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The Effects of Problem-Based Learning on Interest in Mathematics for Elementary Students across Time

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THE EFFECTS OF PROBLEM-BASED LEARNING ON INTEREST IN MATHEMATICS FOR ELEMENTARY STUDENTS ACROSS TIME

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Elementary school is a transition time for student interests and motivation and there is a need for teachers to provide opportunities to facilitate continued interest. One area of concern is in the Science, Technology, Engineering, and Mathematics (STEM) disciplines. One pedagogical approach that may help with facilitating interest is problem-based learning (PBL; Barrows, 1996). The purpose of this study was to assess changes in students' reported levels of individual interest in mathematics across time and to assess differences in individual interest based on amount of PBL exposure. Participants included students (*n* = 45) involved with Project GEMS (Gifted Education in Mathematics and Science; Roberts, 2008), which was a federally funded grant through the Jacob K. Javits Gifted and Talented Students Education Program. Interest in mathematics was measured at the beginning of the first fall semester students entered the program and at the end of each subsequent spring semester with a 17-item interest measure consisting of four sub scores: emotion, value, knowledge, and engagement. Results indicate a negative linear trend for composite and sub factors of interest across time except value. The PBL intervention did not moderate the change in interest across time. Conclusions, possible limitations, and future directions are discussed.

Introduction

Elementary school is an important time for students' development. Students are learning core concepts that will help them as they transition to middle and high school. Teachers place an emphasis on their students' achievement, but there is more to a successful education than achievement. Student motivation is an important topic in education and elementary school is an important time for changes in motivation (Gottfried, Fleming, & Gottfried, 2001; Harter, 1981). As students get older, they tend to focus more on performance in a class (i.e., getting good grades) instead of learning concepts out of enjoyment. Harter (1981) describes this change as a shift from internal to external forms of motivation. According to Hidi and Harackiewicz (2000), the shift to external forms of motivation may lead to difficulty with motivating students to learn; however one possible method for counteracting the shift in motivation would be to stimulate students' interest in topics that they are to learn.

Interest has been defined as "a psychological state of engaging or the predisposition to reengage with particular classes of objects, events, or ideas over time" (Hidi & Renninger, 2006, p. 112). Interest can be thought of in terms of situational and individual interest. Situational interest refers to a short-term change in affect in response to stimuli whereas individual interest refers to a relatively stable desire to reengage with material across time (Hidi & Renninger, 2006). The construct of interest has been related to both intrinsic motivation and achievement (Ainley, Hidi, & Berndorff, 2002; Schiefele, 1991). Unfortunately, as with motivation, interest in school subjects tends to decline across time, particularly in science, technology, engineering, and mathematics (STEM) disciplines, and the decline may begin as early as elementary school (Hidi, 2000; Hidi, Renninger, & Krapp, 2004; Schiefele, 2009). With the decline in mathematics interest, educators need pedagogical approaches that may help maintain or facilitate interest.

One approach that may help with facilitating interest in mathematics is problem-based learning (PBL; Barrows, 1996). PBL is a pedagogical approach in which students collaborate in small groups to solve ill-structured real life problems. Some research has assessed the change in interest levels in PBL environments, but the research assessed situational interest based on characteristics in the environment and instructor, and in topics other than mathematics. For example, Rotgans and Schmidt (2011) examined teacher characteristics that influenced student's situational interest across a normal class day and found that those teachers who provided guidance on a similar cognitive level were more likely to have interested students. Phillips, Pugh, Machlev, and Bergstrom (2012) found that pre-service teachers rated their interest in a PBL topic on motivation higher when surveyed at the end of the unit, than during the unit. The above studies assessed interest and PBL at the college level. However, there hasn't been research on how PBL influences interest in elementary school students, particularly in mathematics.

There is some support for using PBL as an instructional approach to facilitate interest, but the studies have not assessed this approach longitudinally. In addition, PBL has not been examined as an approach to facilitate individual interest, which is a relatively stable desire to reengage with material across time (Hidi & Renninger, 2006). The purpose of this study was to assess changes in students' reported levels of individual interest in mathematics across time and to assess differences in individual interest based on amount of PBL exposure. Two research questions were explored.

Research Question 1: How does individual interest in mathematics, both a composite and subcomponents of emotion, value, knowledge, and engagement outside of class, change across five-years in elementary school students who have higher ability?

Research Question 2: Are there differences in individual interest in mathematics, both a composite and subcomponents of emotion, value, knowledge, and engagement outside of class, across five-years in elementary school students who have higher ability based on the amount of a problem-based learning intervention in mathematics that they receive?

To address the research questions, the following literature review will discuss (a) the construct of interest and present information on interventions that may impact interest, and (b) PBL and its possible impact on interest.

Literature Review

Interest

Interest has been described as "a psychological state of engaging or the predisposition to reengage with particular classes of objects, events, or ideas over time" (Hidi & Renninger, 2006, p. 112). Among the different conceptualizations of interest, there is a consensus that there are both situational and individual (i.e., personal) components to interest. Situational interest refers to a short-term change in affect and focus that may or may not persist over time. If someone has a situational interest in a topic, his/her attention is captured by a novel stimulus, e.g., games, puzzles, or jokes (Bergin, 1999; Matarazzo, Durik, & Delaney, 2010; Mitchell, 1993). Individual interest is a predisposition where someone actively seeks to reengage with content over time e.g., actively seeking information that interests the individual (Hidi & Renninger, 2006).

Interest has been used in different motivational theories in some form. For example, in both Self-Determination Theory (SDT; Ryan & Deci, 2000) and Expectancy-Value Theory (Wigfield & Eccles, 2000), interest is conceptualized as an enjoyment component in both the constructs of intrinsic motivation and intrinsic value. Intrinsic motivation has been defined as engaging in an activity just for the enjoyment one gets in the activity (Ryan & Deci, 2000). The definition of intrinsic value is similar to intrinsic motivation. Utility value, or usefulness in content for future goals, has also been associated with interest and thought of as more of an extrinsic motivator (Wigfield & Eccles, 2000). Alexander's Model of Domain Learning (Alexander, 2004; Alexander, Sperl, Buehl, Fives, & Chiu, 2004) posits that having interest in a topic is associated with acquisition of knowledge. As students develop knowledge in a content area, individual interest tends to develop. Together, different motivational theories conceptualized interest and applied the concept to an emotional response and components of value and knowledge.

Theories on the construct of interest have also placed emphasis on some of the following characteristics: emotion, perceived value, knowledge, and engagement, but only one places emphasis on all four characteristics (Renninger & Hidi, 2011). Hidi and Renninger's (2006) four-factor model of interest development appears to be a more complete model of interest because the model places emphasis on all four characteristics of emotion, value, knowledge, and engagement. The model was chosen as a theoretical basis of the interest measure used in the current study based on the model's completeness (Wininger, Adkins, Inman, & Roberts, 2014). Hidi and Renninger's model has four stages with varying amounts of affect, value, knowledge, and engagement via self – directed learning. The first stage is "triggered situational interest" where attention is captured by novel stimuli. Generally one has an affective response to stimuli, either positive or negative, e.g., frustration or curiosity may lead to increased interest. The second stage is "maintained situational interest" where attention is still captured by external sources, but this has either happened on multiple occasions, or the nature of the external prompt requires sustained attention for a period of time (e.g., a group project in a class). With maintained situational interest, one may have general positive emotions toward the topic, and one may develop a sense of value for the topic, which may facilitate the development of individual interest. The third stage is "emerging individual interest." In emerging individual interest, a person is starting to develop their knowledge in a content area and sees value in this material, but still needs some external support, i.e., may need assistance from a teacher to help guide his/her learning when encountering difficulties. In the fourth stage, "well-developed individual interest," the level of engagement may be such that external support is typically not needed. One has a defined knowledge set, positive affect, and value, and often will persist in learning about his/her interest even when difficulties arise. For example, if someone has a well-developed interest in mathematics and they see a new, yet difficult, application of statistics, they will be more likely to engage in the new material and find resources to help them understand the topic. They will also be less likely to give up even if the topic seems difficult. In summary, it appears that the four factors of interest development are dependent upon each other, i.e., one cannot skip stages of interest development. Table 1 provides a summary of Hidi and Renninger's model with regards to emotion, value, knowledge, and self-directed learning.

Table 1

Summary of Hidi and Renninger's (2006) model

	Positive Emotions	Value	Knowledge	Self-Directed Learning
Triggered situational	Present	Absent	Minimal	Absent
Maintained Situational	Present	Present (developing)	Minimal	Absent
Emerging Individual	Present	Present	Moderate	Present (co-regulated)
Well-developed Individual	Present	Present	Substantial	Present (Self-regulated)

Interest across time. Unfortunately, as with motivation, interest tends to decline across time, particularly in STEM disciplines including mathematics (Fredricks & Eccles, 2002; Hidi, 2000; Hidi et al., 2004; Schiefele, 2009). Hidi (2000) suggests that the change in subject interest may begin as early as upper elementary school. In this section, interest decline is discussed in the context of a composite interest score, and sub factors of emotion, perceived value, knowledge, and engagement along with suggestions for facilitating each sub factor. The above sub factors align with the stages of Hidi and Renninger's (2006) model for interest development.

Composite. As mentioned above, interest tends to decline across time, and this decline tends to start in the elementary school years (Fredricks & Eccles, 2002; Hidi, 2000). Fredricks and Eccles (2002) examined longitudinal changes across childhood through adolescence for interest and competence beliefs in mathematics in three staggered cohorts. The authors found a decline in mathematics interest until high school where there was a slight increase. This decline and rebound is similar to a documented change in a closely related construct, intrinsic motivation (Gottfried et al., 2001). The decline in interest and intrinsic motivation makes sense because during later elementary school through high school, students shift their focus away from merely learning for enjoyment to learning to perform well on assessments (Harter, 1981). In high school, there are more opportunities to select classes to take, and this may explain some of the rebound in interest and intrinsic motivation.

Emotion. Some of the literature that measures "interest" appears to measure the emotional/affective responses and assesses interest in other theoretical orientations, e.g., SDT (Ryan & Deci, 2000) and Expectancy-Value Theory (Wigfield & Eccles, 2000). Most studies addressing emotional aspects of interest study participant's situational interest in a task short term. Participants typically respond to questions about how much he/she likes a topic or how much he/she enjoys a given task, e.g., reading expository texts (Ainley et al., 2002; Ainley, Hillman, & Hidi, 2002).

Additionally, some literature assesses emotional/affective responses longitudinally, but fewer studies have assessed emotion alone (i.e. not embedded within a composite score). For example, Eccles, Wigfield, Harold, and Blumenfeld (1993) assessed subjective values across time in the domain of mathematics, but the questions assessing emotion were not assessed independent of other values, e.g., attainment value, so interpreting whether emotion declined across time was not possible. However, Wigfield and colleagues (1997) did assess interest/emotion separate of other values and noticed differences across time, but the differences were not consistent across cohorts. For example, one cohort declined across a two-year period while a second group increased. When averaged, it appears that emotion declines across time. The decline is consistent with the intrinsic motivation literature where intrinsic motivation shifts to more extrinsic motivation (e.g., Harter, 1981) from third grade through the start of high school.

Emotional responses are a sign of situational interest in a topic (Hidi & Renninger, 2006). Some tasks that may help elicit emotional responses of interest include novel stimuli or situations, e.g., puzzles, games, and humor (Bergin, 1999; Matarazzo et al., 2010; Mitchell, 1993). Novelty is what sparks one's interest in a given topic and can elicit a positive emotional response (Silvia, 2005). Silvia (2005) investigated how novel stimuli influence interest and found that those who interacted with novel or complex stimuli were more interested in the task. Another task that may help with situational interest is group work (Hidi & Harackiewicz, 2000). Hidi and Harackiewicz (2000) reported that people working in groups reported higher levels of situational interest than those working alone on the same projects. The above recommendations suggest that to facilitate situational interest and positive emotional responses, teachers need to use novel tasks and also encourage group work.

Value. According to Brophy (2008) value in content depends on students' understanding when, where, and why someone would use said content. Brophy (2008) also mentions that most of the literature investigating value refers to utility value, which is usefulness in content. Perceived utility value in mathematics tends to decline across time (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Wigfield et al., 1997). Wigfield and colleagues (1997) examined values in multiple disciplines, including mathematics, in elementary school students in three cohorts and found that on average value in mathematics was relatively lower across time; however, the values were more stable for older cohorts (i.e. the value declines become less steep across time). Jacobs and colleagues (2002) examined the same population for differences in value across grades one through twelve. Results indicated a decline in value across time although the data were aggregated from different cohorts, i.e., different people made up different grade points. Given the above information, it seems that value in mathematics decreases across time, but ratings become more stable with time. The change in value may relate to students making more realistic expectations given that students have more opportunities to see value in the content, whether it is usefulness or valuable for assessment (Wigfield & Eccles, 2002).

There is a need to stabilize value declines and some intervention studies have helped by having participants relate core concepts to everyday life. Hulleman and Harackiewicz (2009) investigated how a relevance intervention would influence value and interest in science. In Hulleman and Harackiewicz (2009), students in the intervention group were asked to write about course content and how the content relates to everyday life over the course of one semester. The control student group outlined their readings over the semester. Those prompted to identify the value of the material were more likely to be interested in the content and chose to enroll in more science courses during future semesters. Hulleman, Godes, Hendricks, and Harackiewicz (2010) investigated a similar intervention with psychology and mathematics students, and found similar results – when students are asked to make connections from the content to their future goals, they become more interested in the content. The above literature suggests that increasing the perceived value in content helps facilitate interest in the topic, and perhaps bridge the gap between situational and individual interest.

Knowledge. Prolonged exposure and involvement with content not only helps with developing value, but also developing a knowledge base. The construct of knowledge is multifaceted including domain knowledge and topic knowledge (Alexander, 1992; Alexander, Kulikowich, & Schulze, 1994). Domain knowledge refers to what someone knows about a field, e.g., mathematics, whereas topic knowledge is more specific, e.g., fractions. Although there have not been any longitudinal studies involving interest and knowledge, increased domain and topic knowledge have been associated with increased interest (Alexander, Kulikowich, & Jetton, 1994; Alexander et al., 1994; Murphy & Alexander, 2002).

The relationship between interest and knowledge depends on actual knowledge and expertise (Alexander, 1992). Most research assessing student knowledge development has focused on undergraduate and graduate students. Even at the undergraduate level, the level of domain knowledge is relatively small, so it would seem that those with even less domain knowledge would not exhibit as much individual interest. One aspect to consider is a student's perceived level of knowledge or competence. Some research suggests perceived competence declines across time. In other words, as students are exposed to more content, they feel like they know less (Eccles et al.,1993; Fredricks & Eccles, 2002).

Engagement. Those who engage with content outside of class are more likely to have an interest in the content (Simpkins, Davis-Kean, & Eccles, 2006). Involvement, or engaging in the material, is important for increasing interest. Engaging with content (i.e., being cognitively active with the material) seems almost intuitive for facilitating continued interest because without exposure, whether it comes from teachers, or parents, one would not have the opportunity to further develop his/her interest. Renninger and Hidi (2011) suggest that once interest is maintained, students will start to self-direct their involvement in learning content, but those who fall in the emerging individual interest stage may still need help with facilitating his/her learning. One way to foster involvement is in an active classroom (Rotgans & Schmidt, 2011). In an active classroom, students are actively working on content rather than passively listening to a lecture. One example of an active learning classroom is a problem-based learning classroom (PBL; Barrows, 1996).

Summary. The literature suggests a decline across time in interest in mathematics (Hidi, 2000). The decline has been observed in terms of a composite interest/emotion and in a closely related construct, intrinsic motivation (Gottfried et al., 2001). Declines were also observed for value and sub components of value, i.e. utility value and intrinsic value (e.g., Fredricks & Eccles, 2002). Perceived competence tends to decline across time perhaps because students are being exposed to more and more material (Eccles et al., 1993). There is little in the literature about engagement outside of class as a function of time, but what was found suggests that those with an interest in a topic were more likely to engage in activities outside of class (Simpkins et al., 2006). Previous research suggests that an approach that incorporates novelty, group work, task value, knowledge acquisition, and engagement can play a role in the development of interest. Interventions that use these strategies can help facilitate situational and individual interest in a topic. Based on this review and the lack of prior research specifically measuring individual interest and its sub-components longitudinally, it is predicted that composite interest will decline across time. No directional hypotheses can be made for the sub-factors as the analyses are exploratory in nature. See Table 2 for examples of longitudinal studies.

Table 2

Examples of longitudinal studies assessing interest and sub-factors

Construct	Longitudinal examples
Composite Interest	Fredericks and Eccles (2002)
Emotion	Wigfield et al. (1997)
Value	Fredericks and Eccles (2002) Jacobs et al., (2002) Wigfield et al., (1997)
Knowledge	Not applicable
Engagement	Not applicable

Problem-based learning

One pedagogical approach that may influence interest is problem-based learning (PBL; Barrows, 1996). PBL is an active learning technique where students dedicate extended time and resources to solve an applied, real-world, problem. This technique was originally developed for medical school students at McMaster University. Through the years, PBL has been extended to other disciplines (e.g., science, art, mathematics) and other levels of education (e.g., elementary, secondary, post-secondary). In this section, characteristics of PBL are discussed in relation to facilitating interest followed by uses of PBL in STEM disciplines, and particularly in mathematics.

The original characteristics of PBL are (a) learning is student-centered, (b) learning occurs in small student groups, (c) teachers are facilitators or guides, (d) problems form the organizing focus and stimulus for learning, (e) problems are a vehicle for the development of clinical problem solving skills, and (f) new information is acquired through self-directed learning (Barrows, 1996, pp. 5-6). Gallagher, Stepien, Sher, and Workman (1995) stated that initiating learning with a problem was more realistic since in real life problems, all necessary information and solutions are not given to someone at the onset of problem solving. By learning from a problem, students will have a better understanding of why they are learning a particular set of information.

PBL has been used as a pedagogical approach in STEM disciplines. Gallagher and colleagues (1995) set the framework for introducing PBL into secondary school science classrooms. The recommendations included making sure the ill-structured problem was related directly to the important concept being learned, giving the students the opportunity to examine the question beyond the classroom, giving students the opportunity analyze and manage their own data, and giving the students the opportunity to present their proposed solutions to their colleagues (pp. 139-140).

Once PBL was implemented as a pedagogical approach in elementary and secondary schools, the approach was used to see if there were differences in achievement based on instructional strategy. For example, Drake and Long (2009) assessed differences in performance in science classrooms using PBL versus direct instruction. Results indicated that there were differences in achievement prior to implementing the PBL unit, but students in the PBL unit had a larger growth in performance compared to the direct instruction group.

Most of the research involving PBL has been from a science perspective, but there have been advances to study PBL in mathematical contexts. Project M^3 (Mentoring Mathematical Minds; Gavin, Casa, Adelson, Carroll, & Sheffield, 2009) was developed to offer an advanced curriculum for elementary students who performed well in mathematics. Project M^3 was developed around curriculum standards for students who are gifted and mathematically inclined, but the essence of PBL is implemented in the program. With this program, students are able to use their skills to solve a variety of problems, and have extended opportunities to think about the material they are studying. There are opportunities for help and additional challenge if needed. Results from Gavin and colleagues (2009) suggest that this PBL program is associated with better performance in mathematics compared to peers with similar ability.

Interest in mathematics was not assessed in the aforementioned study; however, based on the characteristics of PBL, PBL may be able to influence interest in mathematics. Students are introduced to a novel, ill-structured problem, and this novelty may influence interest by capturing student’s attention (Mitchell, 1993; Silvia, 2005; Matarazzo et al., 2010). Students also solve the problems in small groups, which has been associated with increased interest relative to working alone (Hidi & Harackiewicz, 2000). By spending time investigating the problem, there is an opportunity to see the value in the content by the students applying what they are learning to the real world (Hulleman & Harackiewicz, 2009; Hulleman et al., 2010). While answering the question, students will have to look for further sources of information, thus helping expand their knowledge base (Hidi & Renninger, 2006; Murphy & Alexander, 2002). Also, students may become curious about what they learned in the classroom and may wish to learn more outside of the classroom (Simpkins et al., 2006). The above characteristics could foster both situational and individual components of interest (See Table 3 for connections between interest development and characteristics of PBL).

Table 3

Comparison of interest to PBL

Interest development	PBL characteristics (Barrows, 1996)
Novel stimuli or content may help facilitate situational interest (Mitchell, 1993; Silvia, 2005; Matarazzo, Durik, & Delaney, 2010)	PBL is initiated through a new real world problem
Students who engage in group-work reported being more interested in content than those working alone (Hidi & Harackiewicz, 2000)	"Learning occurs in small student groups"
Students who had to connect value to content had higher interest (Hulleman & Harackiewicz, 2009; Hulleman et al., 2010)	"Learning relates to real world, applied problems"
Students with interest in content were more likely to develop a larger knowledge base (Hidi & Renninger, 2006; Murphy & Alexander, 2002)	"New information is acquired through self-directed learning"
Engagement outside of the classroom has been associated with students with higher interest (Holstermann, Grube, & Bogeholz, 2010)	"New information is acquired through self-directed learning" "Problems are a vehicle for the development of problem solving skills." "Learning is student centered."

Summary. Given the possible connections between facilitating interest and the components of PBL, the following hypothesis and sub-hypotheses were proposed to address research question two.

Hypothesis two: Individual interest in mathematics will be moderated by amount of exposure to a PBL intervention such that more exposure to PBL will lead to more stable individual interest.

Hypothesis 2a: Emotional responses for mathematics will be moderated by amount of exposure to a PBL intervention.

Hypothesis 2b: Perceived value in mathematics will be moderated by amount of exposure to a PBL intervention.

Hypothesis 2c: Perceived knowledge in mathematics will be moderated by amount of exposure to a PBL intervention.

Hypothesis 2d: Engagement in mathematics outside of school will be moderated by amount of exposure to a PBL intervention.

Project GEMS

Project GEMS (Gifted Education in Mathematics and Science; Roberts, 2008) was a five-year program funded through a grant from the Jacob J. Javits Gifted and Talented Students Education Program. The purpose of this program was to help increase achievement in science and mathematics for students of higher ability in underrepresented areas. Schools selected for this program had at least 50 percent of students qualifying for free or reduced lunch. Six schools from a south central Kentucky school district were selected to participate. During this program, students were exposed to varying amounts of problem-based learning in mathematics as part of the curriculum. Students were selected to participate based on various measures such as: The Iowa Test of Basic Skills (ITBS) mathematics and science subtests, The Cognitive Abilities Nonverbal test (CogAT), and teachers' ratings of students' abilities in mathematics and science.

All scores were converted to local grade standardized scores. Then, a composite standardized score was created (ITBS math, science, CogAT nonverbal, teacher math, and teacher science). Scores were sorted from high to low and the top fifteen students within each grade for each school were identified. Once selected to take part in the study, the sample of students were divided into one of three conditions using school affiliation and treatment as grouping variables. The first condition consisted of students in two of the schools who completed two units of problem-based learning in their normal classroom per academic year. The students in this first condition also attended a one-day a week magnet program (i.e., GEMS Academy) where they completed an additional two units of problem-based learning (i.e., PBL plus group). The second condition (i.e., PBL only group) consisted of students from two additional schools who completed two units of problem-based learning in their normal classroom per academic year. The students in the remaining two schools served as the control group and did not receive PBL exposure as part of this program.

From third through fifth grades, students completed units from Mentoring Mathematical Minds (Gavin, Chapin, Dailey, & Sheffield, 2006). Mentoring Mathematical Minds units ranged from 29 to 41 days based on a 50-minute class time. During the sixth grade, students completed units from Math Innovations (Sheffield, Chaplin, & Gavin, 2010). In addition, the sixth graders in the PBL plus group, i.e., students who went to the GEMS academy, completed Math Innovation units from the seventh grade curriculum book. Math Innovation units ranged from 19 to 27 days based on a 45-minute class time. See Tables 4 and 5 for project GEMS curriculum units (Roberts, Tassell, Inman, & Wininger, 2011).

Table 4

Mathematics Curriculum for PBL Plus Condition

	Mentoring Mathematical Minds			Math Innovations	
	3rd Grade	4th Grade	5th Grade	6th Grade	7th Grade
In-Class	• “Unraveling the Mystery of the MoLi Stone: Place Value and Numeration” (fall semester) • “What’s the *Me* in *Me*asurement All About?” (spring semester)	• Factors, Multiples, and Leftovers: Linking Multiplicatio n and Division” (fall semester) • “Getting into Shapes” (spring semester)	• “Treasures from the Attic: Exploring Fractions” (fall semester) • “Funkytown Fun House: Focusing on Proportional Reasoning and Similarity” (spring semester)	• “A Balancing Act: Focusing on Equality, Algebraic Expressions and Equations” • “Notable Numbers: Focusing on Fractions, Decimals and Percents” • “Sizing Up Shapes: Focusing on Geometry and Measurement” • “Fraction Times: Focusing on Multiplication and Division of Fractions and Decimals” • “At This Rate: Focusing on Ratios and Proportions”	
GEMS Academy (Pull-out program)	• Awesome Algebra” (fall semester) • ”Digging for Data” (spring semester)	• “At the Mall with Algebra” (fall semester) • “Analyze This!” (spring semester)	• “Record Makers and Breakers” (fall semester) • “What Are Your Chances?” (spring semester)		• “Puzzling Proportions: Focusing on Rates, Percents and Similarity” (fall semester) • “Sizing Up Solids: Focusing on Surface Area and Volume” (Spring semester)

Note: PBL Plus students in 6th grade completed Math Innovations course 2 (7th grade) units while at the GEMS Academy

Table 5

Mathematics Curriculum for PBL Only Condition

	Mentoring Mathematical Minds			Math Innovations
	3rd Grade	4th Grade	5th Grade	6th Grade
In-Class	• "Unraveling the Mystery of the MoLi Stone: Place Value and Numeration" (fall semester) • "What's the *Me* in *Me*asurement All About?" (spring semester)	• Factors, Multiples, and Leftovers: Linking Multiplication and Division" (fall semester) • "Getting into Shapes" (spring semester)	• "Treasures from the Attic: Exploring Fractions" (fall semester) • "Funkytown Fun House: Focusing on Proportional Reasoning and Similarity" (spring semester)	• "A Balancing Act: Focusing on Equality, Algebraic Expressions and Equations" • "Notable Numbers: Focusing on Fractions, Decimals and Percents" • "Sizing Up Shapes: Focusing on Geometry and Measurement" • "Fraction Times: Focusing on Multiplication and Division of Fractions and Decimals" • "At This Rate: Focusing on Ratios and Proportions"

The present study

As stated previously, there are general declines across time in achievement motivation and interest in STEM disciplines, and declines may begin as early as elementary school (Hidi, 2000; Hidi et al., 2004; Schiefele, 2009). The literature suggests that active pedagogical approaches such as problem-based learning (Barrows, 1996) may be useful to help maintain interest levels in STEM disciplines across time. Although Project GEMS (Roberts, 2008) was implemented to help with achievement in mathematics and science in a geographic region that is underrepresented in STEM disciplines, the present study assessed how individual interest in mathematics changed across time and whether a PBL intervention moderated individual interest in mathematics (i.e., whether more PBL resulted in more stable individual interest). Two research questions were proposed. The first research question was exploratory in nature, except relating to composite interest. For the second research question, one hypothesis and four sub-hypotheses were proposed. Table 6 summarizes the research questions and hypotheses.

Table 6

Summary of Research Questions and Hypotheses

Research Questions	Hypotheses
Research Question 1:How does individual interest in mathematics, both a composite and subcomponents of emotion, value, knowledge, and engagement outside of class, change across five-years in higher ability elementary school students?	1. Individual interest in mathematics will decline across time. Questions regarding sub factors are exploratory in nature.
Research Question 2: Are there differences in individual interest in mathematics, both a composite and subcomponents of emotion, value, knowledge, and engagement outside of class, across five-years in higher ability elementary school students based on the amount of a problem-based learning intervention in mathematics that they receive?	2: Individual interest in mathematics will be moderated by amount of exposure to a PBL intervention such that more exposure to PBL will lead to more stable individual interest. 2a: Emotional responses for mathematics will be moderated by amount of exposure to a PBL intervention. 2b: Perceived value in mathematics will be moderated by amount of exposure to a PBL intervention. 2c: Perceived knowledge in mathematics will be moderated by amount of exposure to a PBL intervention. 2d: Engagement in mathematics outside of school will be moderated by amount of exposure to a PBL intervention.

Method

Participants

"Select" students from six elementary schools in one south central Kentucky district were chosen to participate in Project GEMS (Gifted Education in Math and Science; Roberts, 2008). Students who were a part of Project GEMS for all five years with completed data served as participants for this study. The initial sample consisted of approximately 90 students, but due to a variety of reasons, e.g., moving, incomplete data (where there were two or more missing testing times across the five year period), the final sample consisted of 45 students. The final sample consisted of 22 males and 23 females. There were 20 students in the PBL plus condition, 12 in the PBL only condition, and 13 in the control condition. Eight of the 45 participants had partially completed data where averages from the other measurements were entered.

Materials

Mathematics interest measure. Various measures have been developed to assess situational (e.g., Linnenbrink-Garcia et al., 2010) and individual interest in mathematics (e.g., Aiken, 1974, Fennema & Sherman, 1976, Stevens & Olivarez, 2005). However, most of these measures suffer from several limitations such as: lack of a clear conceptual/theoretical basis, limited breadth (usually just assess emotion), and designed for high school or college populations. Wininger and colleagues (2014) developed the mathematics interest measure as a part of Project GEMS (Roberts, 2008). This 17-item measure consists of four sub factor scores: Emotion (questions 1, 2, 3, and 4), Value (questions 5, 6, and 7), Knowledge (questions 8, 9, 10, and 11), and Engagement outside of class (questions 12, 13, 14, 15, 16, and 17). The above-mentioned sub scores represent components of individual interest from Hidi and Renninger's (2006) model of interest development. Students respond to questions on a one to five Likert-scale ranging from never to always. An example of an emotion question is "math is interesting." An example of a value question is "learning about math is important." An example of a knowledge question is "I know a lot about math." An example of an engagement question is "I like to do math problems outside of school." See Appendix A for mathematics interest measure. Wininger and colleagues found that the reliability estimate of the overall measure was .90. Estimates for each sub score were .92 for emotion, .71 for value, .87 for knowledge, and .83 for engagement. Construct validity, in particular the factor structure of the measure, was supported for the four sub factor scores through two exploratory and one confirmatory factor analyses (see Wininger et al., 2014 for further information).

Procedure

Participants initially completed the math interest measure at the beginning of the first semester they were in Project GEMS (Roberts, 2008). Participants were placed into one of three groups, PBL plus, PBL only, or control, based on which school they attended. The first group received PBL instruction in mathematics, and attended a one-day per week pull out program (GEMS Academy) where students had extra access to additional PBL instruction. Participants in the PBL+ group typically completed two PBL units in math per semester, i.e., one in their normal class and one in the GEMS academy. The second group received PBL instruction in mathematics, but did not attend a pull out program. Participants in the PBL only group typically completed one PBL unit per semester. The third group was a control group for this study and did not receive PBL instruction.

Data were collected at the beginning of the first semester of the program, fall ’09, and at the end of each spring a student was in the program, spring ’10 through spring ’13, using the math interest measure (Wininger et al., 2014). Students completed this measure online with teachers present to read instructions and provide help if needed.

Results

Descriptive statistics were calculated for composite interest and the subtypes of emotion, value, knowledge, and engagement. Skewness and kurtosis were examined and outliers were removed for analyses if they were three standard deviation units above or below the mean on repeated measures. Exclusion criteria led to the removal of participants for the following analyses: composite interest ($n = 2$), emotion ($n = 1$), value ($n = 3$), and knowledge ($n = 3$). Some participants were removed for more than one analysis, i.e., some participants had multiple scores that met exclusion criteria. See Tables 7 through 11 for descriptive statistics.

Separate 3 (*Treatment condition*) x 5 (*Time of testing*) mixed factorial ANOVAs were performed on the composite interest score and the sub factor scores of emotion, value, knowledge, and engagement. Since the hypotheses were made with respect to time, linear trend analyses were examined via the within-subjects contrasts table. Pair wise comparisons were assessed with the Bonferroni method. See figures 1 and 2 for variable trends across time.

Composite Interest

Table 7 summarizes composite interest scores across five years. A significant negative linear trend for interest was found, $F\ (1, 40) = 27.92$, $p < .05$, $\eta_p^2 = .41$. Pairwise comparisons using the Bonferroni correction revealed differences between all data points and spring ’13 (the final assessment point). In addition there were differences between spring ’10 and spring ’12. See Table 13 for pairwise comparisons. The treatment by time of measurement interaction for composite interest was not significant, $F\ (2, 40) = 0.23$, $p = .79$, $\eta_p^2 = .01$. See figures 1 and 2 for variable trends across time.

Table 7

Composite interest across five years

	PBL+ (*n* = 20)	PBL (*n* = 12)	Control (*n* =13)	Total (*n* = 45)
Variable	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)
Fall '09	4.04 (0.59) -0.19 (0.96)	3.69 (0.59) -0.69 (-0.10)	3.91 (0.62) 0.35 (-1.01)	3.91 (0.57) -0.20 (-0.03)
Spring '10	3.81 (0.55) -1.42 (3.60)	3.67 (0.27) 0.14 (-1.07)	4.00 (0.44) 0.59 (-1.26)	3.82 (0.47) -0.81 (2.73)
Spring '11	3.52 (0.63) -0.37 (0.19)	3.66 (0.62) -1.16 (1.84)	3.80 (0.43) 0.36 (-0.53)	3.64 (0.58) -0.65 (1.96)
Spring '12	3.40 (0.66) -0.31 (-0.15)	3.53 (0.48) -0.85 (1.72)	3.74 (0.34) -0.94 (0.33)	3.53 (0.54) -0.76 (0.61)
Spring '13	3.36 (0.58) -0.98 (3.54)	3.08 (0.50) 0.52 (-0.24)	3.45 (0.29) -0.26 (-1.00)	3.32 (0.50) -0.65 (1.96)

Emotion

Table 8 summarizes emotion sub factor scores for mathematics across five years. A significant negative linear trend for emotion was found, F (1, 41) = 23.35, $p < .05$, η_p^2 = .36. Pairwise comparisons using the Bonferroni correction revealed differences between all the time points and spring '13 (the final assessment point). There was no treatment by time of testing interaction for emotion, F (2, 41) = 1.35, $p = .27$, $\eta_p^2 = .06$. In addition, differences among the treatment conditions were found, F (2, 41) = 3.38, $p =$ .04, η_p^2 = .14. Pairwise comparisons using the Bonferroni correction revealed the only significant difference was between the PBL and the control condition where the PBL group was lower than the control group. See figures 1 and 2 for variable trends across time. Additionally, see Table 13 for pairwise comparisons among time points

Table 8

Emotion scores across five years

	PBL+ (*n* = 20)	PBL (*n* = 12)	Control (*n* =13)	Total (*n* = 45)
Variable	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)
Fall ‘09	4.36 (0.67) -1.63 (4.04)	3.96 (1.02) -0.93 (-0.06)	4.21 (0.67) -0.30 (-1.10)	4.21 (0.78) -1.18 (1.22)
Spring ‘10	4.10 (0.75) -0.86 (1.85)	3.83 (0.75) 0.52 (-1.03)	4.23 (0.76) -0.59 (-0.78)	4.07 (0.75) -0.38 (-0.26)
Spring ‘11	3.81 (0.99) -0.64 (-0.46)	3.90 (0.82) -0.28 (-0.79)	4.17 (0.64) -0.23 (-0.97)	3.94 (0.85) -0.66 (-0.14)
Spring ‘12	3.53 (0.94) -0.93 (1.48)	3.54 (0.96) -0.62 (0.63)	4.27 (0.65) -0.50 (-0.48)	3.74 (0.91) -0.84 (0.94)
Spring ‘13	3.29 (0.89) -0.39 (1.51)	2.75 (0.83) 0.47 (0.57)	3.67 (0.62) 0.62 (0.27)	3.26 (0.86) -0.21 (0.44)

Value

Table 9 summarizes value sub factor scores across time. No significant linear trends were present for value, F (1, 39) = 0.18, p = .67, $\eta_p^2 < .01$. In addition, there was no significant value by time of testing interaction, F (2, 39) = 0.93, p = .40, $\eta_p^2 = .04$. See figures 1 and 2 for variable trends across time. Additionally, see Table 13 for pairwise comparisons among time points.

Table 9

Value across five years

	PBL+ (*n* = 20)	PBL (*n* = 12)	Control (*n* =13)	Total (*n* = 45)
Variable	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)
Fall ‘09	4.58 (0.44) -0.68 (-0.91)	4.53 (0.66) -2.36 (6.26)	4.69 (0.54) -1.43 (0.32)	4.60 (0.53) -1.59 (2.81)
Spring ‘10	4.57 (0.66) -2.31 (6.44)	4.78 (0.33) -1.49 (1.70)	4.59 (0.43) -0.84 (-0.02)	4.62 (0.52) -2.28 (7.37)
Spring ‘11	4.48 (0.71) -1.93 (4.22)	4.46 (0.90) -1.72 (1.76)	4.73 (0.36) -1.82 (3.97)	4.54 (0.69) -2.03 (3.86)
Spring ‘12	4.53 (0.60) -1.01 (-0.03)	4.77 (0.39) -1.87 (3.45)	4.84 (0.24) -1.62 (2.10)	4.68 (0.48) -1.60 (1.98)
Spring ‘13	4.60 (0.63) -1.56 (1.55)	4.50 (0.50) -1.39 (2.66)	4.79 (0.39) -1.97 (3.41)	4.62 (0.53) -1.57 (1.89)

Perceived Knowledge

Table 10 summarizes perceived knowledge sub factor scores across five years. There was a significant negative linear trend for knowledge, F (1, 39) = 19.44, $p < .05$, $\eta_p^2 = .33$. Pairwise comparisons using the Bonferroni correction reveal that fall '09 was significantly different from spring '11, and spring '13. In addition, spring '10 was significantly different from spring '13. There was no treatment condition by time of testing interaction for knowledge, F (2, 39) = 0.63, $p = .54$, $\eta_p^2 = .03$. See figures 1 and 2 for variable trends across time. Additionally, see Table 13 for pairwise comparisons among time points.

Table 10

Knowledge across five years

	PBL+ (*n* = 20)	PBL (*n* = 12)	Control (*n* =13)	Total (*n* = 45)
Variable	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)
Fall '09	4.26 (0.53) -0.18 (-0.83)	4.15 (0.49) 0.11 (-0.80)	4.48 (0.56) -0.81 (-0.05)	4.29 (0.53) -0.21 (-0.95)
Spring '10	4.14 (0.60) -1.37 (4.45)	4.08 (0.37) 0.29 (-0.73)	4.34 (0.50) 0.43 (-1.54)	4.18 (0.52) -0.73 (3.13)
Spring '11	3.76 (0.62) -0.73 (0.03)	3.94 (0.52) -0.25 (-0.51)	4.12 (0.38) 0.09 (-1.01)	3.91 (0.54) -0.77 (0.54)
Spring '12	3.83 (0.74) -0.88 (0.82)	4.06 (0.68) -1.08 (1.63)	3.90 (0.58) 0.23 (-0.58)	3.91 (0.67) -0.72 (0.57)
Spring '13	3.90 (0.66) -1.53 (5.82)	3.54 (0.68) 0.41 (1.61)	3.89 (0.44) 0.74 (4.08)	3.80 (0.62) -0.68 (2.68)

Engagement outside of class

Table 11 summarizes engagement outside of class sub factor scores across five years. There was a significant negative linear trend for engagement, F (1, 41) = 77.75, $p < .05$, $\eta_p^2 = .65$. Pairwise comparisons using the Bonferroni correction reveal differences between all data points and spring '13 excluding spring '12. In addition fall '09 was significantly different from spring ’12, and spring ’10 was significantly different from both spring ’11 and spring ’12. See Table 12 for mean differences. There was no treatment condition by time of testing interaction for engagement, F (2, 41) = 2.16, p = .13, η_p^2 = .10. Table 12 summarizes inferential results. See figures 1 and 2 for variable trends across time. Additionally, see Table 13 for pairwise comparisons among time points.

Table 11

Engagement across five years

	PBL+ (*n* = 20)	PBL (*n* = 12)	Control (*n* =13)	Total (*n* = 45)
Variable	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)	*M* (*SD*) Skew (Kurt)
Fall ‘09	3.29 (0.91)	2.60 (0.86)	2.75 (1.13)	2.95 (0.99)
	0.26 (-0.75)	-0.44 (-1.22)	0.61 (-0.17)	0.19 (-0.48)
Spring ‘10	3.17 (0.58)	2.90 (0.28)	3.55 (0.58)	3.21 (0.57)
	0.32 (-0.80)	-1.61 (3.17)	0.91 (0.40)	0.70 (0.50)
Spring ‘11	2.34 (0.84)	2.60 (1.10)	2.49 (0.87)	2.45 (0.91)
	0.45 (-0.39)	0.07 (-0.83)	-0.02 (-0.48)	0.24 (-0.65)
Spring ‘12	2.07 (0.91)	2.12 (0.64)	2.29 (0.55)	2.15 (0.74)
	1.04 (1.57)	0.19 (-0.34)	-0.91 (1.28)	0.58 (1.25)
Spring ‘13	1.98 (0.78)	1.85 (0.70)	1.91 (0.71)	1.92 (0.73)
	0.72 (0.78)	0.34 (-1.26)	-0.03 (-1.74)	0.45 (0.35)

Table 12

Summary ANOVA table

	n	*df*	*F*	*p*	η_p^2
Composite	43				
Time		1, 40	27.92	< .001	.41
Group		2, 40	2.00	.15	.09
Interaction		2, 40	0.23	.79	.01
Emotion	44				
Time		1, 41	23.35	< .001	.36
Group		2, 41	3.38	.04	.14
Interaction		2, 41	1.35	.27	.06
Value	42				
Time		1, 39	0.18	.67	< .01
Group		2, 39	0.68	.51	.03
Interaction		2, 39	0.93	.40	.05
Knowledge	42				
Time		1, 39	19.44	< .001	.33
Group		2, 39	1.28	.29	.06
Interaction		2, 39	.06	.54	.03
Engagement	45				
Time		1, 41	77.75	< .001	.65
Group		2, 41	0.40	.68	.02
Interaction		2, 41	2.16	.13	.10

Note: ANOVA values come from tests of within-subject contrasts, p < .05 criterion for significance

Table 13

Pair-wise comparisons for composite and sub factor scores across five years

		Composite	Emotion	Value	Knowledge	Engagement
Fall ‘09	Spring ‘10	.03	.12	-.03	.09	-.32
	Spring ‘11	.20	.24	.06	.33**	.43
	Spring ‘12	.29	.35	-.11	.31	.76**
	Spring ‘13	.55**	.90**	-.01	.51**	1.00**
Spring ‘10	Spring ‘11	.17	.12	.09	.24	.75**
	Spring ‘12	.25*	.23	-.07	.22	1.08**
	Spring ‘13	.52**	.80**	.02	.43**	1.32**
Spring ‘11	Spring ‘12	.09	.12	-.16	-.02	.33
	Spring ‘13	.35**	.66**	-.07	.18	.57**
Spring ‘12	Spring ‘13	.26*	.55**	.10	.21	.24

*Note: If the mean difference is negative, the second value is larger than the first value. If the mean difference is positive, the first value is larger than the second value. * = p < .05, ** = p < .01*

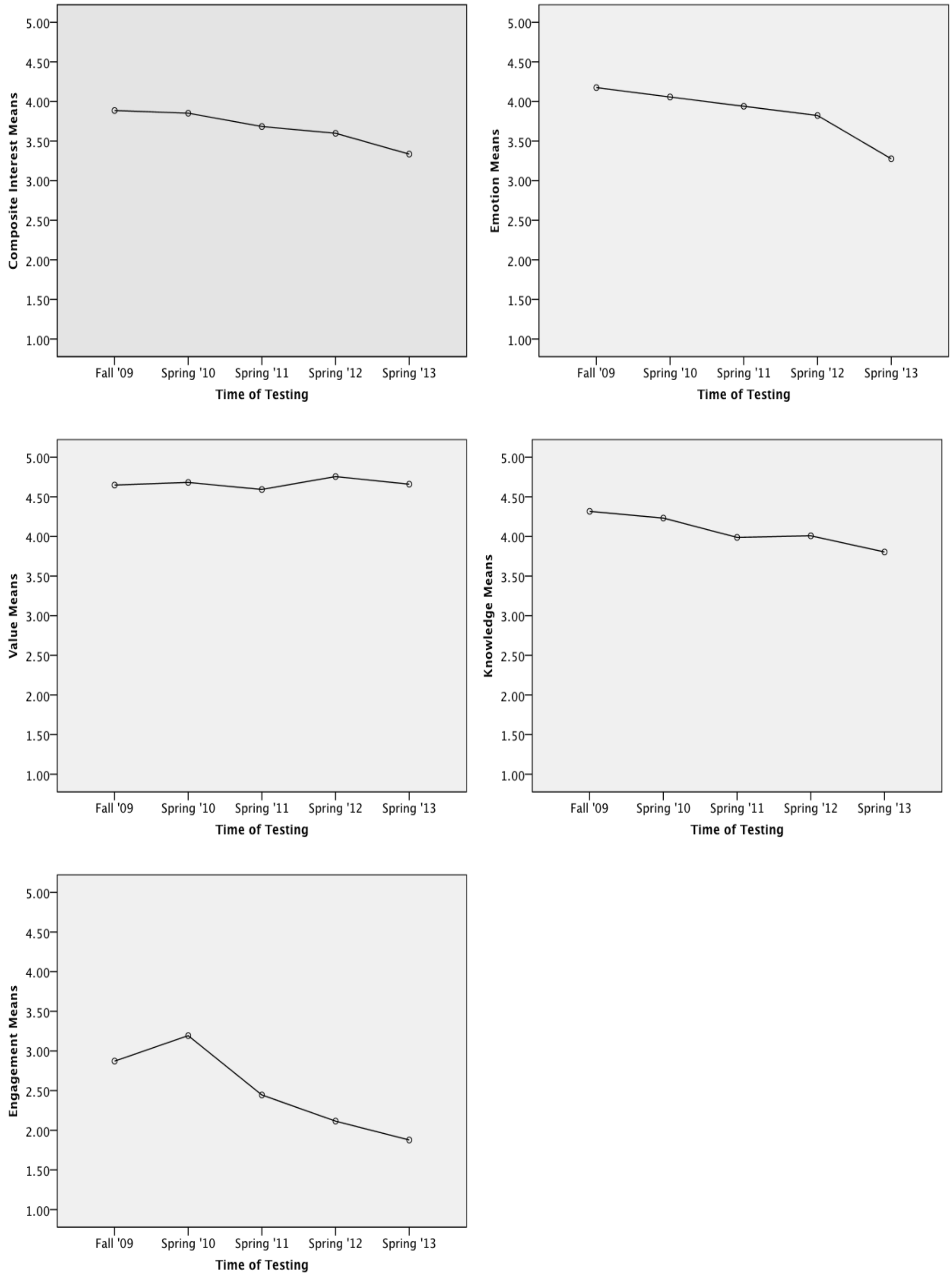

Figure 1. Estimated marginal means for composite interest, emotion, value, knowledge and engagement across five years.

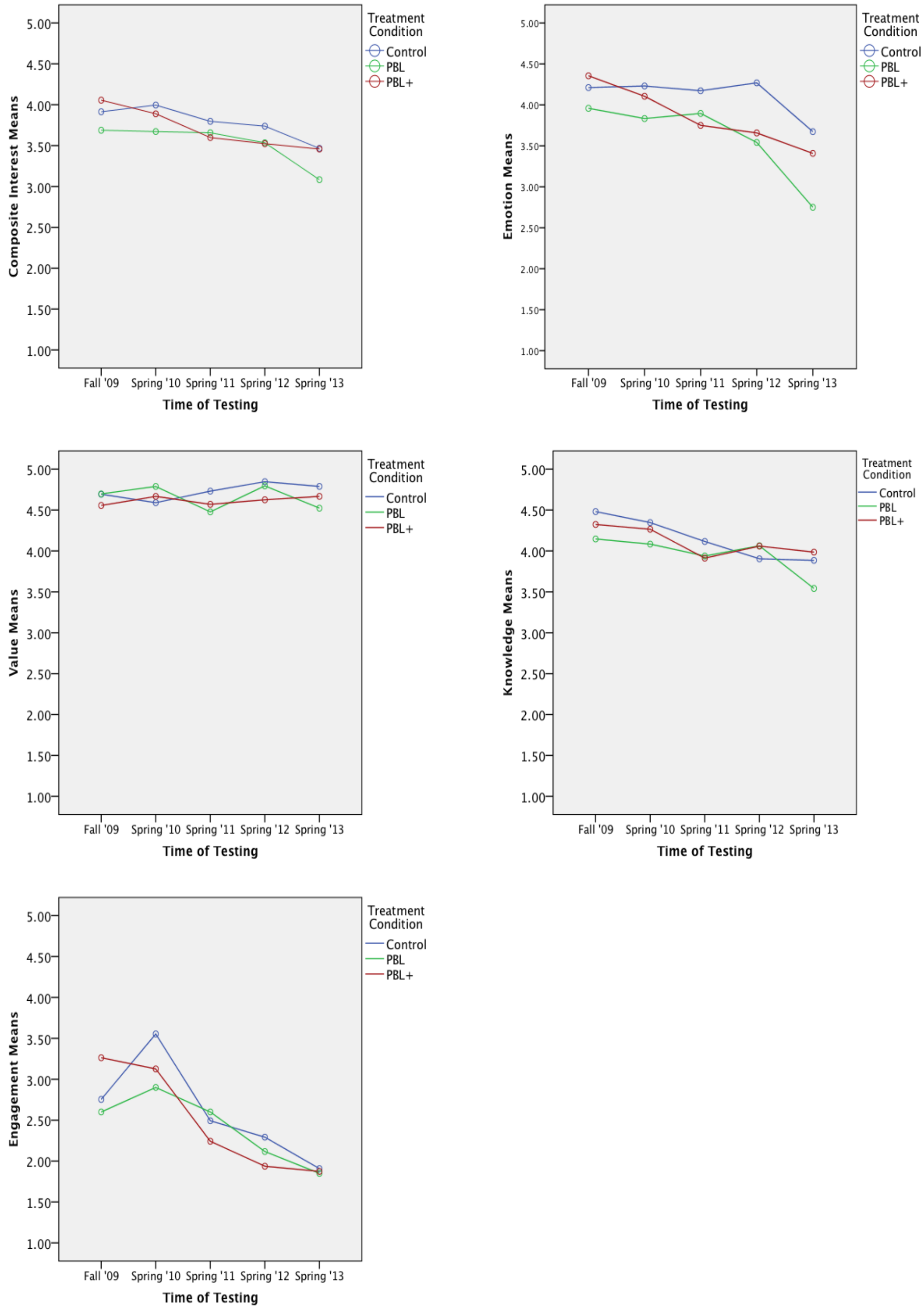

Figure 2. Estimated marginal means for composite interest, emotion, value, knowledge and engagement across five years by treatment condition.

Discussion

The purpose of this study was to assess changes in student interest in mathematics across time, and whether a problem-based learning intervention would influence changes in interest levels across time. Hypothesis one, which stated that individual interest in mathematics would decline across time, was supported. The negative linear trend found for composite interest was consistent with previous literature (e.g., Hidi, 2000). Exploratory analyses of the sub factors related to the first research question revealed negative linear trends across time for all sub factors except value.

Results from the composite interest score are similar to previous literature (e.g., Hidi, 2000). In the current sample, students were enrolled in upper elementary school (grades 3-6) and previous literature suggests that interest starts to decline during this time (Hidi, 2000). Wigfield and colleagues (1997) assessed interest in terms of emotional qualities across time (i.e. questions assessing whether something was interesting or enjoyable). In the current sample, the emotion sub factor declined across time similarly to composite interest. The findings for composite interest and the emotion sub-factor are also consistent with literature on a similar construct, intrinsic motivation. Intrinsic motivation tends to decline across time during elementary and middle school (e.g., Gottfried et al., 2001; Harter, 1981). The shift in intrinsic towards extrinsic motivation is addressed in Cognitive Evaluation theory (CET; Deci, Cascio, & Krussell, 1975), which posits as teachers expose students to more content and more extrinsic incentives based on performance, students will shift from intrinsic forms of motivation to more extrinsic forms of motivation. For example, a student may start off enjoying learning about mathematics and completing mathematics tasks. If a teacher places pressure to perform well on assessments or offers additional rewards for performance, said student would be more likely to engage in mathematics tasks not out of enjoyment, but for the reward (Ryan, Mims, & Koestner, 1983). This brings up an additional interesting finding. In the current sample, engagement in and out of school activities declined across time. Since students lost interest across time, it makes sense that students would be less likely to engage in the content area during "free" time (Simpkins et al., 2006).

In the present study, there was a negative linear trend for perceived knowledge but no trend was found for value (i.e., values were relatively stable across time). Previous literature has suggested that perceived knowledge (i.e., competence beliefs) declines over time, but the decline becomes less steep or less intense with time (Fredricks & Eccles, 2002; Wigfield et al., 1997). For the students in the current sample, although their perceptions of knowledge declined across time, their performance on tests with no established ceiling (e.g., TOMAGS) increased across time suggesting an increase in actual knowledge (Wininger, 2013). One potential explanation for the decline in perceived knowledge is that as students gain more actual knowledge and are made aware of the greater breadth and depth of knowledge still to learn, their feelings of how much they do not know increase. In addition, the complexity of material increases over time and thus, requires greater effort and preparation to succeed.

In the present study, no trends were found for the value sub factor. Scores for the value sub factor were relatively stable, and averaged between 4.54 and 4.62 out of a possible 5 points (see Table 8 for scores of the value sub factor). Previous literature has addressed whether subjective task values have declined across time, but there are mixed results. Fredricks and Eccles (2002) found that importance in mathematics declined across time. Additionally, Jacobs and colleagues (2002) also found a decline in mathematics value across time, but this composite value had questions about enjoyment, usefulness, and importance. Both of the abovementioned studies assessed students across grades 1-12 in math and sports. However, Eccles and colleagues (1993) found no significant grade differences in subjective task values in mathematics, but the participants were younger at the start of the study than those in the present study, e.g., starting in first and second grade.

For the current study, there are possible explanations for why there was no difference in value across time. First, there may have been a restructuring of what was valued. As discussed earlier, students tend to become more motivated by extrinsic rewards over time (i.e., engaging in a task not out of enjoyment, but to get a good grade) (Gottfried et al., 2001; Harter, 1981). When previous literature assessed whether value declined across time, the measure of value included enjoyment; however, in the current study, enjoyment was a separate sub factor. This difference in how value was operationalized may explain differences in findings. Second, the high values may be due to social desirability because averages are near ceiling at all data collection points. When examining the variance of the sub factors, value and knowledge were similar and had lower variance (values approximately .2 to .3) whereas emotion and engagement had higher variance (values ranging from .7 to .9).

Hypothesis two, which stated that interest change in mathematics would be moderated by amount of exposure to a problem-based learning intervention, was not supported. There were no significant findings for either composite interest or any of the four sub-factors. The only studies found that assessed students' interest in a PBL context were assessing situational interest, not individual interest (e.g., Phillips et al., 2012; Rotgans & Schmidt, 2011). Possible explanations for the null findings are addressed in the limitation section.

Limitations

There were several limitations to the current study. The first limitation relates to the attrition among students in each condition. The original sample was to consist of the top 15 students for six schools given a final sample of 90, 60 between the two treatment conditions and 30 in the control condition. Across five years, the final sample decreased to 45 students, an attrition rate of 50 percent. Students were excluded from the final sample for multiple reasons (e.g., moving at any time after the first collection point, failure to collect responses, etc.).

A second limitation is related to fidelity of implementation, i.e., were the PBL units implemented with fidelity with regard to both quantity and quality? Teachers in the PBL conditions were supposed to complete two units of PBL each year in grades 3-5 and five units across the year in grade 6. Teachers at the GEMS academy were supposed to teach two PBL units per year. In addition, teachers at the GEMS academy were supposed to create additional supplementary PBL units each year. Additional units were created for the science portion of the curriculum for GEMS academy students, but it is unknown as to whether additional units were created that incorporated mathematics or had a STEM approach. Further inquiry has yielded no additional information as to whether additional units were created.

A third limitation that builds upon the previous limitation is that some of the teachers at the treatment schools were reassigned to different grade levels each year.

Some teachers were also added to the initiative any given year and were completely new to the PBL curriculum with no prior PBL professional development. These changes were problematic for ensuring proper training for each new PBL or PBL+ teacher because the professional development was catered primarily for continuing teachers with new teachers getting additional help via remedial sessions.

A fourth limitation relates to teachers' commitment to adopting PBL in the treatment schools. Teachers in the PBL and PBL+ conditions received professional development training on how to use PBL in the classroom and how to teach students of higher ability (Roberts, 2008). Although training on how to use PBL was provided, no specific strategy was identified to foster commitment to this new instructional approach.

To assess whether teachers were committed to adopting PBL in the treatment schools, teachers completed the Stages of Concern Questionnaire (SoCQ; George, Hall, & Stiegelbauer, 2008) during the first two years of Project GEMS (Roberts, 2008). The SoCQ measures teachers concerns and confidence about implementing different strategies in schools, i.e., for this study, implementing PBL in the classroom. Teachers answer questions that load on to seven factors: unconcerned, informational, personal, management, consequence, collaboration, and refocusing (See Table 14 for descriptions of SoCQ factors). When examining data for the first year, averages were not above 50 percent for factors that suggest higher commitment, e.g., consequence, collaboration, and refocusing. Fewer teachers completed the measure for the second year, but averages tend to decrease from year one to year two, suggesting lower confidence in implementing PBL and lower commitment to adopting PBL. This measure was discontinued after the second year because there were reservations about interpreting the scores. The scores were normreferenced from an outdated sample; consequently, interpretations of provided scores are questionable.

Table 14

SoCQ factor descriptions in regard to PBL

Stage of Concern	Description
Refocusing	Focused on what changes could be made in the PBL curriculum that would help increase potential benefits
Collaboration	Focused on collaborating with other instructors
Consequence	Focused on how PBL would influence students he/she directly teaches
Management	Focused on using PBL in regards to optimizing uses of resources/information
Personal	Uncertain about demands of using PBL what he/she will personally gain from using PBL
Informational	General interest in learning more about how to use PBL
Unconcerned	Has no interest in using PBL

Note: Adapted from George, A. A., Hall, G. E., & Stiegelbauer, S. M. (2008). *Measuring implementation in schools: The stages of concern questionnaire.* Austin, TX: SEDL.

A fifth limitation relates to purity of the control group during the period of Project GEMS (i.e., a normal control school would have continued with teaching the same curriculum for the duration of the grant). Teachers in the control condition schools did not receive PBL professional development under the grant for project GEMS; however, the teachers did receive professional development for teaching mathematics for different initiatives supported by other grants running concurrently with the timeline of Project GEMS. During the professional development, teachers in the control condition were trained on a variety of things: how to use the curriculum (i.e., project-based learning with Number Worlds or mathematics puzzle worksheet for Marcy Cook's Math Strategies), formative assessment (i.e., assessing student progress and giving feedback without a grade), and about how to differentiate instruction in the classroom for the given curriculum. Control school teachers' professional development may help explain the lack of differences in composite interest and the sub-factors between the treatment and control groups.

A sixth limitation is differences in the curriculum used for the PBL units. The key question is whether Math Innovation units (Sheffield et al., 2010) meet the requirements for being PBL units. In grades 3-5, students completed units from Project M^3 (Gavin et al., 2006) and in grade 6 students completed units from Math Innovations (Sheffield et al., 2010). In M^3 (Gavin et al., 2006) lessons, students are first introduced to a real world problem, e.g., students are asked to design a fence for a new animal given a list of supplies and using adult footprints as a guess of dimensions. Students also have to figure out the best configuration of the fence given the size of the land. There are many solutions to solving this problem so the problem is ill structured. Students work in groups with some teacher guidance throughout the lessons. Clearly, the M^3 (Gavin et al., 2006) curriculum meets the criteria for PBL (Barrows, 1996). Whether the Math Innovation lessons (Sheffield et al., 2010) meet PBL criteria is less apparent. Each chapter started with an introductory statement that related to the content of the chapter, but the statement was not a problem that guided the entire chapter. In addition, the curriculum resembled a more traditional "textbook" approach to the teaching and learning of mathematics. What makes the Math Innovations lessons PBL in nature is found in the teacher's manual where methods for engaging students in working together and problem-solving are located. Therefore, the Math Innovation lessons (Sheffield et al., 2010) capture an essence of PBL, but the M^3 units appear to be closer to PBL units than the Math Innovation units. The difference in curriculum in the 6^{th} grade might be a contributing factor to the significant drop off in the composite interest scores and the sub factor scores. One potential explanation for the differences is that there were new expectations for students in the sixth grade (i.e. having a new curriculum that required daily PBL expectations spanning the entire school year with five units compared to one PBL unit per semester in grades 3-5 spanning anywhere from 29 to 41 days).

Future directions

As mentioned, there were several limitations to the current study related to attrition, implementation fidelity of PBL units, adequacy of PBL training for teachers to adopt use of PBL, teacher consistency, purity of the control group, and potential curriculum differences. These limitations provide clear direction for several future research ideas.

First, most longitudinal educational research studies have attrition so there is a need to take steps to help minimize attrition rates. As mentioned previously, there were attrition issues in the current study due to moving and missing data collection time points. Future research should strive for more structured data collection so that missing data collection times will be minimized.

Second, for future research there is a need to better monitor the fidelity of PBL unit implementation. As mentioned previously, the amount of PBL professional development varied from year to year to cater to what the teachers needed, but it is unknown as to whether the teachers provided an accurate assessment of what they needed to feel competent in delivering PBL units. This may have influenced whether the units were implemented with fidelity. In the current study, Project GEMS personnel put a plan in place to systematically monitor the implementation of PBL units; however, the plan was not followed. In future research, a plan for monitoring implementation fidelity should be created and followed throughout the duration of the project. In addition, all participating schools should strive to have teachers teach the same grade unless an emergency situation necessitates a change (e.g., moving out of the school district).

Third, there is a need to examine methods for facilitating commitment to PBL adoption. In addition, a better assessment of teacher commitment to adopting PBL should be identified to assess methods of facilitating adoption.

Fourth, there is a need to examine different PBL curricula and how closely those curricula are aligned with PBL best practices. As mentioned before, the current study had two approaches that are purported to capture the essence of PBL: Project M^3 (Gavin et al., 2006) units and Math Innovations (Sheffield et al., 2010) units. Future research should include a content analysis of different PBL curricula and compare the curricula to characteristics of PBL (see Table 3 for characteristics of PBL).

Finally, there needs to be a closer examination of the mathematics interest measure (Wininger et al., 2014). As mentioned previously, the subtest of value for the interest measure may have been susceptible to social desirability. In a future study, students could answer the mathematics interest inventory and a measure of social desirability to see if the two measures are correlated.

Conclusion

The purpose of this study was to assess changes in students' levels of individual interest in mathematics across time and to examine how the amount of exposure to PBL instruction affected changes in individual interest. Individual interest in mathematics declined across time, which was consistent with previous literature and was found with a theoretically based measure of individual interest for the composite score and three of the four sub factors. All sub factors of the interest measure declined across time except value. Although the second hypothesis, which stated that individual interest in mathematics would be moderated by exposure to a PBL intervention, was not supported, there were numerous limitations that may help explain why.

Even with a theoretically based measure of individual interest, there were significant negative linear trends with moderate effect sizes for composite interest (η_p^2 = .41), emotion (η_p^2 = .36), and knowledge (η_p^2 = .33), as well as a strong effect for engagement outside of class (η_p^2 = .65). It is important to point out that although there were numerous citations for longitudinal change in interest and in intrinsic motivation, those studies only come from two unique datasets. It is alarming that the decline in interest is happening at such a young age. There are long-term implications for having lower levels of interest, such as limiting the type of job one might pursue. When examining U.S. News top 100 jobs list, a majority of the top jobs require a background in mathematics (100 best jobs). Given this information, there is a continued need to identify instructional practices that help facilitate interest in mathematics. In the current study, PBL was suggested as an approach that may facilitate interest in mathematics. Although there were numerous limitations in the current study that may have hidden the impact of PBL on interest, PBL in its purest form should help facilitate interest given the connection between facilitating interest and characteristics of PBL (see Table 3 for connections between facilitating interest and characteristics of PBL). More research is needed to identify ways to facilitate interest for mathematics during students' formative years.

APPENDIX A

Math Interest Measure

Please answer the questions below honestly there are no right or wrong answers.

1	2	3	4	5
Never	Rarely	Sometimes	Most of the Time	Always

1. Math is interesting.
2. I like math.
3. Math is fun.
4. Math is cool.
5. Learning about math is important.
6. Learning about math is helpful.
7. What I learn in math is useful.
8. I know a lot about math.
9. I am good at math.
10. I do well in my math classes.
11. Math is easy for me.
12. I watch television shows about math outside of school.
13. I look at websites about math outside of school.
14. I play math computer games outside of school.
15. I read books about math outside of school.
16. I like to do math problems outside of school.
17. Doing well in math is important.

References

Aiken, L. R. (1974). Two scales of attitude towards mathematics. *Journal for Research in Mathematics Education, 5*(2), 66-71.

Ainley, M., Hidi, S., & Berndorff, D. (2002). Interest, learning, and the psychological processes that mediate their relationship. *Journal of Educational Psychology, 94*(3), 545-561.

Ainley, M., Hillman, K., & Hidi, S. (2002). Gender and interest processes in response to literary texts: Situational and individual interest. *Learning and Instruction, 12,* 411-428.

Alexander, P. A. (1992). Domain knowledge: Evolving themes and emerging concerns. *Educational Psychologist, 27*(1), 33-51.

Alexander, P. A. (2004). A model of domain learning: Reinterpreting expertise as a multidimensional, multistage process. In D. Y. Dai & R. J. Sternberg (Eds.). *Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development* (pp. 273–298). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Alexander, P. A., Kulikowich, J. M., & Jetton, T. L. (1994). The role of subject-matter knowledge and interest in the processing of linear and nonlinear texts. *Review of Educational Research, 64*(2), 201-252.

Alexander, P. A., Kulikowich, J. M., & Schulze, S. K. (1994). How subject-matter knowledge affects recall and interest. *American Educational Research Journal, 31*(2), 313-337.

Alexander, P. A., Sperl, C. T., Buehl, M. M., Fives, H., & Chiu, S. (2004). Modeling domain learning: Profiles from the field of special education. *Journal of Educational Psychology, 95*(3), 545-557.

Barrows, H.S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New Directions for Teaching and Learning, 68,* 1-12. Retrieved from Wiley online library.

Bergin, D. A. (1999). Influences on classroom interest. *Educational Psychologist, 34*(2), 87-98.

Brophy, J. (2008). Developing Students' Appreciation for what is taught in school. *Educational Psychologist, 43*(3), 132-141.

Drake, K. N., & Long, D. (2009). Rebecca's in the dark: A comparative study of problem-based learning and direct instruction/experiential learning in two 4th-grade classrooms. *Journal of Elementary Science Education, 21*(1), 1-16.

Deci, E. L., Cascio, W. F., & Krusell, J. (1975). Cognitive evaluation theory and some comments on the calder and staw critique. *Journal of Personality and Social Psychology, 35*(1), 81-85.

Eccles, J., Wigfield, A., Harold, R. D., & Blumenfeld, P. (1993). Age and gender differences in children's self- and task perceptions during elementary school. *Child Development, 64*(3), 830-847.

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Journal for Research in Mathematics Education, 7*(5), 324-326.

Fredricks, J. A., & Eccles, J. S. (2002). Children's competence ad value beliefs from childhood through adolescence: Growth trajectories in two male-sex-typed domains. *Developmental Psychology, 38*(4), 519-533.

Gallagher, S.A., Stepien, W.J., Sher, B.T., & Workman, D. (1995). Implementing problem-based learning in the science classroom. *School Science and Mathematics, 95*(3), 136-146

Gavin, M. K., Casa, T. M., Adelson, J. L., Carroll, S. R., & Sheffield, L. J. (2009). The impact of advanced curriculum on the achievement of mathematically promising elementary students. *Gifted Child Quarterly, 53*(3), 188-202.

Gavin, M. K., Chapin, S. H., Dailey, J., & Sheffield, L. J. (2006). *What's the me in measurement all about?* United States: Kendall/Hunt Publishing Company

George, A. A., Hall, G. E., & Stiegelbauer, S. M. (2008). *Measuring implementation in schools: The stages of concern questionnaire.* Austin, TX: SEDL.

Gottfried, A. E., Fleming, J. S., & Gottfried, A. W. (2001). Continuity of academic intrinsic motivation from childhood through late adolescence: A longitudinal study. *Journal of Educational Psychology, 93*(1), 3-13.

Harter, S. (1981). A new self-report scale of intrinsic versus extrinsic orientation in the classroom: Motivational and informational components. *Development Psychology, 17*(3), 300-312.

Hidi, S. (2000). An interest researcher's perspective: The effects of extrinsic and intrinsic factors on motivation. In C. Sansone & J. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (309-339). San Diego, CA: Academic Press.

Hidi, S., & Harackiewicz, J. (2000). Motivating the academically unmotivated: A critical issue for the 21st century. *Review of Educational Research, 70*(2), 151-179.

Hidi, S. & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111-127.

Hidi, S., Renninger, K. A., & Krapp, A. (2004). Interest, a motivational variable that combines affective and cognitive functioning. In D. Dai & R. Sternberg (Eds.), *Motivation, emotion, and cognition: Interactive perspectives on intellectual functioning and development* (89-115). Mahwah, NJ: Lawrence Erlbaum Associates.

Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science, 326,* 1410-1412.

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. *Educational Psychology, 102*(4), 880-895.

Jacobs, J. E., Lanza, S., Osgood, D. W., Eccles, J. S., & Wigfield, A. (2002). Changes in children's self-competence and values: Gender and domain differences across grades one through twelve. *Child Development, 73*(2), 509-527.

Linnenbrink-Garcia, L., Durik, A. M., Conley, A. M., Barron, K. E., Tauer, J. M., Karabenick, S. A., & Harackiewicz, J. M. (2010). Measuring situational interest in academic domains. *Educational and Psychological Measurement, 70,* 647-671

Matarazzo, K. L., Durik, A. M., & Delaney, M. L. (2010). The effect of humorous instructional materials on interest in a math task. *Motivation Emotion, 34*, 293-305.

Mitchell, M. (1993). Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *Journal of Educational Psychology*, *85*(3), 424-436.

Murphy, P. K., & Alexander, P. A. (2002). What counts? The predictive powers of subject-matter knowledge, strategic processing, and interest in domain-specific performance. *The Journal of Experimental Education, 70*(3), 197-214.

Phillips, M. M., Pugh, K. J., Machlev, M., & Bergstrom, C. R. (2012, April). *Exploring interest and goal orientation in a problem-based learning (PBL) environment.* Poster presented at the annual conference of the American Educational Research Association, Vancouver, BC, CAN.

Renninger, K. A., & Hidi, S. (2011). Revisiting the conceptualization, measurement, and generation of interest. *Educational Psychologist, 46*(3), 168-184. doi: 10.1080/00461520.2011.587723

Roberts, J. (2008). *Project GEMS (gifted education in math and science)*. Unpublished manuscript, Western Kentucky University: Bowling Green, KY.

Roberts, J., Tassell, J. T., Inman, T., & Wininger, S. (2011, November). *Jazzed about Javits—GEMS data showing impact on student learning in math and science.* Presented at the annual conference of the National Association for Gifted Children, New Orleans, LA.

Rotgans, J. I., & Schmidt, H. G. (2011). The role of teachers in facilitating situational interest in the active learning classroom. *Teaching and Teacher Education, 27,* 37-42.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68-78.

Ryan, R. M., Mims, V., & Koestner, R. (1983). Relation of reward contingency and interpersonal context to intrinsic motivation: A review and test using cognitive evaluation theory. *Journal of Personality and Social Psychology, 45*(4), 736-750.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational Psychologist, 26*(3 & 4), 299-323.

Schiefele, U. (2009). Situational and individual interest. In K. Wentzel & A. Wigfield (Eds.), *Handbook of Motivation at School* (197-222). New York: Routledge.

Sheffield, L. J., Chaplin, S. H., & Gavin, M. K. (2010). *Sizing up shapes: Focusing on geometry and measurement.* Dubuque, IA: Kendall Hunt

Silvia, P. J. (2005). What is interesting? Exploring the appraisal structure of interest. *Emotion, 25*(1), 89-102. doi:10.1037/1528-3542.5.1.89

Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental Psychology, 42* (1), 70-83.

Stevens, T., & Olvarez, A. (2005). Development and evaluation of the mathematics interest inventory. *Measurement and Evaluation in Counseling and Development, 38*, 141-152.

The 100 best jobs. (2014). U.S. News. Retrieved April 4, 2014 from http://money.usnews.com/careers/best-jobs/rankings/the-100-best-jobs

Wigfield, A., & Eccles, J. S. (2000). Expectancy-Value theory of achievement motivation. *Contemporary Educational Psychology, 25,* 68-81. Doi: 10.1006/ceps.1999.1015.

Wigfield, A., & Eccles, J. S. (2002). The development of competence beliefs, expectances for success, and achievement values from childhood through adolescence. In A. Wigfield & J. S. Eccles (Eds.), *Development of achievement motivation* (pp. 91-120) Academic Press.

Wigfield, A., Eccles, J. S., Yoon, K. S., Harold, R. D., Arbreton, A. J. A., Freedman-Doan, C., & Blumenfeld, P. C. (1997). Change in children's competence beliefs and subjective task values across the elementary school years: A 3-year study. *Journal of Educational Psychology, 89*(3), 451-469.

Wininger, S. (2013, September). *Current research projects.* Presentation to the Western Kentucky University Psychological Science colloquium.

Wininger, S., Adkins, O., Inman, T., & Roberts, J. (2014). *Development of a student interest in math scale for gifted and talented programming identification.* Manuscript submitted for publication