of student engagement (Uekawa, Borman, & Lee, 2007). Project based methods have been seen as one of the best teaching method of the 21st century (Galvan & Coronado, 2014) to develop the 21st century skills needed to function successfully in a constantly evolving high-tech world (Capraro & Nite, 2014). Researchers have shown statistically significant correlations between collaborative teaching strategies and development of 21st century skills such as digital literacy, inventive thinking, and effective communication (Wan

Husin et al., 2016). STEM PBL provides student-driven and student-centered instruction, uses authentic, real-life topics to provide context for content learning, increases student collaboration, and increases substance and rigor (Cook & Weaver, 2015). PBL allows for a variety of learning styles with real world orientation beyond basic facts, encourages higher order thinking, promotes meaningful learning from projects that connects students' new learning to prior knowledge (Moylan, 2008). It has been reported that rigor is more strongly linked to engagement (Cooper, 2014) in projects that require hands-on making, active experimentation, and "minds-on" experiences (Wohlwend & Peppler, 2015) and when students are authentically engaged in a lesson they are more successful (Blackburn & Williamson, 2009). STEM PBL can help all students understand relevance, accept rigor, and improve academic achievement (Clark & Ernst, 2008). STEM PBL successfully increases student engagement by merging relevant real-world applications and rigorous content knowledge.

Methodology

In order to study the effects of STEM PBL on student engagement a quasi-experimental design was used. Three focus groups were created and students were randomly assigned to one of the three groups taught by the two teachers. Quantitative data from the three focus groups was collected to assess student engagement within a STEM PBL classroom compared to a non-STEM PBL classroom.

Participants

Participants in this study were students and teachers from an inner city, Title 1 school where 88% of the student population was of low socioeconomic status. Teachers who participated were offered free professional development (PD) and a stipend for their participation. Two exemplar teachers (teacher A and teacher B) were selected as the "Case Study Teachers", and data were collected on 147 of their students. Both teachers participated in over 300 hours of professional development over the course of three years. Teacher A worked in a STEM focused middle school, she participated in 380 hours of STEM PBL professional development, and her instruction focused on bridging mathematics and real-world experiences. Teacher B taught in a non-STEM focused school, she participated in a four-year study to improve algebra teaching and learning where she participated in 419 hours of professional development that focused on content knowledge, improving questioning techniques, and integrating instructional tools such as GeoGebra, calculators, and manipulatives.

While all of their students participated and completed the instrument, only data for the 147 randomly preselected students were provided to the research team. The students were classified by gender, at risk or not at risk, and ethnicity (Asian, African-American, Hispanic, or Caucasian). The three focus groups received different interventions.

Interventions

The intervention was administered in two settings. Teacher A was formally trained in STEM PBL (setting 1) and teacher B received PD on mathematics content dealing with rational number and algebra without a pedagogical component (setting 2). Students were divided into three focus groups. Teacher A taught the students of Group 1 in a controlled STEM PBL lesson. Teacher A also taught the students of Group 2 but did not use STEM PBL for that lesson. Teacher B who was not trained and did not implement STEM PBL, but received content professional development taught the students of Group 3. Groups 2 and 3 received similar lessons with the exact same content. The purpose of Group 2 was an attempt to isolate the teacher effect. At the end of each lesson with the interventions applied, students completed the Rutgers University Mathematical Engagement Structures Inventory (RUMESI) to measure engagement.

Instrument and Data Collection

The RUMESI instrument was adapted from Goldin et al. (2011) and was designed to measure student engagement during mathematics instruction. RUMESI contains 37 items and takes about 10 – 15 minutes to complete. The instrument was administered at the end of instruction and students were asked to respond to an overall feeling, or perception, of class that day. Students rated questions on a five-point Likert scale where 1 represented "this does not represent how I felt in class today" and where 5 represented "this greatly represents how I felt in class today". An exploratory factor analysis (EFA) was performed on the data collected from the 37 items of the RUMESI and all items loaded into 8 components. These 8 components were named and identified as engagement structures that measure the different types of motivating desires and possible engagement features. Shown in Table 3.1 (Adapted from Goldin et al., 2011) are the 8 engagement structures and their measurement descriptions. A score of each structure was calculated for each student based on his or her survey responses. These scores were then used to analyze the engagement level of each focus group.

Table 3.1

Instrument Engagement Structures

Structure	Measurement Description
I'm Really Into This (IRIT)	Measures the motivation to solve the problem for its own sake; leading to sense of flow and accomplishment.
Check This Out (CTO)	Measures the motivation to achieve a nonmathematical "payoff" which can lead to intrinsic interest in the task or heightened extrinsic interest.
Let Me Teach You (LMTY)	Measures motivation to share knowledge, receiving satisfaction from teaching, and helping others.
Look How Smart I Am (LHSIA)	Measures the motivation to impress others with the goal of achieving recognition that their own thinking is correct.
Get the Job Done (GTJD)	Measures the desire to fulfill an assigned task, receiving a sense of satisfaction from having fulfilled the commitment.
Pseudo Engagement (PE)	Measures the students desire to stay under the radar, which decreases engagement.
Don't Disrespect Me (DDM)	Measures when a student felt that they were being disrespected, which distracted from engagement and desire to gain mathematical understanding.
Stay Out of Trouble (SOOT)	Analyzes the students desire to avoid trouble or negative attention.

Factor Analysis

To search for patterns of correlations (Henson, Capraro, & Capraro, 2004) among the 8 structures a second order exploratory factor analysis EFA was performed (Navruz, Capraro, Bicer, & Capraro, 2015). The factor analysis was conducted using Statistical Package for the Social Sciences (SPSS) software version 24. A factor analysis is usually performed on studies with large sample sizes around 300 (Henson et al., 2004) therefore, because the sample size was much smaller, the data were inspected to ensure that it could be factor analyzed. Pallant (2007, p.185) indicated that the data should meet three criteria: (1) the correlation matrix should have several correlation coefficients of .3 and above, (2) Bartlett's test of sphericity should be statistically significant ($p<.05$), and (3) the Kaiser-MeyerOklin (KMO) measure of sampling adequacy should be 0.6 or greater. To test the criteria a correlation analysis was performed. The correlation matrix showed that half of the coefficient indices were equal to, or greater than .3. The KMO measure of the sampling adequacy resulted in a value of 0.821 and the Bartlett's test of sphericity found an approximate Chi-Square value of 300.966 with $p<0.05$.

After examining these results the 8 structures measuring student engagement were subjected to an EFA using the extraction method principal component analysis (PCA) with Varimax rotation. Table 3.2 presents the factor pattern matrix consisting of the coefficients that indicated the unique contribution of each variable to each factor (Henson et al., 2004), coefficients with an absolute value less than 0.44 where suppressed. All variables loaded under 2 components that were named Academic Engagement (component 1) and Behavioral Engagement (component 2). The factors obtained were second order factors (SOF) because they were abstracted from the 8 'previously abstracted' factors and not the original observed variables (Navruz et al., 2015). Factor analysis scores were saved as variables using regression method when running the EFA in SPSS. Factor scores are composite variables that provide information about the item placement on the factors (DiStefano, Zhu, & Mîndrilă, 2009). Using the means of the regression factor scores, confidence intervals were then produced to compare the effects of the factors on individual intervention groups. The value of Cohen's *d* and effect-size correlation, r, was calculated using the means and standard deviations for each possible combination of groups.

Table 3.2

Rotated Component Matrix of Engagement Structures

Structure	**Component** 1	2
GTJD		.775
SOOT		.675
LMTY	.610	
PE	-.833	
CTO	.542	
DDM	-.791	
IRIT	.710	
LHSIA	.819	

Note. Structure Coefficients less than .31 omitted

Results

The EFA resulted in the creation of two SOF, (1) academic engagement (AE) and (2) behavioral engagement (BE). The confidence intervals, in Figure 3.1, were computed using the regression factor scores saved during the

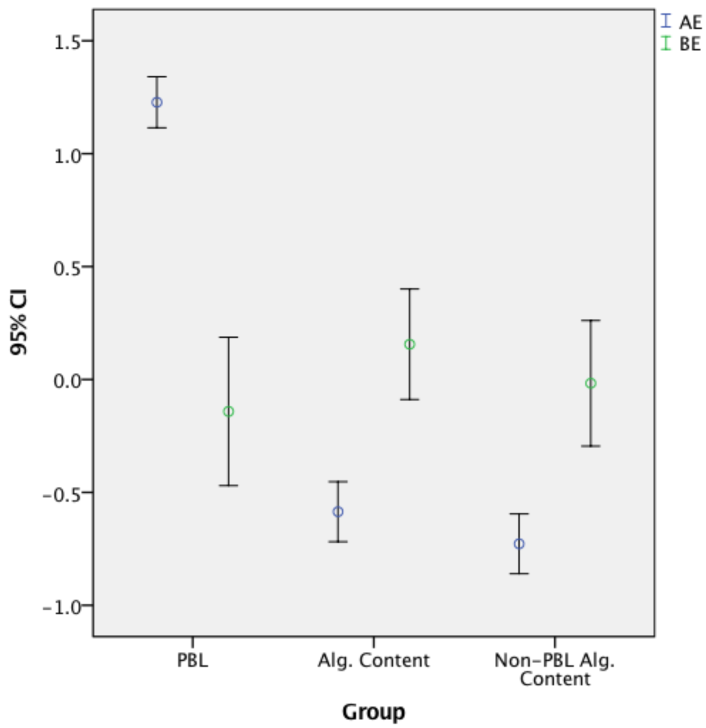


Figure 3.1. Academic engagement (AE) vs. behavioral engagement (BE).

The comparison between groups, using BE regression factor scores for the group means, indicated that the intervention did not have a statistically significant impact on behavioral engagement. The comparison of the AE scores resulted in a statistically significant difference between group 1 verses groups 2 and 3. The mean, standard deviation, and Cohen's *d* of the two factors are presented in Table 3.3, comparing Group 1 to Group 2 and Group 1 to Group 3.

Table 3.3

Descriptive Statistics and Effect Size Estimates for Academic and Behavioral Engagement

	Group 1		Group 2		Group 3		Group1 vs. Group2	Group1 vs. Group3
	Mean	SD	Mean	SD	Mean	SD	Cohen's *d*	Cohen's *d*
AE	1.228	0.4029	-0.5854	0.4724	-0.7278	0.4413	2.837	3.136
BE	-0.1415	1.167	0.1562	0.8700	-0.0167	0.9261	-0.1858	-0.0766

Discussion

The results can be used to verify that there exists an improvement in student academic engagement between the intervention groups, comparing traditional mathematics lessons verses STEM PBL lessons. It is shown there are no statistically significant effects on BE between the STEM PBL lessons verses the traditional math lesson so the obtained results are not likely a teacher effect because the effect disappears for the other group taught by the same teacher but with a different pedagogical strategy. The strong effect of STEM PBL shown on AE provides evidence that STEM PBL has a positive impact on student academic engagement. Similar studies have shown strong links generated by combining academic rigor with the relevance of applying their knowledge to real-world situation (Siri, Zinner, & Lezin, 2011). Increasing cognitive rigor of tasks engaged in by students has been shown to be effective for improving academic achievement and classroom engagement (Paige et al., 2013). In another similar study, results showed that students who experienced PBL instruction had significantly higher overall critical thinking compared with students who experienced lecture, and they continued to have higher scores 2 years afterwards (Tseng, Chang, Lou, & Chen, 2013). Previous researchers support that school engagement is an important predictor of academic achievement (Dotterer & Lowe, 2011) and engaging students in STEM PBL promotes instructional strategies' that challenge students to innovate and invent (Kennedy & Odell, 2014); this supports how STEM PBL not only improves student engagement but emphasizes the possibility to improve academic achievement. Overall, the present study shows that the academic rigor and relevance provided through STEM PBL lessons increases students' academic engagement. Further, longitudinal research is needed to observe the possible long-term effects of STEM PBL on student academic engagement and examine its impact on mathematics achievement.

4. CONCLUSIONS

In first examination of this study, the results imply that student engagement, as measured by the instrument, was greater with the STEM PBL instructional strategy than the other two. When examining the individual engagement structures it is assumed that students are more likely to feel higher levels of IRIT (I am Really Into This), CTO (Check This Out), LMTY (Let Me Teach You) and LHSIA (Look How Smart I AM) given that these four structures all deal with positive feeling about their learning experience. The strong effects of STEM PBL on these four structures shows evidence that STEM PBL has a positive influence on student engagement which is reasonable given that STEM PBL instruction is an inquiry-based strategy where students learn through hands on techniques and build a product or model to exhibit their learning. Students in the STEM PBL instructional group have lower scores on DDM, SOOT, GTJD, and PE versus the non STEM PBL groups. Therefore, they did not sense anyone disrespected them, did not feel it necessary to fake their engagement (pseudo engagement), did not engage in the activity to stay out of trouble, or simply just to get the job done. While there was no statistically significant difference on GTJD and SOOT the acquired effects were strong and favored the STEM PBL instructional method. The activities that make use of collaboration through STEM PBL (Sahin et al., 2014) could be accountable for the positive attitudes, engagement, and have the potential to help students learn from each other. Overall the instrument results showed that STEM PBL has a positive effect on student engagement and that the teacher alone does not account for the obtained effects nor does a traditional lesson.

When examining the study for a second time a factor analysis assisted in confirming the previous findings. The exploratory factor analysis resulted in the creation of two-second order factors, (1) academic engagement (AE) and (2) behavioral engagement (BE). The behavioral engagement factor consists of the structures GTJD and SOOT which both describe engagement related to behavior. The remaining six engagement structures, LMTY, LHSIA, IRIT, CTO, PE, and DDM, make up the academic engagement structure formed. The comparison between groups, using BE regression factor scores for the group means, indicated that the intervention did not have a statistically significant impact on behavioral engagement but the comparison of the AE scores resulted in a statistically significant difference between group 1 verses groups 2 and 3. This result suggests and verifies that there exists an improvement in student academic engagement between the intervention groups, comparing traditional mathematics lessons verses STEM PBL lessons. Since there is no statistically significant effects on BE between the STEM PBL lessons verses the traditional math lesson so the obtained results are not likely a teacher effect because the effect disappears for the other group taught by the same teacher but with a different pedagogical strategy, but the strong effect of STEM PBL shown on AE delivers confirmation that STEM PBL has a positive impact on student academic engagement. There exists an improvement in student academic engagement between the intervention groups confirming the academic rigor and relevance provided through STEM PBL lessons increases students' academic engagement. Therefore, STEM PBL not only improves student engagement but also emphasizes the possibility to improve academic achievement.

The overall findings in the present study supports the theory that student engagement is profoundly persuaded by characteristics of the lesson more so than the characteristics of the teacher. Implementing STEM PBL in schools can have various impacts on student achievement and attitude (Han et al., 2015) and engaging students in STEM PBL supports instructional strategies' that challenge students to innovate and invent (Kennedy & Odell, 2014). The evidence presented supports that STEM PBL cannot only improve student engagement but highlights the possibility of leading to improved mathematics achievement. Given the engagement outcome is quantifiable and differentiable from the teacher effect then it is possible to use the instrument to determine the effectiveness of a pedagogical strategy for increasing engagement. The study of student engagement would benefit from additional longitudinal research to examine the possible long-term effects of STEM PBL on student engagement and observe its influence on mathematics achievement.

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APPENDIX

Engagement Questionnaire
The questions were reorganized from original order to show structure-question breakdown.

For all questions the ratings were from 1-5.
1 means this does not represent how I felt in class today
5 means this greatly represents how I felt in class today.

LMTY – Let Me Teach You 4-20

16. I wanted to teach another student something that I knew that this other student did not know.
17. I listened carefully to the ideas of someone I was trying to help.
18. I helped someone see how to do the math.
19. Others listened carefully to my ideas

SOOT – Stay Out Of Trouble 5-25

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

GTJD – Get The Job Done 5-25

30. I wanted to make sure that all the required work was completed.
31. The most important thing for me was getting the answer to the problem.
32. I worked on getting the answer to the problem.
33. I tried to get members of my group to work to get the answer to the problem.
34. I wanted the teacher to think I am a good student.

PE – Pseudo Engagement 2-10

37. I wanted to look like I was doing work even when I wasn't.
38. I worried that I might get in trouble with the teacher.

CTO – Check this Out 4-20

7. I realized that if I worked hard at the problem I could figure it out.
3. As I made progress, I became more interested in understanding the math.

36. I felt proud about what I accomplished
5. I felt that learning the math today would benefit me or pay off for me.

DDM – Don't Disrespect Me 6-30

25. I was not going to let someone disrespect me and get away with it.
21. I argued strongly in support of my ideas.
22. I had an unpleasant disagreement.
41. I achieved a good understanding of the math we worked on today.
23. My ideas were challenged by others
24. Some person or some group of people tried to disrespect me.

IRIT – I'm Really Into This 3-15

1. I concentrated deeply on today's math problem.
4. I was so into my work that I tuned out things going on around me.
2. I was fascinated by the math today.

LHSIA – Look How Smart I AM 8-40

11   I wanted people to think that I'm smart.
12. I tried to impress people with my ideas about the problem.
13. People seemed impressed with the ideas I shared about the problem.
14. People saw how good I was at the math we did today.
15. I felt smart.
20. I wanted to show someone that my way was better.
42. I was a lot better at math than others today.
21. I argued strongly in support of my ideas.