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Impacting Student Attitudes Toward Mathematics Through Project-Based Learning: A Multiple Intelligence Based Approach

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Abstract

Reflecting on my first year of teaching, the number one hindrance to my students' progress in mathematics seemed to be that my students strongly disliked the subject. Therefore in my second year of teaching at a diverse Catholic school in New England, I completed an action research project that implemented project-based learning (PBL) based on Multiple Intelligence (MI) theory into my mathematics classroom. I wanted to to see if the experience would first, impact student attitudes to make students *like* math more, and second, if PBL would allow students to see mathematics as applicable to the real world. Therefore, this action research project used a mixed-method design to examine student ($N = 20$) attitudes towards mathematics. Students completed the research-tested Attitudes Towards Mathematics Inventory (ATMI) as well as an open-ended reflective survey both before and after the PBL experience to assess the impact of the intervention. Results indicated that while PBL did not improve most student attitudes towards mathematics—at least in terms of students liking math more—it did cause almost every student to see math as useful in the real world.

Impacting Student Attitudes Toward Mathematics Through Project-Based Learning: A Multiple Intelligence Based Approach

Winston Churchill said: “attitude is a little thing that makes a big difference.” After teaching just one year I saw that this was most definitely the case in a classroom environment. During my first year of teaching the largest frustration that I encountered as an educator is that my students *hated* mathematics and saw it as totally irrelevant to their lives. Despite every effort to make my classroom interactive, applicable, and discovery-based, students still loathed the subject with their very being. Even my brightest students saw no purpose in it and had no desire to dig deeper into its mysteries.

Therefore, this action research project focused on finding an effective way to impact, and therefore improve, student attitudes towards the subject of mathematics. This is important because I believe that an improved outlook translates into higher motivation, better performance, greater class participation, and a deeper understanding of the subject. Generally speaking, I believe it is obvious that students put more effort and time into things they enjoy or at least appreciate.

Therefore, I attempted to impact student attitude towards mathematics by introducing project-based learning into my two predominately junior mathematics classes during the fall 2012 semester. Project-based learning (PBL) is a student-centered approach to learning where students ask questions and then seek out and present answers to problems that come from their own experiences and interests (Bell, 2010; Blumenfeld et al., 1991). By challenging students to see mathematics in a different light—especially in a way that is relevant to them— I hoped that PBL would build enthusiasm for the subject and the class as a whole.

In addition, I was curious to see if combining PBL with Multiple Intelligence (MI) theory would further impact attitudes. MI theory is based on a "pluralistic view of the mind, recognizing… that people have different cognitive strengths and contrasting cognitive styles" (Gardner, 2006, p. 5). In short, instead of presenting the question of "Are you smart?" to students MI theory asks students "What are you smart at?" Despite popular belief among my students, mathematics is more than "getting the right answer." In fact, as MI theory supports, there is room for creativity, free thought, and even fun. This action research project helped explore if my students could discover this fact for themselves.

Importance of Study

While PBL is not a new idea, there is much room for study about its effects in a mathematics classroom. Therefore, I wanted to discover if projects do in fact have educational value in mathematics despite the substantial loss of time that it causes in teaching curriculum. This action research project helped me, and will therefore perhaps help other mathematics teachers, to evaluate if PBL is an effective teaching strategy towards improving student attitudes towards mathematics.

Purpose Statement

The purpose of this action research project was to explore the impact of project-based learning, designed through multiple intelligence theory, on student attitudes towards mathematics as well as students' views of math as being relevant in the real world.

Research Questions

The main research questions explored in this action research were:

1. How does project-based learning, implemented through the theory of multiple intelligences, impact student attitudes towards mathematics?

2. How does project-based learning impact students' perception that mathematics has real world applications?

Literature Review

While extensive research has been done on aspects of attitudes towards mathematics, PBL, and MI theory, few if any have been conducted combining the three. Therefore, the literature review that follows first discusses each of these three areas separately and then provides an analysis that gives a framework for how project-based learning and multiple intelligence theory could combine to potentially impact student attitude.

Student Attitudes Towards Mathematics

Attitude towards mathematics can be defined by how much a person particularly likes or dislikes mathematics and by how important or unimportant a person perceives mathematics to be in their lives (Hannula, 2002; Ma & Kishor, 1997). Attitude, then, is not about aptitude or ability, although these may or may not affect a person's attitude, but instead concerns the general disposition a person has towards the subject.

Middleton and Spanias (1999) commented that students' attitudes towards mathematics decline as students transition from elementary school into high school. In addition to this drop, it becomes stable and less likely to change than in earlier grades (Ma & Kishor, 1997). Some research has indicated that attitudes towards mathematics are directly related with student achievement, however this has not always been found true in all cases (Ma & Kishor, 1997; Middleton & Spanias, 1999). Regardless, Middleton and Spanias did find that success helps students to see mathematics as more worthwhile and say that such success is "highly influential in forming… motivational attitudes" (p. 79).

Improving student attitude. Seeing that students do not always view mathematics in a positive light, especially in high school, it seems necessary to find methods to improve student attitudes. Asante (2012) studied 181 senior high students in Accra, Ghana assessing student attitudes towards mathematics and recommended that "the teacher should develop positive relationships with students and stress classroom activities, which involve active teaching-learning process and students' participation in the class" (p. 129) to improve student attitudes towards mathematics. Middleton and Spanias (1999) supported Asante's recommendations in their research saying that the reasons mathematics attitudes turn negative is due to a "lack of teacher supportiveness and classroom environment" (p. 67) and say that teachers must teach worthwhile skills that are seen as "useful, both in immediate terms and in preparing [students] to learn more in the fields of mathematics" (p. 81).

Hardré (2011) also said that making math relevant plays an integral role with students' motivation towards math. This begins, she explained, by finding out "where students are and beginning there" (p. 230). She found that tapping into future career goals of students "offers potential for powerful internalized motivation" (p. 230). In addition, Hardré found that through using varied ways to involve students in mathematics as well as teaching the many uses of the subject, students gain self-efficacy and motivation to attempt the more challenging aspects of mathematics. Engagement it seems—both between teacher and student and student and material—has an integral relationship with how students view mathematics.

Hannula (2002) made another important observation about improving student attitudes through a qualitative case study done on 'Rita,' a lower secondary school student. Through her case study Hannula found that "attitudes sometimes can change dramatically, in a relatively short time" (p. 42). In fact, Hannula commented, "it took only half a year" (pp. 42-43) to see large changes in Rita's perception of mathematics. While this case study did not provide detailed steps at reaching this change besides an increase in mathematical understanding, it does show that even within the limited timeline of this action research project attitude shifts could occur within my students.

Project-Based Learning

Bell (2010) defines PBL as "a student driven, teacher-facilitated approach to learning" (p. 39). In PBL students may investigate, negotiate, hypothesize, debate, experiment, and plan by asking questions and seeking answers to problems that come from their natural curiosity or interests (Bell, 2010; Blumenfeld et al., 1991). Under the supervision of the teacher—who takes more of an advisor role (Newell, 2003)— students choose a "big idea, authentic issue, or vital concept" (Markham, 2011, p. 39) that aligns with the course objectives. Students then draft a driving question or goal, research, create, and produce a product to be presented orally or in writing.

PBL can come in a variety of forms. The model of 'project exercise,' as defined by Helle, Tynjälä, and Olkinuora (2006), most closely resembles the type of PBL implemented in this action research project. In this model students apply "knowledge and techniques *already* acquired to an academic issue in a subject area already familiar to them" (p. 289). However, the project I introduced included a real-world application component as well.

Goals of PBL. Researchers have defined a wide array of goals and purposes of PBL. Some of these include helping to foster responsibility, independence, and discipline (Bell, 2010). Other purposes include having a holistic, interdisciplinary experience that engages students in real-world tasks (Helle, Tynjälä; Olkinuora, 2006). In addition, throughout the research, there are a number of consistent goals associated with PBL. Through PBL students should:

1. Become complex problem solvers and critical thinkers
2. Develop deeper and broader content knowledge
3. Increase in communication and collaboration skills
4. Practice becoming self-monitors of progress

(Bell, 2010; Blumenfeld et al., 1991; Helle, Tynjälä, & Olkinuora, 2006; Markham, 2011; Newell 2003). While this list is far from exhaustive, it provides a good framework of goals for PBL in action.

In addition, PBL practices what Tony Wagner (2008) calls survival skills. These are the abilities that focus on answering the question: "What does it take… for all high school graduates to be 'citizenship-ready' or 'jury-ready'?" (Wagner, 2008, p. 100). These skills are far more than learning how to solve a quadratic equation or define a polynomial. Instead they are life skills that prepare students to be successful outside of an educational setting. The following are the 'Seven Survival Skills' outlined by Wagner:

1. Critical Thinking and Problem Solving
2. Collaboration Across Networks and Leading by Influence
3. Agility and Adaptability
4. Initiative and Entrepreneurialism
5. Effective Oral and Written Communication
6. Accessing and Analyzing Information
7. Curiosity and Imagination

Reflecting on this list and the definition of PBL, it is clear that PBL teaches and requires each of the skills mentioned above if implemented correctly.

Impact of PBL. Newell (2003) claims that PBL is “a revolutionary way to learn” (p. 5) that helps students develop better comprehension, problem-solving skills, and teaches students to “learn how to learn, learn about the world, learn who they are and what they want to become” (p. 5). Özdener and Özçoban (2004) concur adding that it increases these skills both personally and as collaborative groups. Many argue that through PBL students become equipped for the 21st century as they develop as critical thinkers and begin to analyze real-world concepts that cannot be achieved through the traditional style of teaching (Bell, 2010; Markham, 2011; Newell, 2003).

Besides equipping students for the 21st century, Boaler (1999) also found that PBL has an impact on student development and test scores. Boaler followed two groups of mathematics students in England for three years, one that used the traditional method of teaching and one that focused solely on PBL, and found that three times as many students from those in the PBL group attained the highest grade possible on national exams—even though at the beginning of the three years the groups were heterogeneous in ability level. Boaler pointed out that even though the traditional group worked hard and learned the necessary skills (although not to the level of the PBL group!), “they could not see any connection between their school math and the math they encountered in real situations” (p. 30). However, Boaler says that those in the PBL group saw a much bigger picture of mathematics and could apply it to numerous situations. This group had learned the developmental skill of “think[ing] for themselves” (p. 30).

More importantly than increased test scores, as related to this action research project, articles state that the model of PBL provides increased motivation (Bell, 2010; Blumenfeld et al., 1991) and therefore may allow for a shift of attitude. Because PBL is student-centered, it takes individual interests and passions into account increasing intrinsic motivation (Bell, 2010). Therefore, students find the projects more relevant and useful to their lives and “develop a sense of ownership of the learning process" (Helle, Tynjälä, & Olkinuora, 2006). This relevance provides the motivation for students to "develop their own interests and pursue deeper learning" (Bell, 2010, p. 41). In short, "PBL gives students a reason to learn" (Markham, 2011, p. 39).

Multiple Intelligence Theory

MI theory, introduced by Howard Gardner in the 1980s, is based off the idea that "human cognitive competence is better described in terms of a set of abilities, talents, or mental skills, which [are called] intelligences" (Gardner, 2006, p. 6). Gardner has since defined nine different intelligences including linguistic, logical-mathematical, musical, bodily-kinesthetic, spatial, interpersonal, intrapersonal, naturalist, and existential intelligence. McFarlane (2011) says that "the implications for educators and students are tremendous in terms of the richness and flexibility MI brings to teaching and learning" (paragraph 4). These nine different intelligences provide a broad model for which educators can present concepts to a diverse group of learners.

Impact of MI. Research has found that MI theory can help students learn skills efficiently (Sulaiman, Hassan, & Yi, 2011). Another supported this claim saying that it is a "powerful tool that can help achieve educational goals more effectively" (Hopper & Hurry, 2000, p. 26). Through MI based instruction students take a more proactive role in learning as instruction is differentiated for students based on each student's unique talents (Gardner, 2006; Hopper & Hurry, 2000; McFarlane, 2011; Sulaiman, Hassan, & Yi, 2011).

Researchers have also found that teaching based off of MI theory has a "positive impact" on students and caused them to "gain self-confidence and motivation" (Sulaiman, Hassan, & Yi, 2011, p. 430). Hopper and Hurry (2000) noted that "when the pupils began to recognize that using diverse learning activities in lessons was… a means of learning, and that different people learn in different ways, pupils' motivation to learn dramatically increased" (p. 29). It is possible that this increased motivation and variety may improve students' attitude towards mathematics.

MI Theory and PBL. Because both PBL and MI theory is based on the concept of choice and the importance of personalization (Bell, 2010; Blumenfeld et al., 1991; Hopper & Hurry, 2000), it seems logical to apply MI theory to PBL. As students choose projects that are relevant, they also do so in such a way that compliments their talents and strengths. Middleton (1995) commented on the importance of recognizing these individual differences saying, "it is reasonable to assume… that individual differences among students, and the ways in which mathematics complements these differences, determine to a large extent the degree to which mathematics is perceived as motivating" (p. 255). Blumenfeld et al. (1991) echoed that the "interest and value" (p. 375) students find in something increases overall engagement. Therefore, if students find projects both relevant and personalized, students might have an increase of liking towards the subject. At least in one study combining PBL and MI theory the approach was shown to be more effective than the traditional explanation model of teaching (Özdener and Özçoban, 2004).

PBL As a Method to Impact Student Attitudes

If attitude is related to both a liking and disliking factor as well as how something is perceived as useful or useless, it seemed possible that PBL could improve student attitudes towards mathematics if implemented well. Since by its very nature PBL requires students to be more engaged with the teacher, other students, and the material itself it seemed reasonable to think from the research above that PBL, especially when constructed under MI theory, could increase student attitudes towards mathematics. Therefore, the purpose of this study was to see if this was in fact the case as I implemented PBL into my classroom.

Method

Given the purpose stated above, this mixed-method study used a pre-designed quantitative survey as well as original open-ended surveys both before and after the PBL experience. Studying the outcome of the PBL experience—the projects themselves—triangulated this quantitative and qualitative data further.

Participants

Participants ($N = 20$) were composed of two classes of majority junior mathematics students (ages 15-18). One class (12 students) was an honors Pre-Calculus class, all of which chose to participate. Of these 12 students, eight were juniors and four were seniors, most having a strong mathematical foundation and motivation to succeed. The second class, Algebra II, was a college preparatory class of 11 students, all juniors. However, one student dropped out of the school before the study even began and two students chose not to participate bringing the number participating from the class from 11 to eight. This class was made up of equally motivated students, however, these students found math generally more difficult than the honors class mentioned above. All participants were be selected, after giving consent (see Appendix A for consent form), from a convenience sample given that I picked students who were at the same point in their high school career (mostly juniors) yet with various mathematical abilities.

Location

This study took place at a very small, diverse urban Catholic school located in New England. Many of the school's students are from immigrant families and represent a wide range of cultures. The school does not have a specified math curriculum, which made it very easy to insert PBL into my classroom without the stress of meeting curriculum deadlines.

Instruments and Materials

Pre-project surveys. A pre-designed survey was used to assess students' attitude towards mathematics (see Appendix B) in order to provide validity to my study. The Attitudes Towards Mathematics Inventory (ATMI) consists of 40 questions that measure four factors affecting student attitude—self-confidence, value, enjoyment, and motivation. It has a validity of 0.97 with college students (although it was initially designed for high school students) and the content validity has been established (Tapia, 1996). The survey is based on a 5-point Likert scale that ranges from *Strongly Disagree* (1) to *Strongly Agree* (5). Examples of questions that students were asked to agree or disagree with included statements such as "Mathematics is a very worthwhile and necessary subject" and "I have a lot of self-confidence when it comes to mathematics." In addition to this initial ATMI survey students completed a pre-project survey (see Appendix C) where they were asked to respond to a series of original open-ended questions about how they saw mathematics as relating to and useful in the real world.

Post-project surveys. The ATMI survey was given again after the projects were complete as well as another original open-ended reflective survey designed to gather students overall thoughts after the PBL experience (see Appendix D). This open-ended survey asked students to reflect on how PBL affected their attitude towards math and included questions such as "In what ways, if any, did this project impact the way you look at math?" The survey also included two of the same open-ended questions as the pre-project survey asking how students saw math as useful. This post-project survey surfaced an additional qualitative depth of information about how student attitudes were impacted by the PBL experience.

Design and Procedure

This mix-method study took place in the first semester of the 2012-2013 school year. During the first week of school I presented the PBL process to my students and gained consent. I did not explicitly indicate to my students the precise reason why we would be doing projects (as not to lead their thoughts) but instead just stated that I hoped that PBL would help them to look at mathematics in a different way. Once consent was given, the 20 participants took the initial ATMI survey on Friday September 7, 2012 of as well as completed the pre-project survey that was attached. The pre-project surveys were coded and grouped by major themes.

I distributed the project (see Appendix E) to my students on Tuesday October 16, 2012. During this class period we thoroughly talked about what PBL was, the expectations of the project, the requirements, and then finished class by going to the computer lab to take a short quiz indicating what MI categories students most closely identified with. The project, entitled "Math Your Way," required the students to pick a topic that we had covered in class and answer the question: "How can this math concept be used in the real world?" Students were required to take the topic of their choice, research the question above, and then choose any medium they wished to present their findings to the class. The project involved multiple checkpoints, as described below, and included not only making a final project but also writing a reflection on their experience.

A week after the project was assigned they were required to present a proposal (see Appendix F) to the class detailing their project idea and how they planned to implement it. After proposals were given students were given a worksheet (see also Appendix F) to complete since a core component of PBL is the "an ongoing, reflective process" (Markham, 2011, p. 40) where "the organizational blueprint that students have designed for themselves guides them and allows them to stay focused and on-task" (Bell, 2010, p. 40). Since students were new to the PBL learning experience I provided the structure of this "blueprint" as they moved forward with the project.

Students were then given an additional two weeks to work either independently or collaboratively on their projects. Following those two weeks I conducted an in-class workshop where students conferenced with me about their progress since teacher feedback is an essential part of the PBL experience (Markham, 2011). During this day students completed another worksheet (see Appendix G) that reiterated the projects' goals, driving question, and expectations. Finally, students presented their projects a week later on Tuesday, November 13, 2012.

The day after projects were due I had students complete the post-project survey in class while their project experience was still fresh in their minds. These surveys were coded and were then reduced and collapsed into major themes that discussed how students viewed the impact of the project on their attitude towards how well they liked math as well as their view of math as being useful. One week later students took the same ATMI survey in order to assess quantitatively through a paired t-test if their attitudes had shifted through the PBL experience. A paired t-test was conducted between each student, each class, and overall to determine the effect of PBL on student attitudes towards math.

In order to provide additional triangulation to these qualitative and quantitative surveys, I also looked extensively at the projects themselves, and the rubrics that I used to grade them, to assess the successfulness of PBL. By examining the quality of their projects, the effort put into them, and the questions they asked along the way I was able to get a more complete understanding of the value of the project experience as well as any potential attitude shifts.

Findings

The purpose of this action research project was to explore the impact of PBL on student attitudes towards mathematics as well as students' view of math as relevant in the real world. Themes emerged from the data that seemed to show that while only some students saw a positive shift of attitude towards mathematics through the PBL experience, PBL made most students see math as useful and applicable in the real world or in their future.

Attitudes Towards Mathematics

The original research question asks if PBL, implemented through MI theory, impacts students' attitudes towards math. The findings below first present data on students' initial attitudes as found through the original ATMI survey as well as through the pre-project survey distributed at the beginning of the school year. It then looks to how these attitudes were affected by the PBL experience by using data from the second ATMI survey as well as through the open-ended post-project survey.

Pre-project viewpoints. Student answers from the initial ATMI survey, based on a 5-point Likert Scale ranging from viewing math negatively (1) to positively (5), were averaged to reveal that students had a variety of mathematical attitudes ranging from fairly negative to very positive. With the average of 3.00 being a neutral according to the Likert scale on the survey, 60% (12 students) viewed math positively with averages above 3.00. Of these twelve students, two were shown to view math very positively with averages above 4.00. Consequently, 40% (8 students) were shown to have slightly negative attitudes towards math with averages between 2.00 and 2.99. It should also be noted that collectively the honors Pre-Calculus class, who have experienced more math success in their lifetime, had a slightly positive attitude towards math (3.34) while the non-honors Algebra II class viewed math faintly negatively (2.95). Together the classes averaged to a slightly positive attitude value of 3.19. These results are summarized in Table 1.

Table 1

Initial ATMI Survey Results

Student	Enjoyment	Motivation	Self-Confidence	Value	Overall
Student 1	2.80	1.80	2.67	3.40	2.78
Student 2	3.20	3.00	3.87	4.50	3.75
Student 3	3.40	3.40	3.93	4.10	3.78
Student 4	1.80	1.80	2.67	2.60	2.33
Student 5	2.70	2.00	3.73	2.30	2.90
Student 6	2.30	2.40	2.07	3.10	2.43
Student 7	3.00	2.60	3.20	3.30	3.10
Student 8	2.60	1.60	2.53	3.10	2.58
Algebra II	2.73	2.33	3.08	3.30	2.95
Student 9	2.90	3.60	3.47	4.00	3.48
Student 10	3.60	4.00	4.93	4.30	4.33
Student 11	3.30	3.60	4.60	3.90	3.98
Student 12	3.10	3.20	4.00	3.50	3.55
Student 13	2.30	1.60	1.87	2.50	2.10
Student 14	3.40	3.20	4.00	4.00	3.75
Student 15	3.10	2.80	3.60	3.20	3.28
Student 16	2.20	2.40	3.27	3.70	3.00
Student 17	2.00	2.00	2.47	2.10	2.20
Student 18	3.30	3.00	4.93	3.80	4.00
Student 19	3.20	3.20	4.20	3.90	3.75
Student 20	2.70	2.60	2.47	3.00	2.68
Pre-Calculus	2.93	2.93	3.65	3.49	3.34
Total	2.85	2.69	3.42	3.42	3.19

Note. Averages based on 5-point Likert Scale with 1 being the most negative response and 5 being the most positive response.

In addition, the pre-project surveys were coded and then condensed to reveal that students did have some positive feelings about mathematics, but had many more negative ones as they saw it as difficult, useless, and anxiety filled. The following gives the results to the questions "Describe your overall feelings towards math" and "Why do you think you feel the way you do?"

To begin, 60% (12 students) mentioned mathematics in some way positive making 18 different references throughout the pre-project survey. However, only three of these positive references describing their overall feelings towards math indicated a *liking* of the subject, the rest were concessions to its necessity or acknowledgements that they saw it as easy. For example, one student explained, "It's [math] alright. I like [it] only for the fact that I need to know math in order to get where I want to be in life." Another said, "I pick up on concepts quickly and (usually) use them correctly. I don't really *like* math, though, it just comes fairly easy to me." Of the three students who admitted to liking math one commented, "I like math because its a challenge and I like chalenges." In addition to these positive references, there were also five neutral references towards the subject with students commenting that, for example, "It's alright."

However, the majority of comments were not positive with 75% (15 students) making a total of 31 negative references saying that it was personally difficult (7 students) or that they just do not like it (8 students). Four individual students commented that it caused them stress or anxiety and four students also said that they saw math as boring. One student's comment exemplifies all of these negative sentiments: "I dont like math at all. I think its boring and pointless unless you want to be a math teacher. Its too much work and stress on students, that isnt necessary." While this was the most extreme remark the following is an example of a more common response: "I've never been really good at math. EVER. So my confidence in the subject is very low." At least five students echoed that their disliking of math was linked to the fact that they struggled with the material. This is consistent with Ma & Kishor (1997) who said while aptitude and attitude are not always linked, it is "undeniable that ability is one the critical factors that affects the ATM [attitudes towards mathematics]-AIM [achievement in mathematics] relationship" (p. 43).

In conclusion, both qualitative and quantitative results show that the participants in this study had various attitudes towards mathematics before the PBL experience with at least some expressing negative views. Reasons for these negative attitudes towards mathematics varied from person to person and included students perceiving themselves as not being good at it, math as stressful, and math being boring or useless. The seven students who held the most positive attitudes towards math (those with ATMI averages 3.75 and greater) also were the students that composed the majority of positive qualitative remarks, with five of these seven students saying that math was easy for them.

Post-project viewpoints. After collecting this initial data I then implemented the PBL experience into my classroom. The following are the results of a paired t-test done on the initial and second ATMI survey as well as the findings of a second open-ended post-project survey given out after the project was completed.

The paired t-test showed that 30% (6 students) had a statistically significant difference ($p < .05$) between initial attitudes before the PBL experience as compared to after the PBL experience. All of these shifts were positive. Three of these students were from the non-honors Algebra II class and three were from the honors Pre-Calculus class. The students' initial attitudes varied with two changing from very negative to slightly negative, one from slightly negative to slightly positive, and three from slightly positive to very positive. Consistent with Hannula (2002) at least some students were able to see a change of attitude over a short period of time. It should be noted that when averaged, neither the two different classes nor the group as a whole saw a statistically significant change in attitude. Table 2 summarizes these results.

Table 2

Mean, Standard Deviation, and t-Statistic for ATMI Survey

	Before		After			
Student	M	SD	M	SD	df	t-value
Student 1	2.78	1.12	3.15	0.74	39	2.94*
Student 2	3.75	0.74	4.33	0.53	39	5.11*
Student 3	3.78	0.77	3.70	0.61	39	0.52
Student 4	2.33	1.42	1.95	1.20	39	1.50
Student 5	2.90	0.98	3.05	0.96	39	1.43
Student 6	2.43	0.84	2.65	0.80	39	1.85
Student 7	3.10	0.87	2.93	0.76	39	1.42
Student 8	2.58	0.75	2.85	0.77	39	3.14*
Algebra II	2.95	0.56	3.08	0.70	7	1.11
Student 9	3.48	0.78	3.45	0.99	39	0.18
Student 10	4.33	0.83	4.15	0.70	39	1.48
Student 11	3.98	0.89	4.28	0.88	39	2.62*
Student 12	3.55	0.88	3.78	0.70	39	2.47*
Student 13	2.10	1.28	2.75	1.19	39	2.89*
Student 14	3.75	0.74	3.68	0.73	39	0.90
Student 15	3.28	0.75	3.15	0.74	39	0.96
Student 16	3.00	1.06	3.03	0.66	39	0.16
Student 17	2.20	1.07	2.50	0.99	39	1.74
Student 18	4.00	1.20	3.90	1.28	39	0.68
Student 19	3.75	0.87	3.60	0.96	39	1.03
Student 20	2.68	0.57	2.90	0.63	39	1.94
Pre-Calculus	3.34	0.71	3.43	0.57	11	1.24
Total	3.19	0.67	3.29	0.63	19	1.70

Note. $*p < .05$

In addition, the open-ended post-project survey results were coded and then condensed to reveal similar findings above: the project had various impacts for different students. The following explain the results to the questions: “Comment on any feelings, reactions, or overall impressions you had to the experience of completing the project,” “In what ways, if any, did this project impact the way you look at math?” and “What did you learn from doing this project?”. More results from this portion of the post-project survey will be discussed in the next section.

To begin, it was clear that students enjoyed the project. Eighty-five percent (17 students) referenced the project as fun, interesting, or enjoyable. Three students specifically pointed out the MI theory component of choice in their comments. For example, one student said, who had a very low ATMI score, “I enjoyed doing my project, because it wasn’t like every other regular essay writing project we actually were able to incoporate out actual talents and skills.” Another said, “It was kinda fun. I liked that it was free and we all got to do different things,” and the third student echoed this when he commented, “I liked the overall idea of this project because… it allowed us to choose whatever topics we wanted that we covered.” This is consistent with Hopper and Hurry’s (2000) research on MI theory that found that “several teachers… were able to ‘reach’ more pupils than through more usual routes” (p. 28).

However, despite the post-project survey showing that an overwhelming majority of students enjoyed the project, the survey, in agreement with the ATMI survey, also showed that the project did not seem to impact most students’ attitudes towards math—at least in terms of students liking the subject. Only 20% (4 students) commented that the project made them like math more or view math in a more positive way. Twenty-five percent (5 students), including a student that had a statistically significant positive attitude change as shown in the ATMI survey, directly stated that the project had little to no impact on the way they viewed math. In conclusion, it seems that both quantitative and qualitative data show that while some students did see a positive shift in mathematical attitudes, the majority of students did not view math more favorably because of the PBL experience.

Mathematics As Applicable to Real Life

While the above findings indicate that PBL was for the most part unsuccessful in making students *like* math more, the second research question of if PBL makes students see math as more useful and applicable to the real world had vastly different results. The findings below present students' initial views of math being useful as found in the pre-project survey and then move to show how these perceptions changed after the PBL experience as found in the post-project survey.

Pre-project viewpoints. After coding responses from the pre-project survey on the question "Is math useful in real life? Why or why not?" and "How many ways can you think of how math is useful in the 'real-world'?" it became apparent that students had a range of views of math being useful in the real world before the PBL experience. To begin, 55% (11 students) indicated that they found math to be useful in life with popular reasons being that it is 'everywhere,' (5 students) that it helps you problem solve (3 students), and that it is helpful when dealing with money (3 students). The following student's response is characteristic of many of these 11 students who said that math was in fact useful: "It [math] is useful in real life. There are numbers everywhere and whether you know you are doing it or not, you are using math a lot. You use it to problem solve, shop, handle money, etc." A similar sentiment was echoed when a student wrote, "I think math is useful because we use math everyday whether we realize it or not."

Of the remaining students, 35% (7 students) said before the PBL experience that it depends on whether it is useful or not and 10% (2 students) said that math was not useful at all. Many saying that it is sometimes useful justified their response by saying that it is contingent upon what profession you choose, and as one student said succinctly, "what sort of life you live." For example, a student commented, "Sometimes [math is useful], it depends on what you do." Another in this category said, "I would say yes and I would say no [to math being useful] because math is useful in some situations and yet in other situations it is completely useless." Two also expressed that math can be useful, but only elementary math. This is exemplified in the comment: "Yes [math is useful], to a certain extent. While shopping or making a decision (probability), math can be very useful. However, the chances of me needing to find the end behavior of a graph… are slim to none." Of the two students who said math is *not at all* useful, one justified her response by saying that "technology… can do everything" better than us and the other responded that she believed it not to be useful because not all professions require it.

In addition to these remarks, the 90% of students who said that math was useful (at least in some ways) came up with a collective 57 ways that math is used in real life. Most of these were in the form of professions (27 references), but they also mentioned ways math was useful both personally (23) and in life in general (7). The most common response was that math was used when shopping or grocery shopping (9) followed math being useful in paying bills or personal finances (5). Some interesting responses included that math is useful in problem solving (4), time management (2), and detecting fraud (1).

Post-project viewpoints. Returning to the questions "Comment on any feelings, reactions, or overall impressions you had to the experience of completing the project," "In what ways, if any, did this project impact the way you look at math?" and "What did you learn from doing this project?" an unexpected theme emerged. While I hoped that students would have written about how the project made them *like* math more, as stated above, this was not the case. However, what did show overwhelmingly from coding these post-project survey results is that the project made almost all students more aware of the usefulness and necessity of math in the real world. Below is a summary of results.

Ninety percent (18 students) indicated at some point in answering the above three questions that the project made them see math as useful. Over and over again students said comments such as: "It [the project] made me see that you need to know math because it is going to appear everyday" and "It helped me to expand my knowledge of math in the world." Other comments echoed these sentiments saying, "This project really made me believe that math is used in almost everything" and "I was unaware, as I think many of the students in my class were, as to how much math really is in real life." The litany continued with additional students expressing that "math can actually be used in real life situations," that "algebra can be used in real life," and that "math really is used in everyday life even though we sometimes don't want to admit that." These results are consistent with Bell (2010) who stated "research supports PBL as a tool to engage students in real-world tasks" (p. 42). It should be noted that even though two students did not explicitly state in their responses to the three questions above that the project made them aware of math in the real world, they still indicated that math was useful (see below) but did not attribute this belief to the project.

In addition to these three open-ended questions, I also asked the same two questions posed in the pre-project survey: "Is math useful in real life? Why or why not?" and "How many ways can you think of how math is useful in the 'real-world'?" The findings of these survey questions only further supported the conclusions above. Table 3 summarizes these results.

Table 3

Responses to the Survey Question "Is Math Useful in Real-Life?"

	Number of Students		
Response	Pre-Project	Post-Project	Change
Yes, math is useful in real life	11	17	+ 6
No, math is not useful in real life	2	0	− 2
It depends on whether math is useful or not	7	3	− 4

For the 85% (17 students) that responded, 'yes, math is useful' they justified it saying that it is used everywhere (7 students), that you need it for your future profession (4 students), that you need it to problem solve (3 students), that you need it to understand the world around you (2 students), and that you need it to do important life tasks (2 students). One student provided two justifications. Compared to the pre-project responses it seems reasonable to conclude that these answers were much stronger than, for example, that math helps you with money.

In addition, students named a collective total of 69 ways, 12 more than the pre-project survey, of how math is used in the real world. Many of the ways they mentioned directly corresponded to their peers' projects and 85% (17 students) came up with as many or more ways after the project than before. Again, most of the answers were in the form of professions (37 references) but also included ways math was used personally (25) and in life in general (7). The most common responses were that math was used when grocery shopping (6), baking or cooking (6), problem solving (5), and in construction (5). New, interesting responses included that math is useful in athletics and sports (4), in the stock market (4), and in science or space exploration (4). These new responses, and some of common answers mentioned above, were all topics of student projects.

The results above appear to show that while the PBL experience did not lead students to have a better attitude towards math in terms of liking it more, it did in fact lead most students to see math as applicable in the real world. These findings are consistent with Boaler (1999) who also found that students using a PBL method of education reported, “they could see mathematics all around them, in the workplace and in everyday life” (p. 30)— which is a perhaps more poetic, but still a very close statement, to what numerous students stated in their post-project surveys.

The Final Product: The Projects

With the findings mentioned above it also seems appropriate to discuss the artifacts of this action research study: the projects themselves. Projects applied the topics of slope, the distance and midpoint formula, scatter plots, and absolute value equations to areas of construction, space exploration, basketball statistics, and baking—to name a few. Since the projects were based on MI theory students presented them in multiple ways including posters, children’s books, videos, and Power Points.

Most interestingly, of the six students who showed a significant positive shift of attitude, five of them created excellent projects that incorporated a learned math concept in a real world context. All but one of the twenty students created a project that scored 11 or higher out of the 15 possible points for the “Answers Driving Question—How can your topic be used in the real world?” category on the rubric, with the overall average of 14.25 (for rubric see Appendix E). This seems to further support the finding that students successfully were able to find real life connections of mathematics through this project experience. While this was a requirement and therefore not something that the students incorporated on their own, it should be noted it was one of the only areas of the rubric that students collectively scored well on.

While the real world application piece was the strongest aspect of the projects, students were lacking in many other areas that are essential outcomes to the PBL experience. Many students struggled with the details of the project—turning in things on time, being sloppy, and making mathematical errors in their work. This is something I did not anticipate, as I had never done such a complex project in my class. While some of the final products were outstanding, a few were far below my expectations in terms of neatness, clarity, and overall effort. In addition, students' reflection papers and presentation skills were vastly insufficient with many students using all simple sentences in their papers and only saying a few sentences before having to prompted by me in their presentations. In fact, not following through on the details made 35% (7 students) with excellent ideas and real life connections receive Cs and Ds on their projects overall.

Therefore, it appears that while PBL only showed a statistically significant improvement in 30% (6 students) attitudes towards math in terms of students liking math more, it did make most students much more aware of its real life applications. Although students have much to learn about skills such as public speaking, time management, and writing, the PBL experience did see success. Even if students did not learn to like math more through the PBL, at the very least they learned that math is essential to the world and to their future.

Discussion and Extension

The purpose of this action research project was to explore whether or not PBL, implemented through MI theory, would first, impact students' attitude towards mathematics, and second, make students see math as applicable in the real world. A research-tested ATMI survey as well as original open-ended surveys were used in this mixed-method study. Analyzing the data revealed that PBL was not very effective in making students like math more, but did make students see that math can be found in the world around them.

Discussion of Major Findings

As expected, initial attitudes before the PBL experience as found in the ATMI survey varied among students with 60% (12 students) being positive and 40% (8 students) being negative. Open-ended pre-project survey results confirmed this with 60% (12 students) mentioning math in some way positive. However, within these positive remarks only 15% (3 students) admitted to actually *liking* math while most of the other positive remarks involved students' recognition of being personally good at math or seeing math as necessary for the future. However, 75% (15 students) had something negative to say about math with many commenting that math was hard, boring, or that they just plain do not like the subject.

After implementing the PBL experience it was shown quantitatively through a paired t-test on students' initial and post ATMI surveys that 30% (6 students) showed a statistically significant positive change in attitude. This was not a large percentage of students and was further verified in the post-project qualitative survey results. While the survey overwhelmingly indicated that students enjoyed the project—with three students mentioning specifically how they enjoyed the MI theory component of choice—it did not show that PBL made them like math more. In fact, only 20% (4 students) said that the project made them view math more positively.

However, the results were very different for the second research question of whether PBL allows students to see math as having real-life applications. When asked in the pre-project survey "Is math useful? Why or why not?" just over 50% (11 students) saw math as being useful in the real world before the PBL experience, with 35% (7 students) saying that it depended on the situation, and 10% (2 students) saying that math was not at all useful. Students came up with a collective 57 ways that math is used in real life, but many of these referenced simple arithmetic applications such grocery shopping or paying bills.

After the PBL experience the post-project surveys overwhelming concluded that PBL made students see math as applicable to their life with 90% (18 students) stating on the post-project survey how the project made them see math as useful when asked what they enjoyed about the project, how it impacted their view of math, and what they learned. When asked again directly "Is math useful? Why or why not?" now 85% (17 students) said yes—an increase from 55%— and 15% (3 students) said it depended on the situation, leaving zero students saying that math is not at all useful. This time students came up with a collective 69 ways of how math is used in the real world, with 85% (17 students) coming up with as many or more ways than before. While these answers still included things such as grocery shopping, much more in depth answers were also given including construction, space travel, and the stock market—all topics of projects. It seems that besides making students see math as applicable, PBL also expanded their definition of math from simple arithmetic to more complex topics such as slope, absolute value, and the midpoint and distance formula.

Lastly, looking at the projects themselves it was found that 95% (19 students) did an excellent job of making a real world connection, an essential requirement of the project. However, students struggled to complete the details of the project. While some projects were very impressive, many students lacked organization, neatness, presentation, and writing skills that are essential outcome goals of PBL.

In conclusion, it appears that PBL may not be a meaningful way to make students like math more, yet still it seems to be effective in making students see that math does have real life applications and that it is a necessary component of their future. In addition, while some students did an excellent job on the project, many more were deficient in necessary skills to make their good idea great. In short—PBL seemed to make students see that math matters—whether they like it or not.

Application of Findings

While the benefits of PBL were clearly stated above, there is also a cost to the PBL experience: class time. Just doing a single PBL experience cost me about a week of class time between the introduction, proposal, class workday, and presentations. While this is not necessarily a substantial amount of time, it would add up quickly if PBL were used multiple times throughout the course of a year.

Therefore the main question arises: *Is PBL worth it?* Initially, my thought was 'absolutely not!' Frustrated with the amount of class time it took, the amount of late point deductions, and some of the final projects, I believed that PBL was a waste of time and energy. However, taking a step back and reflecting upon the experience—as well as analyzing the data I collected—my opinion has become just the opposite!

This opinion shift towards PBL being worth the time and effort was first due to the positive outcomes that I did not realize until I analyzed the data: improving six students' attitudes towards math as well as having almost all students see math as useful. Just students realizing the *need* for math in real life, even if they do not like it, has large ramifications for their future education. We do not care about the things in life that do not matter. Even though I could not get students to share my admiration for math, (although one student did write: "It helped me understand why Ms. Wade loves math.") at least the experience made students believe that their time spent in my class 45 minutes a day, five days a week is not totally useless!

The second—and most important— reason that my viewed changed was actually reflecting on the negative outcomes of the project. Looking at some of the downfalls of the projects as mentioned in the findings section—poor writing skills, sloppy final products, weak presentation skills, bad time management—I realized the *necessity* for students to practice the 'Seven Survival Skills' mentioned earlier. These skills are what students need not just to pass tests, but more importantly, to be college, career, and citizen ready. Wagner (2010) says, "it's no longer how much you know that matters; it's what you can do with what you know" (p. 111).

Wagner's theory builds upon what many educators today call '21st century skills.' These skills, as defined by the Partnership for 21st Century Skills (2009), are critical thinking and problem solving, creativity and innovation, and communication and collaboration. When considered, they are really the heart of PBL as students are asked to problem solve and then creatively communicate their solution to a real-life situation. Gasser (2011) echoes these skills when he mentions that problem-based instruction, student-led solutions, risk taking, having fun, and collaboration are some ideas to "raise student expectations and better prepare them for the 21st century" in a mathematics classroom (p. 115).

Finally, my findings suggest that PBL could play an integral part in meeting the National Governors Association Center for Best Practice's (2010) *Common Core State Standards for Mathematics*. These Common Core Standards, specifically the Standards for Mathematical Practice, "describe the varieties of expertise that mathematics educators at all levels should seek to develop in their students" (p. 6). These practices are based off the process standards of the National Council of Teachers of Mathematics and include problem solving, reasoning and proof, communication, representations, and connections. All of these are a part of PBL and were shown in my action research project to need further cultivating in my students. In addition, the

Common Core Standards for Mathematical Practice are also based on the National Research Council's report *Adding It Up* and include the strand of what is called productive disposition—"habitual inclination to see mathematics as sensible, useful, and worthwhile" (p. 6) which is the goal that PBL was most successful in meeting in my study.

Therefore, even though refining these skills mentioned above—all of which PBL cultivates— can be time consuming and at times challenging, they are skills that need to be taught more and more in today's global, collaborative society. If I am cutting them out of my classroom to get more mathematics content in I am missing the much bigger purposes of education. Therefore, it is by both the positive outcomes *and* the very parts of the PBL experience that frustrated me the most that I see a great benefit to making PBL a necessary component of a mathematics curriculum despite loss of class time.

Limitations

Given that this action research study was conducted on only two classes at a unique urban school its most obvious limitation is that these results might not be applicable outside of this particular setting. Also, since no educational research is done in isolation it cannot be indefinitely proven that the six students who saw a significant shift in attitude was due to the PBL experience. This shift could have been due to increase math success with a new teacher, other classroom activities, or additional environmental factors that affected them in their first four months of their junior or senior year. This is not to throw these results away, only to look at them and realize that they exist within the complex structure of any educational environment.

However, this project's biggest limitation was due to the small amount of time available to complete this study (one semester). Because of this, only one PBL experience was feasible making it less salient than if PBL would become an integral part of my classroom culture. Since

PBL is an extensive process, students need time to adjust to the expectations PBL entails. As students had never done a project of this magnitude, many failed to realize—despite extensive efforts and multiple checkpoints—that I was expecting much more than a thrown together poster board or picture book the night before. However, if given another opportunity, which this action research project's timeline did not allow, students could reflect on their previous work (a key component of PBL) in order to create a much better future project.

Also, in relation to what was mentioned previously, sharpening 21st century skills is a process that requires practice and mentoring. These skills are not, and cannot, be perfected in a single PBL experience. In addition, as a teacher it is necessary to reflect on my own practices and implementation of PBL in order that I am providing the necessary structure and support to achieve the outcomes that I want. This also takes time and the opportunity to do more than one project experience.

Future Action and Directions

Given the limitation mentioned above it seems that the next step would be to implement PBL into my classroom for a second, and even third, time in a given academic year. If just one PBL could have such a positive impact on students—at least in some areas—it seems only logical to give students more exposure to this method of learning in hopes of reaping all the educational benefits that PBL potentially offers.

In addition, perfecting PBL, and therefore getting the most out of it, takes time, patience, and practice. The 21st century skills mentioned numerous times throughout this research report take years and many experiences to sharpen. In fact, I would argue that they are never fully perfected even as students transition into their adult life. There is always more to be learned in terms of problem solving skills, critical thinking, collaboration, and communication. This is why

I believe it is necessary to continue to implement PBL learning into the mathematics classroom—and all classrooms for that matter— despite its substantial loss to class time and content.

Students' negative attitudes towards mathematics and the ever-present question of "When will I ever use this in life?" will continue to plague mathematics teachers for years to come. However, I believe that this action research project has shown that PBL, implemented through the theory of MI, has the *potential* to positively impact student attitudes towards mathematics as well as the ability to show students that mathematics is, as one student said, "actually used in real life."

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Appendix A

Sample Consent Form

Dear Parent or Guardian:

As we begin a new school year, I look forward to working with your son/daughter as his or her mathematics teacher. This school year will be my second at St. Mary's Jr./Sr. High, and after the warm welcome that I received from the St. Mary's family last year, I eagerly look forward to another year!

In addition to being your son/daughter's math teacher, I am in my second and final year as a member of the Providence Alliance for Catholic Teachers (PACT). Through PACT, I am able to pursue a graduate degree in secondary education from Providence College in Rhode Island while teaching at a Catholic school in the Diocese of Worcester.

As a member of the PACT program, I am currently enrolled in courses at Providence College. Although most of my course work is done during the summer months, as part of the program, PACT teachers conduct an action research project during the school year.

My action research project will focus on how using projects in math class can help students view math in a different way. I have noticed that many students have a negative attitude towards math and I hope that through a carefully crafted, interactive project done during the first quarter that students will see that math is in fact a subject that is both useful and relevant in their everyday lives.

Data for the study will include surveys, written reflections, class observations, and the project themselves. I will be looking at student responses to these surveys to see how doing projects impacted them as learners.

There are no risks in participating in this study and student participation (or decision not to participate) will have no impact on student grades. I do want to reiterate, however, that all students, regardless of participation in the study, will have to complete the assigned project as part of the required course work for this class.

Throughout the report that I will write based on my findings, I will use pseudonyms for the community, school, and students. You may elect to have your child not participate in my research. In either case, I would appreciate if you would return a signature indicating your decision as soon as possible because I cannot begin the research process without it.

If you have any questions regarding the research project, or about the class in general, please contact me by email at awade@stmaryshigh.org or by calling the main office at (508) 753–1170, where I can return your call at my earliest convenience. If you want further information on my research project, feel free to contact the director of the PACT Program, Br. Patrick Carey, at (401) 865-2657.

Sincerely,

Ms. Andrea Wade

Please sign and have your child return the following slip to Ms. Wade.

Adult

________ I give permission for my child to be a participant in the action research project as described by Ms. Wade

________ I do not wish for my child to be a participant in Ms. Wade's action research project

____ ______________________________

(Signature) (Date)

Student

_____ I give my assent to be a participant in the action research study as described by Ms. Wade

_____ I do not wish to be a participant in the research study as described by Ms. Wade

____ ______________________________

(Signature) (Date)

Appendix B

Attitudes Towards Mathematics Inventory (ATMI)

Directions: This inventory consists of statements about your attitude towards mathematics. There are no correct or incorrect responses. Read each item carefully. Please think about how you feel about each item. Choose the number that most closely corresponds to how each statement best describes your feelings and place it on the line next to the statement. Please answer every question.

Name: ____

I am in Ms. Wade's (circle one)

Algebra II Class *Honors Pre-Calculus Class*

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

1. Mathematics is a very worthwhile and necessary subject. ____________
2. I want to develop my mathematical skills. ____________
3. I get a great deal of satisfaction out of solving a mathematics problem. ____________
4. Mathematics helps develop the mind and teaches a person to think. ____________
5. Mathematics is important in everyday life. ____________
6. Mathematics is one of the most important subjects for people to study. ____________
7. High school math courses would be very helpful no matter what I decide to study. ____________
8. I can think of many ways that use math outside of school. ____________
9. Mathematics is one of my most dreaded subjects. ____________
10. My mind goes blank and I am unable to think clearly when working with mathematics. ____________
11. Studying mathematics makes me feel nervous. ____________

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

12. Mathematics makes me feel uncomfortable. ____________

13. I am always under a terrible strain in math class. ____________

14. When I hear the word mathematics, I have a feeling of dislike. ____________

15. It makes me nervous to even think about having to do a mathematics problem. ____________

16. Mathematics does not scare me at all. ____________

17. I have a lot of self-confidence when it comes to mathematics. ____________

18. I am able to solve mathematics problems without too much difficulty. ____________

19. I expect to do fairly well in any math class I take. ____________

20. I am always confused in my mathematics class. ____________

21. I feel a sense of insecurity when attempting mathematics. ____________

22. I learn mathematics easily. ____________

23. I am confident that I could learn advanced mathematics. ____________

24. I have usually enjoyed studying mathematics in school. ____________

25. Mathematics is dull and boring. ____________

26. I like to solve new problems in mathematics. ____________

27. I would prefer to do an assignment in math than to write an essay. ____________

28. I would like to avoid using mathematics in college. ____________

29. I really like mathematics. ____________

30. I am happier in a math class than in any other class. ____________

31. Mathematics is a very interesting subject. ____________

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

32. I am willing to take more than the required amount of mathematics. ____________

33. I plan to take as much mathematics as I can during my education. ____________

34. The challenge of math appeals to me. ____________

35. I think studying advanced mathematics is useful. ____________

36. I believe studying math helps me with problem solving in other areas. ____________

37. I am confortable expressing my own ideas on how to look for solutions to a difficult problem in math. ____________

38. I am comfortable answering questions in math class. ____________

39. A strong math background could help me in my professional life. ____________

40. I believe I am good at solving math problems. ____________

Appendix C

Pre-Project Survey

Please answer the following questions as completely as possible using **complete sentences** unless otherwise indicated**.** Remember **there are no right or wrong answers**. Please be as **honest** as possible and write as much as you wish.

---

1. Describe your overall feelings towards math.

2. Why do you think you feel the way you do?

3. Is math useful in real-life? Why or why not?

4. If you answered "yes" to question #3 name as many ways that you can think of how math is useful in the "real-world." Please list!

Appendix D

Post-Project Survey

Dear Student,

Please answer the following questions as completely as possible using **complete sentences.** Remember **there are no right or wrong answers**. Please be as **honest** as possible and write as much as you wish.

Name: ____

I am in Ms. Wade's (circle one)

Algebra II Class *Honors Pre-Calculus Class*

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1. Comment on any feelings, reactions, or overall impressions you had to the experience of completing your project.

2. In what ways, if any, did this project impact the way you look at math?

3. Is math useful in real-life? Why or why not?

4. If you answered “yes” to question #3 name as many ways that you can think of how math is useful in the “real-world.” Please list!

5. Did this project make you feel more engaged in class? Why or why not?

6. What did you learn from doing this project?

Appendix E

Math Your Way Project

Math Your Way

"I'm just not a math person!"

This is something I have heard over and over again. However, it is simply not true! Instead, the truth is that **people learn differently**. Some people prefer to take notes while listening to a lecture; others would rather get up and move around in class to learn.

Besides this…

Everyone has different strengths!

We are not all good at the same thing! Dr. Howard Gardner, a professor at the Harvard Graduate School of Education, developed a theory called Multiple Intelligences based on this observation that people have several different types of intelligences, rather than one general type. In fact, he identified eight different intelligences:

1. **Social Smart** (Interpersonal)
2. **Self Smart** (Intrapersonal)
3. **Musically Smart**
4. **Spatially Smart**
5. **Nature Smart** (Naturalist)
6. **Language Smart** (Verbal/Linguistic)
7. **Logic/Math Smart**
8. **Body Movement Smart** (Kinesthetic)

Before we start the project we will take a short online quiz to find out what your strengths are. http://www.literacyworks.org/mi/assessment/findyourstrengths.html

List your top three intelligences:

1. ______________________________
2. ______________________________
3. ______________________________

In addition,

Math matters!

From the internet, to the prices of clothing, to your smartphones— everything you love about life works because of math. You just have to discover it… and take the time to understand it. This takes work but the process can be fun if you allow it to be.

The Question:

Pick a topic that we have covered so far and answer the question:

How can this math concept be used in the real world?

The Assignment:

It's time to do math ***YOUR*** way. Using one (or more) of Gardner's Intelligences – the one that most applies to you – create a project that answers the question above.

Topic Suggestions:

- Solving Linear Equations in Real Life
- Problem Solving Using Algebraic Models
- Solving Linear Inequalities in Real Life
- Solving Absolute Value Equations in Real Life
- Functions and Their Graphs in Real Life
- Slope in Real Life
- Piecewise Functions in Real Life
- Absolute Value Functions in Real Life

→**This is NOT an exhaustive list!** Anything we have covered in class thus far is fair game for a project to be done on. A good place to start is picking a topic that interests you and doing some research. DO NOT just steal an example from the book – this is not good enough!

→You **MUST use material from this class** – it can be anything that we've learned this year. The point is to explain why math matters in your own way.

Project suggestions to demonstrate your research include (but are not limited to):

- Movie
- Music Video
- Song Lyrics
- Commercial
- Cookbook
- Restaurant Menu
- Scrapbook
- Cartoon
- Children's Book
- Research Project
- Newspaper
- Acted Interview

BE CREATIVE! – Keep it appropriate and have fun!

Groups:

- You may work independently or in a group of **no more than three people**
- If you are going to work in a group pick people that are going to do the work, that you work well with, and that are you are able to meet with outside of class time

Requirements:

- **PROJECT PROPOSAL** Due: ________________________________
  *ONE PER GROUP

  - Proposals should include:
    - Group members
    - The project idea
    - Intelligence(s) addressed
    - **Detailed** description of how your project answers the question
  - Besides the written proposal, you will be expected to give a **3-4 minute verbal explanation** in front of your peers on the due date given above where you will be given feedback about your project

- **CHECKPOINT** Due: ___________________________________

  - Present **visible evidence** of FINAL project progress. For example:
    - Making a music video/video/interview – show me the *completed* script/lyrics
    - Making a children's book/cartoon/scrapbook/cookbook– show me multiple *completed* pages
  - There will be **ZERO CREDIT** given for
    - A verbal explanation
    - Scrap paper with sketches
    - Something I can tell you did last period
  - This is a great day to get feedback on how your project is coming!

- **FINAL PROJECT** Due: __________________________________

1. **Written typed response** explaining the project experience
   **EACH MEMBER OF YOUR GROUP MUST TURN THIS IN!*

   Questions to address (Check off as you complete):

   - _____How did you incorporate your particular intelligence(s) in your project?
   - _____What did you like about this project?
   - _____What didn't you like?
   - _____What challenges did you face when completing this project?
   - _____If you had to do this project again what would you do differently?

   Answers should be typed in 12-point font and double-spaced. Make sure you answer every question!

2. A **self-evaluation** (if working independently) or a **group-evaluation** (if working in groups) of each group member. If you worked in a group you must fill out a self-evaluation as well.
   **EACH MEMBER OF YOUR GROUP MUST TURN THIS IN!*

3. **The final project** in finished form with **a reference list**
   **ONE PER GROUP*

Rubric:

Your Name: ______________________________

		Possible Points	Actual Points
PROPOSAL	Names listed	2	________
20 pts	Overview fully described	4	________
	Intelligence noted	3	________
	Driving question answered	7	________
	Oral presentation	4	________
CHECKPOINT			
10 pts	Visible evidence presented	10	________
PROJECT			
Content of Project	Answers Driving Question	15	________
45 pts			
	How can ________________ be used in the real world?		
	0-5 Makes weak connection, uninteresting		
	6-10 Makes moderate connection, somewhat interesting		
	11-15 Makes strong connection, very interesting		
	Math is accurate	10	________
	Clarity of material, effort	10	________
	Complexity of topic	5	________
	Sources cited	5	________
Presentation	Well organized, clear, prepared	7	________
20 pts	Explained so class can understand	7	________
	Effort, teamwork during Presentation	6	________
Creativity	Originality, pizzazz, WOW factor	10	________
10 pts			
Written Reflection	Thoughtful, flows smoothly	4	________
20 pts	Addresses intelligences incorporated	3	________
	Describes what was liked about project	2	________
	Describes dislikes of project	2	________
	Explains any challenges faced	3	________
	Explains changes for future	4	________
	Typed in 12-point font, double-spaced	2	________
Evaluation	Completed	3	________
10 pts	Teamwork, according to group	7	________
Late Deductions	Minus 15-points for each part late		________
	TOTAL:	**135**	______ **/ 135**

Comments:

Grading: This project will count towards 135 points on second quarter grade.

Each day late (proposal or final project) will result in a 15-point deduction of your grade. Be on time!!

121-135	points	90-100%	A
108-120	points	80-89%	B
95-107	points	70-79%	C
88-95	points	65-69%	D
0-87	points	0-64%	Failing

Group-Evaluation:

Your Name: ______________________________

Person you are evaluating: __________________

On a scale of 1-5, 5 being the highest, please rate your ***group members*** *on the following:*

_____ Use of time
_____ Communication with group members
_____ Willingness to contribute ideas
_____ Effort

Please comment about this person's overall effort on the project, justifying your ratings above:

Self-Evaluation:

Your Name: ______________________________

On a scale of 1-5, 5 being the highest, please ***rate yourself*** *on the following:*

_____ Use of time
_____ Effort
_____ Communication with group members (if you worked in a group)
_____ Willingness to contribute ideas (if you worked in a group)

Please comment about your overall effort on the project, justifying your ratings above:

Appendix F

Math Your Way Proposal and Proposal Worksheet

Project Proposal:

Name/s: ____

Math Topic: ____

1. **Brief Overview of Plan:**

2. **Multiple Intelligence(s) Addressed:**

3. **How does your project answer the question** (use separate paper if necessary)?

   How can ________________________________ *(fill in topic) be used in the real world?*

Proposal Worksheet:

Group Members: ____

Comments from Ms. Wade:

Comments from classmates:

Fill in the following questions after you presentation.

1. What **suggestions** do I want to incorporate into my project?

2. Am I happy with my project idea? If yes, why? If no, what can I change?

3. Make a **timeline** of how you are going to go about finishing your project.
    a. Question to think about:
        i. What else do I need to do?
        ii. How am I going to do it?
        iii. When am I going to do each step?
    b. Some are filled in for you

What needs to be done?	**How am I going to do it?**	**When am I going to do it?**
The Presentation		
Written Reflection		
Self/Group Reflection		

Appendix G

Math Your Way Project Workday Worksheet

Project Workday Worksheet:

Name(s):____________________

Comments from Ms. Wade:

Fill in the following questions.

1. What is the biggest thing I have left to do? How am I going to do it?

2. How can I make my **presentation** interesting and informative?

3. In the next week, **what could I add to my project** to make it really stand out?

4. Make a **timeline** of how you are going to go about finishing your project.

LOOK AT THE RUBRIC underneath each topic. Ask yourself… if I was grading myself what would I get?

What needs to be done?	How am I going to do it?	When am I going to do it?
Content Answers Driving Question 15 *How can __________________ be used in the real world?* Math is accurate 10 Clarity of material, effort 10 Complexity of topic 5 Sources cited 5		
The Presentation Well organized, clear, prepared 7 Explained so class can understand 7 Effort, teamwork during Presentation 6		
Written Reflection *one per person!* Thoughtful, flows smoothly 4 Addresses intelligences incorporated 3 Describes what was liked about project 2 Describes dislikes of project 2 Explains any challenges faced 3 Explains changes for future 4 Typed in 12-point font, double-spaced 2		
Self/Group Reflection *one per person!* Completed 3 Teamwork, according to group 7		
Creativity Originality, pizzazz, WOW factor 10		