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A Statistical Analysis of the Effects of Project-Based Learning on Student High School and College Outcomes

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A Statistical Analysis of the Effects of Project-Based Learning on Student High School and College Outcomes

by

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Dedication

This dissertation is dedicated to my mother, Pamela Cade Craig, whose passion for education lives on through my work.

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A Statistical Analysis of the Effects of Project-Based Learning on Student High School and College Outcomes

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This dissertation research study is an analysis of the effects of project-based learning on a cohort of high school students' achievement on mathematics and science standardized tests and graduation rates. The study also investigates college enrollment and first year grade point averages (GPA) for students taught solely through project-based instructional methods in high school. In the 21st century, STEM fields dominate our work force, but there is a decline in interest and persistence towards these fields that can be traced back to high school achievement in mathematics. The people that are choosing and prepared for STEM majors and careers are not representative of the US population, as they are lacking ethnic and gender diversity. The underlying premise is that inquiry-based teaching practices engage and motivate students leading to increased learning; however this premise is not currently fully supported with empirical research.

This research compares students that attended a high school that teaches all courses through project-based learning with a matched control group of students. I first analyzed the demographic makeup of students that chose to apply to Manor New Tech, a STEM-focused, PBL school. Then, I developed multiple linear regression models that allowed me to determine that students attending the PBL school performed as well as the control group on math standardized exams and significantly better on one of the science

standardized exams. Further analysis showed that ethnic and gender achievement gaps on the standardized assessments were maintained when students attended the PBL school. Similarly, students that attended the PBL school as likely to graduate high school. Comparing the PBL school with a more affluent school that also teaches all courses through PBL showed that graduates from the PBL school of focus in this research were significantly more likely to enroll in 2-year institutions of higher education and just as likely to enroll in 4-year and private institutions in Texas as the more affluent school.

Finding that attendance at MNTH does not harm students' standardized test performance or graduation rates could imply that being taught through PBL does not enhance high school and college outcomes. It could also imply that students taught at the PBL school, MNTH, are not experiencing authentic PBL, or conversely that students attending the comparison school, MHS, are receiving instruction through project-based methods as well. Lastly, the standardized assessments used to measure achievement may not be sensitive to some higher order skill development that may occur when taught through inquiry-based methods. Future research plans are to create new achievement measures that will capture more robust learning than traditional standardized tests. Using these instruments, further analysis of difference in students' performance when they are taught through inquiry methods will be conducted.

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CHAPTER 1: INTRODUCTION

At the turn of the 21st Century, technological advancements have drastically changed America. Innovation within Science, Technology, Engineering, and Mathematics (STEM) fields has opened up a new future of careers in the United States (NRC, 2011). By 2018, STEM careers are projected to account for the sixth largest portion of job openings in the United States. Of these projected 2.8 million jobs, 1.2 million will require a bachelor's degree (Carnevale, Smith, & Strohl, 2010). However, among students that are completing degrees, there is an overall decline in the percentage choosing STEM majors and career fields (Casey, 2012). Further, the people that are choosing and prepared for STEM majors and careers are not a mirrored representation of the US population, as they are lacking ethnic and gender diversity (Kuehler, Marle, Decker, & Khaliqi, 2012). This lack of persistence in STEM fields can be traced back to student experiences in high school, where students fail to develop an interest in STEM and leave lacking the foundational math and science skills needed for success in STEM majors (Olson, 2006).

1.1 High School STEM Preparation

Students in the United States are lacking the foundational skills in math and science needed to pursue STEM majors (Olson, 2006). The National Assessment of Education Progress (NAEP) is a national standardized assessment used to measure students' understanding in various subjects (i.e. mathematics, reading, science, writing, the arts, civics, economics, geography, and U.S. history) (National Center for Educational Statistics, 2014). Since the NAEP exam is standardized throughout the country and administered the same way everywhere, it is possible to use the results on this exam to compare students' academic achievements over time. Long-term trend analysis for the NAEP assessment found no significant difference in mathematics knowledge and skill performance for seventeen-year-old students since 1973 (NAEP, 2012). Further, on the 2013 NAEP administration, only 26% of students performed at or above the *proficient* level of performance on the mathematics NAEP.

NAEP score trends for White students versus Black and Hispanic students have shown a significant gap in academic performance between these ethnic groups. In 2007, White students outperformed Black students by 31 points on the 8th grade Mathematics NAEP exam. This gap is consistent with the previous administrations of the exam since 1990 (NCES, 2014). In 2009, the Mathematics achievement gap between Hispanic and White students was 26 percentage points, favoring White students (Department of Education, 2011). Scores on the NAEP exam for Mathematics show a gap between White and Hispanic students that has remained consistent between 1990 and 2009. There are also significant gaps in achievement on science and math standardized tests between students based on socioeconomic status (DOE, 2011).

Students in the United States continue to perform at or below their international counterparts in math and science. The Programme for International Student Assessment (PISA) is an international exam designed to assess students' understanding of mathematics, science, and reading concepts. In 2012, among the 34 countries part of the Organization for Economic Co-operation and Development (OECD), the United States ranked 27th in mathematics performance on PISA and 20th in science. Although US math performance was determined below average compared with other countries in OECD, US science performance was close to the OECD average. US students perform particularly poorly on cognitively demanding mathematical tasks that require students to apply mathematical content in a variety of contexts (OECD, 2012).

The first hurdle toward pursuing a STEM career is high school graduation. Overall, students are disengaged in the high school classroom environment, causing high dropout rates nationwide (Archambault, Janosz, Fallu, & Pagani, 2009). Although many factors contribute, in the era of accountability failure to make adequate progress in science and mathematics can prevent students from graduation, since successful completion of these exams is a graduation requirement in many states, including Texas. The overall Admitted Freshmen Graduation Rate (AFGR) for the 2012-2013 was 81.4% for the US and 88% for Texas. AFGR is calculated by finding the percentage of high school freshmen that graduate after four years from their 9^{th} grade school year.

1.2 Interest and Motivation in STEM

The overall decline in interest and lack of persistence in STEM can be traced back to students' interest in STEM in high school. College students that choose STEM majors and fields not only make this decision in high school, but the choice is due to interest in science and math; even more so than high achievement and enrollment in high level STEM courses (Maltese & Tai, 2011). A study conducted with 6,000 students found that the odds of a student having interest in STEM at the end of high school was nine times as high for students that reported interest in STEM at the beginning of high school. Further, the number of male students interested in STEM in high school vastly outnumbered the number of females interested in STEM (Sadler, Sonnert, Hazari, & Tai, 2012).

Students are lacking exposure in high school to STEM careers, which might provide interest in the field and motivation to persist (Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008). A poor understanding of the power, impact, and creative nature of many engineering fields explains the low interest in the field. Students' misconceptions result in a feeling that STEM careers are not aligned with their life and career aspirations (National Academy of Engineering, 2008). Students that are interested in STEM often have a better understanding of the field due to a family member or friend working in the field. Therefore exposure to authentic STEM activities in high school should increase motivation and interest toward choosing STEM majors and fields by helping change the misconstrued image of these fields (NAE, 2008).

1.3 One Solution: PBL

This overall loss of interest and lack of achievement in these STEM fields (described above) has caused alarm for educational policy makers (Technology, 2010). Many STEM focused schools and academies have been implemented across the US in hopes of inspiring students to future careers in STEM and minimizing the achievement gap (Ravitz, 2008). Some of these offer rigorous but traditional science and mathematics curriculum, while others focus on applying STEM in context, and developing communication, critical thinking, and collaboration skills critical for success outside of school. One of the approaches focused on learning STEM in context is Project-Based Learning (PBL).

Project-Based Learning increases students' engagement in their STEM content knowledge by providing opportunities to "learn by doing" (Barron, 1998). In order for Project-Based Learning as envisioned today to be occurring in a classroom, the following five pieces must be present (Krajcik & Blumenfeld, 2006).

1. A driving question or challenge
2. Engagement in authentic activities while exploring the challenge.
3. Collaboration within the school and with experts in the community.
4. Learning technology that allows students to participate in learning activities that otherwise would be impossible.

5. A tangible end product that is a solution to the challenge or question.

PBL might be expected to attract students to STEM careers and close the achievement gap because it provides a context and purpose for learning STEM content and it increases interest and motivation toward STEM by providing knowledge and awareness of STEM careers. All of these effects of PBL will be discussed in detail in Chapter 2.

Among inductive teaching and learning methods, PBL has been shown to be effective. Empirical evidence suggests that students taught through PBL retain content knowledge longer than their traditional counterparts and PBL has a positive impact on skill development when assessment was both given immediately and delayed (Prince & Felder, 2006). Further, PBL compared to traditional instruction has been shown to increase or at least maintain students' learning of content in K-12 classrooms as assessed on state standardized assessments (Boaler, 2002; Finkelstein, Hanson, Huang, Hirschman, & Huang, 2010; Geier et al., 2008; Petrosino, 1998; Rivet & Krajcik, 2004; R. M. Schneider, Krajcik, Marx, & Soloway, 2002). Standardized test scores are readily available nationwide, therefore these scores are often used for quantifying students' math and science ability. Yet there is a lack of empirical studies comparing matched students' math and science achievement while attending an exclusively project-based school with that of their traditionally taught counterparts. One possible exception would be Geier et al. (2008), which compared students taught though PBL, but in that case the study was conducted in a heavily researcher supported environment and project-based curriculum was only used in students' science classes.

A school focused on Project-Based Learning was the site of this dissertation research. Manor New Technology High School (MNTH) is part of the New Technology Network. In accordance with the requirements for fidelity of implementation of the New

Tech Model, Manor New Tech follows a small school model, all classes are to be taught through project-based curriculum, admission is lottery-based, and the school has a 1:1 student to computer ratio. In addition to following the New Tech Model, Manor New Tech is also part of the Texas-STEM initiative, an initiative focused on increasing engagement and student performance in science, technology, engineering, and mathematics across the state of Texas. Currently the school population is comprised of 71% underrepresented minority students and 55% eligible for free or reduced lunch (Texas Education Agency, 2015a).

The school opened its doors in August 2007 as an alternative learning experience for Manor Independent School District's high school students. The small school model only allows a maximum class size of 100 students; therefore students interested in attending MNTH are placed in a lottery to determine attendance. The school focuses on providing students exposure to STEM fields through offering Project Lead the Way engineering courses, requiring students to take integrated courses (e.g. Phylgebrics: integrated physics and algebra, Biotech: integrated Biology and engineering), and priding themselves on teaching all classes through project-based instruction (Manor New Tech, 2015).

The admission process at MNTH is designed to be inclusive. The application is written in both English and Spanish and mailed to every 8th grade student's household in the district and is available online. There is no academic requirement other than admittance into the 9th grade; therefore the application is simply basic information for the student (e.g. name, address, siblings). Although students are chosen through a lottery, students and their parents have the option to put their child's name in the lottery to attend MNTH, so the choice is not entirely random.

Manor New Tech has outperformed district and state averages on the state-mandated standardized test (Gourgey, Asiabanpour, Crawford, Grasso, & Herbert, 2009). Still, the question remains about whether this success is due to self-selection/parental support or the experience of PBL. Some speculate that the self-selection that occurs when students and parents are provided school choice results in a population of students that are already academically driven or have a supportive family (Cullen, Jacob, & Levitt, 2005; Murnane, Newstead, & Olsen, 1985). It is possible that the initiative to attend an innovative school, such as MNTH, could impact students' success in High School, and these students that apply to the school would be successful in a traditional high school environment.

Since Manor New Tech High School opened its doors in 2007, recruitment efforts and attention around the community has resulted in more students in the lottery than the school could support. Since 2009 approximately 50 students each year are waitlisted for attending MNTH and the result is that these students attend the more traditional high school within the district. This provides an interesting opportunity for a natural experiment, leading to the following questions of interest in this dissertation research:

(1) How are the students who apply to MNTH different demographically from other students in the district?
(2) Does MNTH have a positive effect on students' achievement in STEM?
    a. If so, is there evidence that MNTH is effective at reducing achievement gaps between demographic groups?
(3) Does MNTH have a positive effect on students' graduation rates?
(4) How do college enrollment rates and first-year college GPA distributions differ between New Tech schools and compare with state and national averages?

CHAPTER 2: LITERATURE REVIEW

This chapter first looks at the variety of reform-focused schools that are opened as an alternative to traditional learning institutions, and describes the demographic makeup for students that choose to apply to attend these alternative schools. This leads to the first research question for this dissertation research that looks at how students that choose to apply to a project-based, STEM high school differ from the rest of the students in a school district. Next a review of the literature is provided that follows a theoretical framework arguing that teaching through context and inductive teaching methods increases learning, interest, and motivation, and consequently student success. Following this framework, it should follow that students taught through project-based learning, an inductive teaching method that is situated in a context, could experience positive effects on their high school standardized test achievement, high school graduation, college enrollment, and first year college grade point average through an increase in learning and interest and motivation. This leads to the second, third, and fourth research questions that focus on potential effects of PBL on students' high school and college success outcomes.

2.1 Reform-Focused Alternative Schools

Students in the United States are falling further and further behind international students in achievement in math and science (NCES, 2014; Wagner, 2010). There is a growing concern across America based on this current state of education. In order to address this global achievement gap, national initiatives have been put in place to implement STEM academies and alternative school choices for K-12 students (NRC, 2011). This influx of school options such as, inter- and intra-district transfer, charter schools, and magnet schools, has resulted in parents having more voice in their students schooling experience (Hastings, Kane, & Staiger, 2006; M. Schneider & Buckley, 2002). Since these alternative school choices have been put in place, there is a lack of empirical studies that show whether students that choose to attend these schools would have performed well in math and science even if they hadn't chosen to attend these alternative schools (NRC, 2011).

SCHOOL CHOICE

School choice initiatives have grown in popularity since the turn of the millennium in hopes of solving a problem of inequity in quality of schools' performance (Abdulkadiroglu & Sönmez, 2003). Lower performing schools were often located in poorer neighborhoods, and traditional designation of school attendance being based solely on students' proximity to a school resulted in the most historically disadvantaged students, ethnic minorities and economically disadvantaged students, being forced to attend these low performing schools (Abdulkadiroglu & Sönmez, 2003; Cullen et al., 2005).

School choice allows the parent to choose the school their child would attend instead of traditional attendance based solely on where a student lives within a district. A study conducted with students in Chicago Public School system found that students that "opt-out" from attending their designated high school in the district were 7.6 times more likely to graduate from high school than a sample of students matched on observable characteristics (e.g. academic performance, ethnicity, SES) (Cullen et al., 2005).

Early research found that choosing to attend Catholic Schools and other private schools also had a significant positive effect on student achievement when compared to attending public schools (Sander, 2001). The resulting positive effects of student performance when choosing to attend a school could be arising from unobservable characteristics such as higher parent involvement and student motivation (Cullen et al., 2005; Murnane et al., 1985).

CONSIDERATIONS WHEN CHOOSING SCHOOLS

Providing choice in school attendance empowers parents that were once constrained by the neighborhood where they lived, yet simply providing parents a choice assumes that all parents have equal exposure to the school options available to their children. Access to social platforms providing relevant information for school options, language barriers, transportation considerations, and socio-economic status are still major obstacles faced by parents with school-aged children (C. A. Bell, 2009). These barriers in access to higher performing school options are very important to consider since English language learners, ethnic minorities, and economically disadvantaged students are often designated to attend the lower performing schools (Cullen et al., 2005).

When provided school choice, African American parents ranked teaching of moral values as the most important characteristic used to choose a school for their child to attend, whereas Hispanic parents explained that good discipline was their primary consideration. White parents explained that the schools' test performance was the most crucial characteristic for choosing a school (Weiher & Tedin, 2002). Students whose parents ranked academic achievement as the most important characteristic for school choice performed better on standardized tests when they won a lottery to attend an academically better performing school, but students of parents that ranked the schools performance as less important actually incurred academic losses when attending such a school (Hastings et al., 2006). This result supports the idea that parental influences could be impacting a students' academic performance.

SELECTION BIAS

The study comparing Catholic Schools with public schools used a popular two-step method that controlled for differences in background information for students before comparing the two samples, claiming that controlling for these variables would remove any selection bias. This method assumes that students are randomly assigned to either school or that there is no correlation between performance and school choice. Unfortunately, when students or their parents choose to attend a Catholic school the assumptions are being violated (Murnane et al., 1985).

In 2008, a case study was undertaken at the site of this dissertation research, Manor New Tech High School. (Gourgey et al., 2009) discuss how MNTH students outperformed the traditional school in district, Manor High School, but the authors explain that they were provided limited access to these data that supported this claim, and due to this limitation were they unable to imply causal or correlational relationships based on student achievement data while controlling for differences between the two schools' student populations.

It is very important when comparing schools on differences in academic achievement to follow a research design that acknowledges the selection bias that occurs when students choose to attend a school (Murnane et al., 1985). This dissertation compares students that attended a Project-Based School with students that applied to attend said school, but were waitlisted. This dataset provides a unique opportunity in that it does not violate the assumption of random assignment to attend the schools. Which leads to the design of the study and the first research question described in Chapter 3.

2.2 Theoretical Framework

The structure of the rest of this chapter follows the theoretical framework depicted in Figure 1. Beginning at the bottom of the framework, there is supporting literature that situating learning in context increases learning, student motivation, and interest. There is also literature to support that inductive teaching methods increase learning, motivation, and interest. Finally empirical studies are reviewed that show that Project-Based Learning (PBL), an inductive teaching method that is also situated in context, increases learning, motivation, and interest. It should then follow that if students' learning, motivation, and interest are increased, this should increase students' high school and college success outcomes, specifically standardized test achievement, high school graduation, college enrollment, and first-year college GPA.

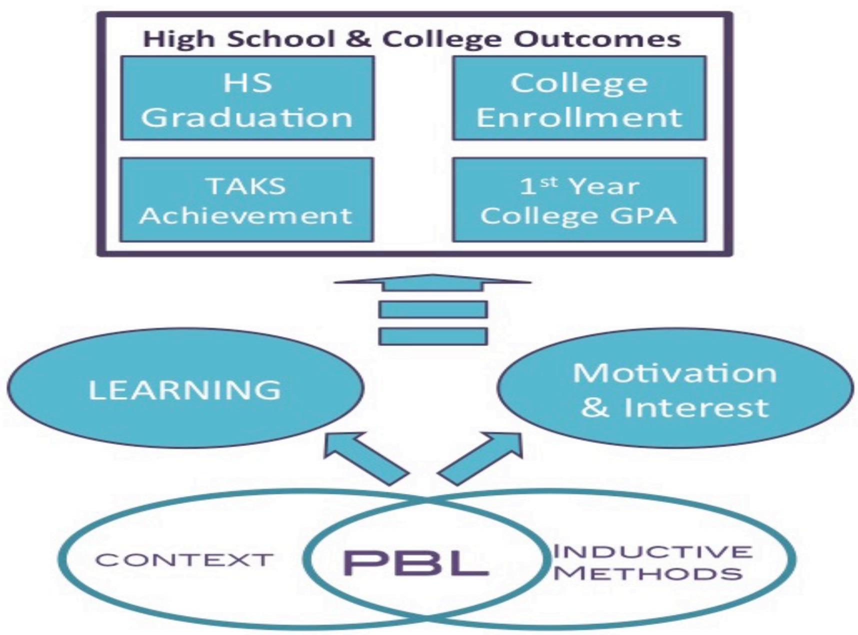

Figure 1: Theoretical Framework Schematic

2.3 Review of Relevant Literature

BACKGROUND DEFINITIONS OF CONTEXT AND KNOWLEDGE

This research looks at *knowledge* from a constructivist framework, i.e., that knowledge is constructed from the learners' experiences (Piaget, 1967). Knowledge is not a collection of discrete skills and pieces of information, but instead a web of connections, transferable to all of one's experiences and applicable to all contexts. If knowledge were a collection of discrete facts and algorithms, then obtaining knowledge most efficiently would be done by memorizing all of the bits of information for a content domain. This traditional view of knowledge resulted in educational systems that fostered the memorization of definitions, algorithms, and other rote skills, but did not promote the ability to use and apply these skills to authentic activities. "It is common for students to acquire algorithms, routines, and decontextualized definitions that they cannot use and that, therefore, lie inert" (Brown, Collins, & Duguid, 1989, p. 33).

Traditional educational structures were developed with the idea that knowledge and context are separate entities; therefore one can "know" without "knowing how." The *situated cognition* perspective explains that the context in which knowledge is situated and the knowledge itself are inseparable. Learning and cognition cannot be constructed without activity. Therefore, in order for learning and understanding content to be possible, they must be situated in a context (Brown et al., 1989).

From the situated cognition perspective, conceptual knowledge is constructed through doing authentic activity within a system. The construction of knowledge occurs as a result of the interactions within the environment (Collins, Greeno, & Resnick, 1992). Instead of a compilation of a hierarchy of skills and information, knowing is a web connecting information and skills on a variety of levels and applying said knowledge to a variety of contexts within and outside of the content domain (Brown et al., 1989).

CONTEXT INCREASES LEARNING, MOTIVATION, AND INTEREST

When students are learning more abstract concepts in STEM disciplines, providing a context allows students to connect their experiences with the concepts they are trying to learn, and in turn conceptually understand the material. Providing context allows students to connect to previous knowledge and experiences, providing them with an additional tool for solving abstract math problems (Boaler, 2002). Research and policy around mathematics education continue to stress the importance of contextualizing mathematics in a way that is relevant to students' lives, to help increase their learning of mathematics by providing students with access to various analytical tools (NCTM, Common Core 2010).

Context through Anchored Instruction

Anchored Instruction is an instructional approach that situates content within the context of an authentic problem scenario (The Cognition and Technology Group at Vanderbilt, 1992). The Cognition and Technology Group at Vanderbilt (CTGV) has created and researched Anchored Instruction technologies that were designed to provide this anchoring context to students. The Jasper Series is a collection of these instructional technology materials with video narratives created by CTGV that provided learners with complex problems.

In the early 1990's the Jasper Series was implemented in 16 schools in nine states. The results suggested that students in the treatment Jasper group learned basic math concepts as well as the matched control group. Also, the Jasper group exceeded the control group in their ability to solve single, complex two step, and complex multi-step word problems (CTGV, 1992). The study also found that students learning in the Jasper group had significantly improved attitudes toward mathematics and described less anxiety toward mathematics than the control group.

A similar study conducted with Taiwanese elementary students using the Jasper Series in their math classes also found that students' problem-solving skills were significantly better for students in the Jasper group over the control group regardless of their previously determined math or science abilities. Also, being taught with the Jasper curriculum had significant positive impact on students' attitudes toward mathematics and students' motivation to learn mathematics (Shyu, 2000). Therefore providing a context through anchored instruction increases or at least maintains students' learning of content and increases students' motivation and overall interest in the subject.

Research and theory around Anchored Instruction has continued to argue the importance of situating instruction within a context, but simply the presence of an anchor or a story problem is not enough to ensure meaningful, conceptual learning. A good anchoring context requires ongoing support to drive the learning process (Pellegrino & Brophy, 2008). Therefore the instructional method must provide the needed support when curriculum is housed within a context.

Context of Engineering

In a study on undergraduate engineering students' perceptions of science, technology, engineering, and mathematics at the University of California, Berkeley, one student explained, "The problems in math have absolutely no significance at all. It's purely an exercise" (McKenna, McMartin, Terada, Sirivedhin, & Agogino, 2001, p.11). Learning the mathematics without a context results in disconnect of students' conceptual understanding of mathematics and sways students' perceptions of the purpose and value of learning the mathematics content.

McKenna et al. (2001) found through their interviews that undergraduate engineering students perceive math as lacking relevance, whereas engineering is viewed as the only subject that has an application to solving real-world problems. Therefore providing students the opportunity to learn mathematics through a context such as engineering should increase students' perception of and interest in mathematics through providing relevance of the content to their lives.

Context by Presenting Contrasting Cases

A Time for Telling paradigm uses the presentation of contrasting cases to provide a context that challenges students' thinking and allows them to construct their own deep understanding of a concept. Only once students have constructed their own knowledge structures through this context are they delivered content in more traditional methods (e.g. lecture, discussion, textbooks), thus providing the needed conventional structures for students to organize the newly learned information (Schwartz & Bransford, 1998).

Inventing with Contrasting Cases (ICC) is an example of "Just in Time" Teaching where learners are provided a context and asked to create a process or formula to solve a problem. It is not until the learners have constructed their own formulas that they are then "told" the conventional formulas and provided instruction. Tell and Practice (T&P) is an instructional practice in which learners are told new formulas and content, then provided an opportunity to practice through solving problems using the given formulas. The main difference between these two practices is when it is during the instruction that the "telling" occurs (Schwartz, Chase, Oppezzo, & Chin, 2011).

Schwartz et al. (2011) conducted two studies comparing these two instructional frameworks with adolescent physics students in which all students were taught the same physics concepts using either tell and practice (T&P) or inventing with contrasting cases (ICC). In the first study of 128 adolescents, students were able to use the formulas to solve word problems regardless of the type of instruction that was used with their group, but ICC students that were provided a context first learned the content better and were able to transfer their understanding to unrelated content domains. Similarly, in the second study of 120 students, instruction through ICC resulted in increased learning for both the low and high achieving students compared to students taught through T&P (Schwartz et al., 2011).

Context with Story Problems

Another common way that mathematics is contextualized for students is through the use of story or word problems in both mathematics instruction and assessment. Story problems situate abstract mathematical concepts in either a verbal or situational context. There is a general consensus held by the education community (e.g. content experts, teachers, textbook authors) that story problems are difficult for students (Koedinger & Nathan, 2004; Nathan, Long, & Alibali, 2002; Nathan & Petrosino, 2003). This "Expert Blind Spot" often results in curriculum and instruction that provides context only *after* instruction on the abstract concepts, where providing students context prior to instruction on abstract concepts could also be beneficial.

Math textbooks follow a *symbol precedence view,* in which story problems are given to students as an extension challenge after they have had practice with the abstract algebraic or arithmetic process. Although this view provides context for the content, the timing of the context is after the instruction and presentation of the abstract formulation similar to the tell and practice (T&P) mode of delivery (Schwartz et al., 2011). Curriculum developers and teachers often align their instruction with the textbook progression, therefore if textbooks use *symbol precedence,* then instruction is likely following this order as well (Nathan et al., 2002). Koedinger & Nathan (2004) conducted two studies comparing students' performance on story problems and matched, abstract, equation problems and found that students performed better when they were provided a context through the story problems. Their findings support the theory that context increases learning by providing students context cues from their pre-requisite knowledge and experiences to help solve problems.

Walkington, Sherman, & Petrosino (2012) conducted a qualitative study of high school Algebra 1 students' (N=24) access to mathematical processes when they were provided contexts for problem solving through story problems. The study consisted of an initial, entrance interview in which researchers determined how the students already used mathematics in their lives as well as more general questions regarding the students' interests and hobbies. The same students were interviewed a second time while they solved customized story problems, normal word problems, and symbolic problems. The customized story problems used information gained in the entrance interviews to create story problems that provided context aligned with each student's unique interests. The study found that in order for contextualization to provide the access to mathematical processes, students needed additional support connecting between algebraic, arithmetic, and situational reasoning (Walkington et al., 2012).

In order to increase students' engagement and interest in mathematics by providing context, it is not sufficient to simply make surface connections to students' lives (e.g. change a few characters' names in the story problem). Story problems need to make deep connections to the students' lives in order to foster student engagement in meaningful mathematics. The interest in the stories will keep the students engaged and interested in the mathematics content (Ladson-Billings, 1997).

BACKGROUND DEFINITIONS OF INDUCTIVE TEACHING METHODS

Traditional teaching and learning follows a "teacher-centered" lecture basis in which the teacher provides content and knowledge to students. The only motivation for the students to learn is that the teacher explains that they need to learn new content and that this content will be applicable to their lives after school (Prince & Felder, 2006). Students are more motivated to learn when the content is situated in solving a problem or challenge because the student will develop a need to learn the content in order to successfully solve the problem. "As the students attempt to analyze the data or scenario and solve the problem, they generate a need for facts, rules, procedures, and guiding principles, at which point they are either presented with the needed information or helped to discover it for themselves" (Prince & Felder, 2006, p. 123).

Multiple inductive teaching and learning methods exist in hopes of providing this need of learning new knowledge to the student. In addition to motivating the learner through providing a need to learn, inductive teaching and learning methods are always (a) learner-centered focusing the responsibility to learn on the student instead of the teacher, (b) based on research that suggests students learn by making connections to their existing cognitive structures, and (c) come from a constructivist view point that students construct new knowledge instead of simply absorbing it (Prince & Felder, 2006). Among these inductive instructional methods are inquiry-based learning, Project-Based Learning, problem-based learning, and discovery learning (Prince & Felder, 2006).

This dissertation research focuses on the potential effects of an inductive teaching method, Project-Based Learning. Essential components of Project-Based Learning overlap characteristics of many other inductive teaching methods. Although there is literature on the effects of Project-Based Learning on student learning and engagement, it was necessary to review literature for many of these similar teaching methods (e.g.

Problem-Based Learning, Guided Inquiry, Learning by Design) in addition to some hybrid methods (e.g. Learning by Design) in order to situate the PBL results in the larger inductive paradigm.

Problem-Based Learning

Problem-Based Learning is an inductive teaching method in which students work in groups to develop a plan and solve open-ended, authentic problems. Although very similar to Project-Based Learning, one main difference between the two instructional approaches is that Problem-Based Learning is usually a smaller scope (1-3 days) and isn't explicitly aligned with learning outcomes (Prince & Felder, 2006).

Guided Inquiry

Inquiry-Based Learning (IBL) is a minimally guided instructional practice that is often used to encompass a large range of teaching practices based in constructivism that focus on the learner constructing new information through active investigation (Jennings & Mills, 2010). One of such inquiry-based practices that is more structured is Guided Inquiry. Similarly, Guided Inquiry is student centered, hands-on inquiry where students investigate various phenomena (Lynch, Kuipers, Pyke, & Szesze, 2005).

Learning By Design

Learning By Design (LBD) is a hybrid project-based and inquiry-based approach to learning science with roots in problem-based learning (PBL) and case-based learning (CBL). LBD curriculum provides students with opportunities to learn through real-life contexts. The curriculum is collaborative, learner centered, inquiry-based, and design-based. The teachers' role in this curriculum shifts to the teacher as a facilitator (Kolodner et al., 2003).

Project-Based Learning

History of Project-Based Learning. Project-Based Learning is rooted in a pedagogy called "the Project Method" developed in the early 20th Century. The Project Method was developed in hopes of teaching students to think and providing them with a purpose for their education. According to the originators, purposeful activities, learning through a context, should be the driver of instruction in education as it is the needed factor for a worthy life. Projects were viewed as an instance of purposeful activity that provided students with context. A project allowed students to delve into their own curiosity about the world, while providing purpose for all students to learn content (Kilpatrick, 1918). The essential characteristics of a "project" were (Kilpatrick, 1925, p. 244):

1. Begin with a problem that drives the pupil's thinking.
2. Research is done to attain information pertinent to solving the problem.
3. The problem must be engaging and full of zest.
4. The problem should be that of the learner.
5. The teacher's role is a facilitator, therefore the student should solve the problem with minimal guidance.

Since projects were developed with the students' interests in mind, projects were both engaging to students and situated in a context that was relevant to students' personal lives. This also provided students with a sense of ownership and autonomy in their learning (Kilpatrick, 1925). Research conducted on students in an advanced 5th grade classroom that were taught using the Project Method found that many students expressed that they really enjoyed the experience. They found the projects relevant to their lives, engaging, and interesting. The teacher also felt that the students were more engaged and interested in the content than is usually expected in a classroom (Hennes, 1921).

Bonser (1921) explains that the collapse of the Project Method in the American curriculum was due to poor interpretation of the definition of "project." This resulted in projects with little to no educational value. Many projects that interest students may not lead to the development of understanding that the teacher would like. Student engagement and interest in a project is not enough: the teacher needs to ensure that the project guides students to a deeper understanding of valuable content (Barron et al., 1998; Bonser, 1921).

Due to these issues of misalignment with content standards, the concept of a project as "Purposeful Act" has now evolved in the 21st Century to Project-Based Learning (PBL), so that, in addition to being based in constructivism and situated in a problem or challenge that is of interest to the student, the project is also aligned with content specific learning outcomes and provides opportunities for formative assessment and student self-reflection to promote doing with understanding (Barron et al., 1998).

Modern Perspectives on Project-Based Learning. Still, in the 21st Century, Project-Based Learning takes on a variety of definitions and different authors identify differing elements essential to a Project-Based Learning environment. Krajcik and Blumenfeld (2006) identify the following five key features of PBL (pp. 647-648):

1. They start with a driving question, a problem to be solved.
2. Students explore the driving question by participating in authentic, situated inquiry—processes of problem solving that are central to expert performance in the discipline. As students explore the driving question, they learn and apply important ideas in the discipline.
3. Students, teachers, and community members engage in collaborative activities to find solutions to the driving question. This mirrors the complex social situation of expert problem solving.

4. While engaged in the inquiry process, students are scaffolded with learning technologies that help them participate in activities normally beyond student ability.
5. Students create set of tangible products that address the driving question. These are shared artifacts, publicly accessible external representations of the class's learning.

Barron et al. (1998) identify the following characteristics needed in a curriculum that supports PBL (p. 273):

1. Learning-appropriate goals
2. Scaffolds that support both student and teacher learning
3. Frequent opportunities for formative self-assessment and revision
4. Social organizations that promote participation and result in a sense of agency.

Lastly, Prince and Felder (2006) say that Project-Based Learning begins with a challenge to create a design, model, device, computer simulation, or some other type of final product. The project is completed by the learner providing an oral or written explanation of the process they went through to create the final product. Prince and Felder (2006) explain that there is somewhat of a struggle with teachers as to the amount of autonomy the student has in the choice of the project. Due to this varying opinion on who chooses the project, they separate projects into the following three types: Task-Project, Discipline Project, and Problem-Project. A Task Project is completely defined by the teacher and results in little student motivation and skill development. A Discipline Project allows for some student autonomy because the teacher chooses the subject area and common methods for solving, but the student is able to identify the project. The Problem-Project provides complete autonomy for student choice and solving method (Prince & Felder, 2006). For the purpose of this dissertation research, the author combined all three of these authors' definitions of PBL (see Table 1) and identified these essential characteristics of PBL (also see figure 2):

1. Driving Question: Driving question or problem that provides context and drives instruction
2. Content Standards: Aligned with content specific learning outcomes
3. Exploration Activities: Scaffolded with engaging, authentic activities that allow the student to explore the content.
4. Assessment: Multiple opportunities for self-reflection and revisions.
5. Collaboration: Collaboration inside the class and with experts outside in the community to complete the project.
6. Final Product: Creating a tangible final product that is a solution and focuses on the process for finding the solution

Essential Component of PBL	(Krajcik & Blumenfeld, 2006)	(Barron et al., 1998)	(Prince & Felder, 2006)
Driving Question: Driving question or problem that provides context and drives instruction	√	√	√
Content Standards: Aligned with content specific learning outcomes		√	
Exploration Activities: Scaffolded with engaging, authentic activities that allow the student to explore the content.	√	√	√
Assessment: Multiple opportunities for self-reflection and revisions.		√	
Collaboration: Collaboration inside the class and with experts outside in the community to complete the project.	√		√*
Final Product: Creating a tangible final product that is a solution and focuses on the process for finding the solution	√		√

Table 1: Authors Defined Essential Components and Design in PBL * Prince & Felder (2006) define PBL to *usually* be collaborative

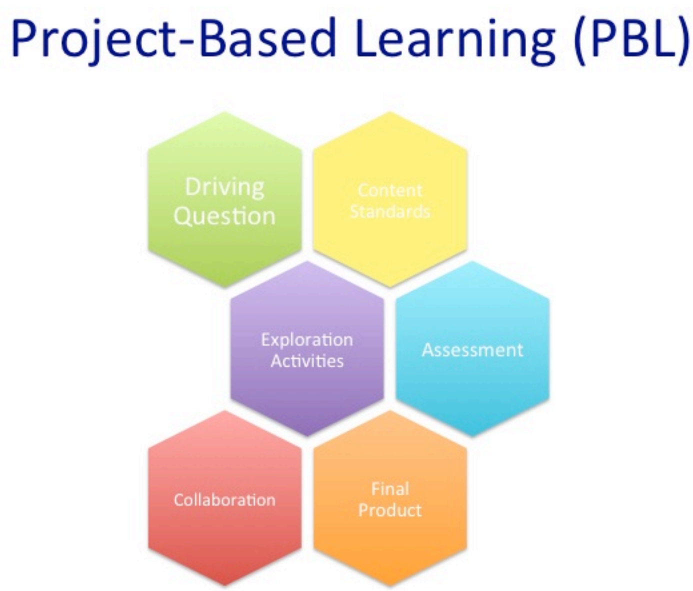

Figure 2: Essential Components of Project-Based Learning

INDUCTIVE TEACHING METHODS INCREASE LEARNING, MOTIVATION, AND INTEREST

Empirical evidence suggests that Project-Based Learning positively impacts students' learning (Boaler, 2002; CTGV, 1992; Geier et al., 2008; Petrosino, 1998; Prince & Felder, 2006; Rivet & Krajcik, 2004; R. M. Schneider et al., 2002). Various other inductive teaching methods (i.e. Problem-Based Learning, a Time for Telling, Guided Inquiry, and Learning by Design) have also shown evidence of increasing learning (Anyafulude, 2012; Finkelstein et al., 2010; Kolodner et al., 2003; Lynch et al., 2005; Mergendoller, Maxwell, & Bellisimo, 2006; Schwartz et al., 2011). Although the latter inductive teaching methods are not completely equivalent to Project-Based Learning, they possess some of the components that are essential to PBL and provide additional evidence in the literature that these components also positively impact student achievement.

Problem-Based Learning

Problem Based Learning includes these components of PBL (see figure 3).

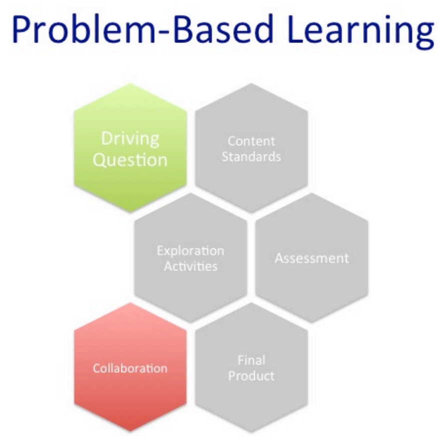

Figure 3: Essential Components of PBL Overlapping with Problem-Based Learning

Dochy, Segers, Van den Bossche, and Gijbels (2003) conducted a meta-analysis of the effects of problem-based learning on students' knowledge and skill development. Their analysis included 43 empirical studies that met their requirements of problem-based learning. They found a robust positive effect on skills of students and did not identify a single study with a negative effect. Moreover this positive effect on skill development is found to be both immediate and long lasting.

For knowledge-focused outcomes they found that students taught through problem-based approaches have less knowledge, but they retain what knowledge they have gained longer. They found a significantly negative effect on knowledge acquisition for students taught through problem-based learning, but they did believe that these findings were due to two studies. These differences in knowledge did diminish after one to two years (Dochy et al., 2003).

Mergendoller et al. (2006) conducted a study on the effects of Problem-Based Learning (PBL) on students' learning of macroeconomics. This study focused on 186 students learning economics through two different problem-based units that were taught by three veteran teachers. The study consisted of five teachers at four high schools in northern California with 346 students. The teachers selected which classes they taught through PBL and which they taught through traditional methods.

They found that across all of the teachers, the students showed an increase of approximately 4% raw score from a pre-test to post-test on macroeconomic knowledge when taught through PBL compared to traditional instruction. Although the authors did not find significant gains based on different background characteristics (e.g. interest in the content, interest in problem solving, and interest in group work), their observations found non-significant positive trends for the benefits from PBL based on these background characteristics. For example, students with middle to lower verbal ability seemed to benefit, although not significantly, from PBL teaching methods (Mergendoller et al., 2006).

Schmidt, Vermeulen, and Van Der Molen (2006) compared a group of medical students taught through problem-based learning and a conventionally taught medical program. They sent out a questionnaire to all medical school graduates from both schools since 1980. The questionnaire asked questions related to medical professional competencies that included both general academic skills and more "PBL-Related" competencies (e.g. interpersonal skills, problem-solving skills, self-directed learning skills, task completion oriented skills). They found that the students taught through problem-based learning methods significantly outperformed the conventionally taught students on the "PBL-Related" skills and performed the same on the general academic skills (Schmidt et al., 2006).

Finkelstein et al. (2010) conducted a study comparing 11th and 12th grade students' achievement in economics when randomly assigned to either a lecture-based (control) or Problem-Based Economics (treatment) group. The large study included 41 teachers that were provided summer professional development on using Problem-Based Economics (PBE) as an instructional practice. They found that being taught with PBE resulted in students answering 2.60 more questions correctly on the Test of Economic Literacy with an effect size of 0.32 (Finkelstein et al., 2010).

Anyafulude (2012) conducted an experimental study investigating effects on student learning of chemistry content for students taught with problem-based and discovery-based instructional methods compared to students taught with a more traditional expository method of instruction. The study included three randomly chosen senior level chemistry classes (375 students) in Agbani Education Zone in Nigeria, Africa. Each class was randomly assigned to problem-based, discovery-based, or expository methods of instruction to teach a 6-week unit. Problem-Based Learning is defined equivalently to Project-Based Learning in that it begins with a question/problem that guides students to work cooperatively to devise a plan and come up with a solution. The study found that students taught through Problem-Based Learning had a significantly higher score ($p<.05$) on the chemistry post-test than the students in the discovery-based or expository-based classrooms (Anyafulude, 2012).

Guided Inquiry

Guided Inquiry, as defined by Lynch et al. (2005) in reference to the Chemistry that Applies (CTA) curriculum used in their study, includes these components in common with PBL (see figure 4).

Figure 4: Essential Components of PBL Overlapping with Guided Inquiry

A study of 8th grade students from 10 different middle schools that used Chemistry that Applies (CTA), a guided inquiry Chemistry curriculum that is similar to PBL, did find overall significant difference in a Chemistry post-assessment, but did not find significant effects based on a variety of demographic characteristics, including ethnicity, SES, and gender. One interaction they did find was that students taught through CTA that had never been labeled ELL or were no longer labeled ELL outperformed the current ELL students on the assessment, which implies that students taught through guided inquiry showed an increase in the ELL achievement gap (Lynch et al., 2005).

Learning By Design

Learning By Design (LBD) includes these components of PBL (see figure 5).

Figure 5: Essential Components of PBL Overlapping with Learning By Design

Kolodner et al., (2003) conducted research on the implementation of their Learning by Design (LBD) curriculum on 240 Middle School students and looked at the effects on (1) students' science content achievement, (2) their ability to design experiments, and (3) their ability to collaborate in groups. The results showed that students in the LBD curriculum showed significant gains in their science content achievement as well as their ability to design experiments and collaborate with their peers. They also found in their analysis that the largest gains in achievement were from students that were classified as strongly disadvantaged economically and had performed the worst on the pre-assessment. Students learning through the LBD curriculum closed the gender gap with their performance from the pre to post assessment (Kolodner et al., 2003).

Project-Based Learning Increases Learning

Project-Based Learning is an inductive teaching method that situates learning in a context (Prince & Felder, 2006). Since students taught through context show increased or maintained levels of learning content (CTGV, 1992; McKenna et al., 2001; Pellegrino & Brophy, 2008; Schwartz & Bransford, 1998), and since students taught through inductive teaching methods that share many of the components essential to PBL (Anyafulude, 2012; Finkelstein et al., 2010; Kolodner et al., 2003; Lynch et al., 2005; Mergendoller et al., 2006; Schwartz et al., 2011), it should logically follow that students taught through PBL experience an increase in learning. Below four project-based curricula are discussed in detail, each of which aligns with the essential components for Project-Based Learning and looks at effects on learning, specifically as measured by standardized assessments. Although there are other measures of learning of content, score on a standardized test is used in this dissertation research, so relevant literature that also looked at effects on this instrument for measuring students' learning were included in this literature review.

Mars Mission Challenge

Petrosino (1998) conducted a study of 5th and 6th grade students enrolled in an 8-week "School For Thought" summer school program in a southeast metropolitan area. The students that participated in the study were predominantly African American (82%) and came from a low socio-economic background (90%). Students participating in the study completed the Mars Mission Challenge unit, which is a project-based curriculum on the topic of rocketry in which students are first shown a video that introduces the context of the problem, thus beginning the inquiry process, then students design and build rockets. A unique component of the study is that students were provided multiple opportunities to reflect and revise their rocket design. Petrosino, (1998) compared students' understanding of experimentation when they would simply investigate without opportunities to reflect and revise with the understanding of students that were provided this opportunity, and found that the latter group showed a significant increase in students' understanding of experimentation.

Phoenix Park Project-Based Curriculum

Boaler (2002) conducted a 3-year, longitudinal study of approximately 300 students in two secondary schools in England where one school, Amber Hill, teaches math traditionally and the other, Phoenix Park, through PBL. The female students entering the two schools had no initial significant difference in their mathematical abilities, but at the end of the three years, students attending the traditional pedagogy school, Amber Hill, scored significantly lower than the boys at their school on a national standardized assessment. Students taught through PBL did not show any significant gender difference in scores on the national assessment, and overall the PBL School's students scored significantly higher on the exam than the traditional school. Also, girls at the PBL School were found to be significantly more positive and confident in mathematics than the girls at the traditional school.

LeTUS Project-Based Curriculum

The Center for Learning Technologies in Urban Schools (LeTUS) is an NSF-funded project that is a collaborative effort between Detroit and Chicago Public Schools and the University of Michigan and Northwestern University. LeTUS designed project-based curriculum that was implemented in the Detroit Public Schools. Big Things is one of the project-based units within LeTUS curriculum that was used in Detroit Middle Schools for four years (1999-2002). The school that was the focus of the study had demographics similar to the district, which is 91% African American and 70% low SES. Students in this study were given a pre and post assessment. The findings of these students engaged in this project-based curriculum indicate significant improvement on the post assessment. Students also demonstrated significant increases on three different levels of questions included on the assessment (Rivet & Krajcik, 2004).

As this project progressed more teachers were trained by the University of Michigan in using the LeTUS curriculum. Another study of the effects of the LeTUS PBL curriculum was with approximately 5,000 middle school students, 91% African American and 70% low SES from 1998-2001. This similar study found significant increases on the Michigan Educational Assessment Program (MEAP) for students participating in at least one of the LeTUS PBL units compared to the rest of the Detroit Public School population (Geier et al., 2008).

Project-Based Science (PBS) Curriculum

Foundations of Science (FOS) is a three year, Project-Based Science (PBS) curriculum, developed in collaboration with the University of Michigan, that integrates Earth Science, Biology, and Chemistry. The National Assessment of Educational Progress (NAEP) is a national standardized test that assesses students' achievement in a variety of content areas including science, mathematics, reading, and geography (R. M. Schneider et al., 2002).

Schneider et al. (2002) conducted a study comparing overall national performance on the 1996 Science NAEP with 10^{th} and 11^{th} graders' performance when they were taught using FOS curriculum. The study was conducted at a small (~450 student) public high school in the Midwest. Students that attend this lottery-based, alternative school come from a diverse background on racial, academic, and socioeconomic factors, but the majority of students were white and from middle to upper class families. Schneider et al. (2002) found that the students taught with the project-based science (PBS) curriculum showed significant gains in achievement on the NAEP. "Even compared with groups that traditionally score higher on achievement tests (middle-class and White students), on average the PBS students, including minorities, outscored the national sample on almost half the items" and scored the same on the remaining items (Schneider et al., 2002, p. 419).

PROJECT-BASED LEARNING INCREASES INTEREST AND MOTIVATION

Since projects are investigations created with the students' interest in mind, by design they should increase students' interest in the content. Projects increase students' interest by allowing them to solve authentic problems and create tangible artifacts (Blumenfeld, 1991). "Students who participate in Project-Based Learning are generally motivated by it and demonstrate better teamwork and communication skills" (Mills & Treagust, 2003, p. 12). PBL provides students with autonomy over their learning by providing students with choices regarding the process for solving the driving question or challenge. This choice is crucial to student success because when given choice students' develop interest that will drive their pursuit to learning (S. Bell, 2010).

Foundations of Science Project-Based Curriculum

Pryor (1996) conducted a three-year study of students participating in the FOS project-based curriculum. Again, FOS is a project-based curriculum that incorporated technology use by providing students with a personal computer with software that mediates scientific inquiry (e.g. data gathering, data visualization and modeling, project planning). Students engaged in the FOS curriculum showed an increase in motivation and overall eagerness to learn science content. There was also evidence of great gains in students' 21st Century Skill ability such as written and oral communication, collaboration, and technology literacy (Pryor, 1996).

Marine Tech PBL Curriculum

The Marine Tech Curriculum was developed in collaboration with Old Dominion University, Norfolk State University, marine industry personnel, and local school systems in hopes of preparing K-12 students for careers in the STEM field by engaging them in project-based activities. The curriculum integrates marine engineering and physical science content through the context of ship building design projects (Verma, Dickerson, & McKinney, 2011).

Verma et al., (2011) conducted a 3-year study with 60 middle and high school students taught using the Marine Tech project-based curriculum for eight Saturdays during the year and a two-week summer academy each summer (approximately 144 hours of experience with the curriculum). Teachers that were to use the Marine Tech Curriculum were provided extensive professional development and support before implementing the curriculum. Results from the study indicate that overall the curriculum was received well by both teachers and students. Students were engaged in the project-based curriculum because it allowed them to discuss and think critically about the content. "Widespread use of Marine Kits and associated Instructional Modules will successfully engage students and attract them toward STEM based careers in the Marine Industry" (Verma et al., 2011, p. 30).

YESTexas PBL Engineering Curriculum

Young Engineers of South Texas (YESTexas) is a summer engineering outreach program that used a project-based curriculum that incorporated multiple competitive design projects from various engineering disciplines (e.g. electrical, environmental, mechanical, civil). The curriculum was designed in hopes of both providing students with exposure to various engineering disciplines as well as motivating students and attracting them to choosing STEM college majors and careers (Yilmaz, Ren, Custer, & Coleman, 2010).

Students interested in the YESTexas program filled out a free application to attend the summer program. Students were first given a score based on the factors low SES, high GPA, and good high school attendance. Students were then chosen for the program based this score and their written essays on their personal educational goals and their demographic backgrounds. Thirty high school students were chosen to attend the summer outreach program from 12 different schools. Half of the students were female and more than 60% of the students were Hispanic (Yilmaz et al., 2010).

Yilmaz et al., (2010) taught the 30 YESTexas students engineering content by engaging them in a variety of projects completed in teams of 3-4 on topics such as bridges, river pollution, and Bluetooth technology. Student data were collected from comprehensive surveys on the students' experience with the curriculum, daily discussion groups, and overall summaries of their experience. The authors found that students that participated in the YESTexas PBL curriculum had an increased interest in studying engineering in the future. Engagement in the project-based curriculum also improved students' critical thinking, collaboration, and documentation skills (Yilmaz et al., 2010).

These Inductive Teaching methods have been researched and overall results generally find that there is often an increase in student engagement and motivation and, relative to traditional teaching methods, student achievement in STEM either increases or stays the same. In summary, Project-Based Learning should increase both students' high school achievement and engagement in learning. The next section will discuss the relationship between high school achievement, engagement, and college outcomes.

LEARNING AND INTEREST INCREASE HIGH SCHOOL AND COLLEGE OUTCOMES

This dissertation research uses the following measures for high school and college success outcomes: standardized math and science exam performance, high school graduation, college enrollment, and first-year GPA. The Texas Assessment of Knowledge and Skills (TAKS) was the state mandated standardized test in Texas until 2011. The TAKS exams were designed to measure students' learning of and ability to apply stated objectives. The math TAKS was organized around the following ten objectives: (1) Functional relationships, (2) Properties and attributes of functions, (3) Linear functions, (4) Linear equations and inequalities, (5) Quadratic and other nonlinear functions, (6) Geometric relationships and spatial reasoning, (7) 2D and 3D representations, (8) Measurement, (9) Percents, proportions, probability, and statistics, and (10) Mathematical processes and tools. The science TAKS exam is organized around the following five objectives: (1) Nature of Science, (2) Organization of Living Systems, (3) Interdependence of Organisms, (4) Structures and Properties of Matter, and (5) Motion, Forces, and Energy. Both the science and mathematics TAKS exam primarily consist of multiple choice questions organized around these learning objectives.

Following the theoretical framework, students that have increased learning due to experiencing project-based curriculum aligned with these stated objectives, should result in successful achievement on the TAKS exam. Also studies discussed in the previous section found that students taught through project-based curriculum outperform their traditionally taught counterparts on state and national standardized exams (Geier et al., 2008; R. M. Schneider et al., 2002) Therefore achievement on the math and science TAKS exams was chosen for this dissertation research to measure students' high school achievement in math and science.

Many factors impact a students' likelihood of graduating high school. In Texas, in addition to completing required coursework, students are required to achieve a passing score on the state standardized exams ("Texas Education Agency," 2015b). Additionally, Archambault et al. (2009) found that students' *behavioral engagement* (i.e. interest in both academic and extracurricular activities) was a strong predictor for whether a student dropped out of high school. Following the framework, if PBL increases learning and achievement, it should follow that students taught through PBL will be more likely to graduate high school. Therefore high school graduation was chosen as a measure of high school success for this study.

Decisions for pursuing or not pursuing college are often decided while a student is still enrolled in high school. Students' college success (e.g. college enrollment, GPA) is strongly influenced by their motivation, attitude, and overall interest during high school (Singh, Granville, & Dika, 2002). Further, high school achievement on standardized exams is a strong predictor of first-year GPA and college retention (DeBerard, Spielmans, & Julka, 2004). Based on the theoretical framework, if PBL increases students' learning of content and increases their overall interest and motivation to excel in school, it should follow that these students would be more likely to not only enroll in college but have a higher first-year GPA.

DIFFERENCES IN ACHIEVEMENT ACROSS DEMOGRAPHIC CHARACTERISTICS

Achievement gaps exist for students based on a variety of demographic characteristics. Historically, NAEP test score trends for White students versus Black and Hispanic students have shown a significant gap in academic performance between these ethnic groups dating back to 1990 (NCES, 2014). There are also significant gaps in achievement on science and math standardized tests between students based on socioeconomic and English language proficiency status (DOE, 2011).

Although Boaler (2002) found that PBL minimizes the gender achievement gap and Geier et al. (2008) found PBL increased achievement for students at a school that enrolls predominantly African American students from economically disadvantaged families, the literature is scarce to support PBL effects on minimizing achievement gaps. Eslami and Garver (2013) explain that skills developed with PBL curriculum such as collaboration, reflection, and scaffolding content through activities align well with the best practices used with students with learning disabilities and English as their first language. Further, Moss and Van Duzer (1998) explain that project-based learning provides ELL students an unique opportunity to converse in English in authentic situations while solving problems in collaboration with their classmates. Therefore, PBL could be an effective way to teach both learning disabled students and students for whom English is their second language, but again, empirical studies that control for these demographic characteristics while looking at the effects of PBL on student learning are lacking. Since some literature supports the use of PBL to minimize achievement gaps, the potential effect of PBL on minimizing achievement gaps was chosen for analysis in this research.

CHAPTER 3: METHODOLOGY

3.1 Research Design

This study was designed to develop statistical models that can be used to predict the impact of attending the PBL School, Manor New Tech High School, on students' high school and college success. High school success was identified as increasing standardized test scores and high school graduation rates, and models were created that compared a group of PBL students with the group that were taught through traditional methods. The college success outcomes for project-based high schools (college enrollment and first year GPA) were compared to state and national statistics on these same outcomes. Thus, the questions that this dissertation research was set forth to answer were:

(1) How are the students who apply to MNTH different demographically from other students in the district?
(2) Does MNTH have a positive effect on students' achievement in STEM?
    a. If so, is there evidence that MNTH is effective at reducing achievement gaps between demographic groups?
(3) Does MNTH have a positive effect on students' graduation rates?
(4) How do college enrollment rates and first-year college GPA distributions differ between New Tech schools and compare with state and national averages?

3.2 Population and Sampling

SITE

Manor Independent School District currently serves 7,723 students in Manor, TX just east of Austin in central Texas. Until 2007, the district only provided one high school for their students, Manor High School. In 2007, Manor New Technology High School (MNTH) opened its doors as an alternative learning experience to the district's students. Students would be chosen through a random lottery to attend this new school, although the lottery does control for gender differences in the applicant pool by choosing fifty girls and fifty boys for each entering class. The school was designed to look like an innovative start-up company. The classrooms all have glass walls and tables instead of desks, and the classrooms are filled with top technology (e.g. SmartBoards, iMacs, Dell computers). The school is part of the New Tech Network model that focuses on teaching through project-based learning while offering integrating classes, teaching 21st Century skills, and incorporating technology. Manor New Tech also follows a "small school" design model, serving 340 students compared with 1,445 students at the district's other high school.

DATA SOURCES

In order to look at the potential effects of attending MNTH for the entire high school career and the first year of college, the cohort of interest for this study was students that applied to Manor New Technology High School in the spring of 2008 and were set to graduate in May 2012. Each year when students apply to MNTH, their names are put in a hat and the school administration picks one male and one female until the freshmen class of 100 students is filled. Each year students that are not chosen from the lottery are placed on a waitlist. The principal of the school provided a list of students' names for the class of 2012 that was divided into those that were picked in the lottery and attended, here labeled as *attended*, and those that were waitlisted, here labeled as *waitlisted*.

These two data sets were combined into a master list of students that attended MNTH as freshmen in 2008-2009 and those that were waitlisted.

Graduation Data

The principals from Manor New Tech and Manor High School both provided a list of students that graduated in 2012 from their respective schools to use in this analysis. There is a limitation to this data set because it is possible that students transferred to another school out of districted and graduated. So the graduation variable used in this analysis was defined as Graduation=1 if the student graduated in four years from the school where they were admitted as a freshman. Therefore, students that were admitted to MNTH in 9th grade then transferred to MHS in 10th or 11th grade were excluded from this dataset. This allows a equal comparison between the two schools for students' likelihood of graduating when exposed to either PBL or traditional instruction for the duration of high school.

PEIMS Data

The Public Education Information Management System (PEIMS) manages all data obtained by the Texas Education Agency (TEA) regarding public education. For each student, this includes: student ethnicity data (Nominal), gender (Dichotomous), Texas Assessment of Knowledge and Skills (TAKS) scores (Interval), socio-economic status (Dichotomous), learning disability (Dichotomous) English language learning status (Nominal), and graduation completion (Dichotomous) (Texas Education Agency, 2013).

TEA provides these data to schools every year. The principal of MNTH provided these data for the entire district for this study.

College Performance Data

The Texas Higher Education Coordinating Board (THECB) is an organization that works with educational establishments, policymakers, and researchers to improve college and career outcomes for Texas students (THECB, 2014). THECB provides post-secondary data on all Texas high schools students' first year performance in Texas two-year, four-year, and independent institutions. Texas statute requires that each Texas district provide a performance report for each of their schools. These two data sources were combined into a "Report of 2012-2013 High School Graduates' Enrollment and Academic Performance in Texas Public Higher Education." This report is available, free of charge, on the THECB public website.

The report includes the number of students that graduated from each Texas high school, the number of those students that enrolled and attended 2-year public Texas colleges, 4-year public Texas universities, and Texas independent colleges and universities. The report also includes the number of students that were "not trackable" and "not found." "Not trackable" students have non-standard student ID numbers, and therefore the state is unable to track their enrollment in higher education. A limitation of this data set, is that "not found" students could either have attended a post-secondary institution in another state or not enrolled anywhere immediately after high school. The report also includes the number of students that attended 2-year or 4-year Texas establishments' average 1st year grade point average (GPA), organized into the following bins (<2.0; 2.0-2.49; 2.5-2.99; 3.0-3.49; >3.5; Unknown).

New Tech Network is a non-profit organization that uses Project-Based Learning with hopes of reforming education by providing students with an innovative, engaging learning environment. Schools that become part of the New Tech Network are provided extensive professional development for their teachers and school staff, as well as ongoing coaching support to help New Tech teachers use PBL as the main mode of delivery of content. There are currently 139 new tech schools nationwide, and of these, 13 New Tech schools reside in Texas, including Manor New Tech High. The New Tech Network website provides a list of their schools in Texas. These data were compiled into a spreadsheet directly from the website.

Data Organization

The names of all of the 2008 rising freshmen for Manor ISD were organized into the *StudentNames* column in a spreadsheet titled *High_School_Student_Data* with a corresponding *MNTHApply* variable coded 0 if the student didn't apply, 1 if the student applied to Manor New Tech. Another variable named *MNTHAttend* was coded 1 if the student attended MNTH, and 0 if the student was waitlisted. Once the list of names was compiled, each name was identified with their student ID number and all identifiable data were destroyed. Next, using PEIMS data from TEA for each student's name, the following demographic and test score variables were created: *ethnicity*, *gender*, *socio-economic status (EconDis)*, *learning disability (SPECED)*, *English language learning status (ELL), gifted and talented (GiftTal), 8th grade Math TAKS, 9th grade Math TAKS, 10th grade Math TAKS, 11th Grade Math TAKS, 8th Grade Science TAKS, 10th Grade Science TAKS, 11th Grade Science TAKS*. These variables were added to *High_School_Student_Data*. Since student ethnicity is a nominal variable, it was coded by TEA as:

1=American Indian or Alaskan Native

2=Asian or Pacific Islander

3=African American

4=Hispanic

5=White, not of Hispanic Origin

In order to prepare these data for analysis, three dummy coded variables were created titled *Asian*, *African American*, and *Hispanic* from the ethnicity variable using "white, not of Hispanic origin" as the baseline for comparison. The data set did not have any students listed as American Indian or Alaskan Native, so a separate variable was not created for this ethnicity. These four variables were added to the spreadsheet *High_School_Student_Data* for later analysis. Similarly, the *female* variable was transformed from M=male and F=female in the original dataset to 0=male and 1=female. The state of Texas uses students' eligibility for free or reduced lunch as an indicator of the students' *socio-economic status* of their family. These data were originally coded 1=eligible for free meals, 2=eligible for reduced-price meals, 9=other economic disadvantage, and 0=not identified as economically disadvantaged. These data were transformed and combined as a dichotomous variable, with 0=not economically disadvantaged and 1= economically disadvantaged (free/reduced/other) and the new variable was titled *EconDis*. The *Gifted and Talented* variable was kept 1=student was participating in a state-approved Gifted/Talented program and 0=student was not. The *English language learning status* variable was kept 1=ESL participation and 0=no ESL participation. Similarly, the *Learning Disability* variable from Texas Education Agency (TEA) was kept as 1=student participates in special education programs and 0=student does not participate in special education program, but retitled *SPECED*.

Lastly, the student names from the graduation lists from Manor High School and Manor New Tech High were combined with their demographic and standardized test score data, and a new variable titled *Admitted Freshmen Graduate* was created with 1=graduated in 2012 from the school they attended their Freshmen year and 0=did not graduate in 2012 from the school they attended their Freshmen year.

In organizing the remainder of the data, a spreadsheet titled *College_Student_Data* was created by adding a *New Tech* variable (1=New Tech, 2=Other) to the "Report of 2012-2013 High School Graduates' Enrollment and Academic Performance in Texas Public Higher Education," provided by the THECB for all Texas high schools. Although there are 13 New Tech Schools in Texas, many of them opened after 2008, therefore they did not have a graduating class in 2012. Many of the other New Tech Schools are housed within another school in the district, therefore the students that attended the New Tech School cannot be distinguished from the school in which they are housed. Therefore, these schools could not be included in the analysis. This resulted in two New Tech schools that had graduating classes in 2012, Manor New Tech and New Tech @Coppell. The *College_Student_Data* spreadsheet was used to compare college success outcomes (i.e. college enrollment, first-year GPA) for Texas project-based schools that are part of the New Tech Network that had a graduating class in the year 2012 and compare to state and national averages.

DATA ANALYSIS

Research Question (1) Methods

In order to answer research question (1), "How are the students who apply to MNTH different demographically from other students in the district?" I first calculated the descriptive statistics for incoming freshmen in Manor ISD in 2008 that applied and didn't apply to MNTH in 2008 for the demographic characteristics: Special Education, Gifted & Talented, ELL Status, Economic Disadvantage, Ethnicity, Gender, and 8th Grade Math and Science standardized test achievement. I then organized this information into a table and investigated these differences by calculating χ^2 for the categorical demographic characteristics and running an Analysis of Variance (ANOVA) for the continuous prior achievement characteristics.

Categorical Characteristics. The χ^2 Test for Homogeneity makes it possible to determine whether there is a difference between two populations on a single categorical variable (Yates, Moore, & Starnes, 2002). A benefit of the χ^2 Test is that it allows us to compare proportions. The χ^2 Test for Homogeneity requires that the following assumptions be met:

1. Samples are independent
2. The variable being studied is categorical
3. No more than 20% of expected frequency count for each cell can be less than five

All of these assumptions were met for these data, except there were times when less than 20% of the expected frequencies were less than 5. In this case, a Monte Carlo method, described below, was used to calculate the p-value for χ^2. The null hypothesis used for χ^2 Test of Homogeneity was that there were no differences in the number of students that chose to apply versus those that chose not to apply for each of the categorical demographic characteristics.

In order to test each of the above null hypotheses, I first calculated the degrees of freedom, *df* (see equation 3 below). Next I used IBM's Statistical Package for the Social

Sciences (SPSS) to calculate the expected frequencies, $E_{r,c}$ (see equation 4 below) for each school at each demographic variable, for both the students that applied and didn't apply to MNTH. Last, I used SPSS to calculate the Pearson χ^2 test statistic (see equation 5) and found the resulting p-value to test differences between the students that applied to MNTH and those that chose not to apply on different levels of the categorical variable.

$$df = (r-1)\cdot(c-1) \qquad (3)$$

$$E_{r,c} = \frac{n_r \cdot n_c}{n} \qquad (4)$$

$$\chi^2 = \sum \frac{\left(O_{r,c} - E_{r,c}\right)^2}{E_{r,c}} \qquad (5)$$

r = the number of students at each school, c = the total number of students counted at each level of the categorical variable, $O_{r,c}$= the observed frequency count in the sample dataset

In order to determine the size of the effect for the demographic characteristics with one degree of freedom, Φ, which is equivalent to the correlation coefficient *r*, was used. Φ=0.1 is considered a small effect, Φ=0.3 is a medium effect and Φ=0.5 is a large effect. For ethnicity, with more than one degree of freedom, Cramer's *V* was calculated to determine effect size, and *V*=0.06 is considered small effect, *V*=0.17 is a medium effect, and *V*=0.29 is considered a large effect.

When the calculated expected frequency was less than five for more than 20% of the cells, a Monte Carlo method was used to calculate the p-value. This method created a model that assumes that the null is true (i.e. no difference between the students that apply and do not apply). Then a probability distribution model was created based on these data with the assumption that the null hypothesis was true and multiple (~150,000) samples were created based on that probability distribution. χ^2 was calculated for each of these samples and a new distribution of these χ^2 for the simulated data were then used to identify the probability (p-value) that the chi squared for the actual data was obtained.

Continuous Characteristics. ANOVA test compares the difference in means between two or more independent groups. Specifically, ANOVA calculates the likelihood that the variance observed within and between groups happened by chance. The assumptions associated with ANOVA are:

1. The dependent variables are interval or ratio
2. The independent variable is two or more categorical groups
3. Observations are independent
4. No significant outliers
5. Dependent variables should be normally distributed for each category of the independent variable
6. Homogeneity of variance for each dependent variable

Each of these assumptions was tested using SPSS to ensure they were met. Then ANOVA was used to test differences observed between the students' prior 8th-grade achievement for students that applied versus those that did not.

Research Question (2) Methods

In order to answer research question (2), "Does MNTH have a positive effect on students' achievement in STEM?" multiple linear regression models were created. Prior to creating the regression models, I calculated the descriptive statistics for students that applied to MNTH and were accepted through the lottery and those that were waitlisted for the demographic characteristics: Special Education, Gifted & Talented, ELL Status, Economic Disadvantage, Ethnicity, Gender, and 8^{th} Grade Math and Science standardized test achievement. I then organized these data into a table and investigated these differences by again calculating χ^2 for the categorical demographic characteristics and running an Analysis of Variance (ANOVA) for the continuous prior achievement characteristics, to determine the likelihood that these differences between groups happened by chance ($\alpha = 0.05$). A detailed explanation of both of these methods is available above in sections titled Categorical Characteristics and Continuous Characteristics.

I identified any significant differences between the two samples on these demographic characteristics and included these in my linear models to control for this variability. Using the data compiled and aligned with other student outcome data in the spreadsheet *High_School_Student_Data*, I created multiple linear regression models using SPSS. The multiple linear regression method allowed modeling of a relationship between multiple predictor variables. Linear Regression requires that the following assumptions be met:

1. Dependent variable is continuous.
2. Independent variables can be either continuous or categorical.
3. Independence of observations.
4. Linear relationship between the dependent variable and each independent variable.
5. Data shows homoscedasticity
6. Data must not show multicollinearity
7. No significant outliers, no high leverage points, and no highly influential points

The dependent variable for all of these data is scaled standardized TAKS scores, which are continuous, so the first assumption is met. The independent variables economic disadvantage, ethnicity, and MNTH_Attend are categorical and the prior achievement TAKS score is continuous, so the second assumption is not violated with these data. All other assumptions were shown as met through the use of reports in SPSS.

I created three models for each standardized test dependent variable, Y_i= 9th grade math TAKS score, 10th grade math TAKS score, 11th grade math TAKS score, 10th grade Science TAKS score, and 11th grade Science TAKS score. For each TAKS exam, the first model only included the main effect of attendance to MNTH, while the second model included prior 8th grade achievement on the Math and Science TAKS test, and the third model included ethnicity and economic disadvantage. Note these additional models included these demographic predictors since they were identified a priori as significantly different for the students accepted to MNTH and those waitlisted.

I then created five linear regression model equations (see Equation 2) for the dependent variables where the coefficients of the predictor variables (β_j) represent the expected change in the dependent variable (Y) as the corresponding predictor variable (x_j) changes, holding all other predictor variables constant. This model tested whether there were any statistically significant effects of attending MNTH, while controlling for necessary demographic characteristics, on students' performance on their high school Math or Science TAKS exams.

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i x_i \quad (2)$$

Research Question (2a) Methods

In order to answer research question (2a), "If so, is there evidence that MNTH is effective at reducing achievement gaps between demographic groups?" I used the linear regression models created for *RQ2* and constructed interaction variables between each level of the demographic variables (e.g. Ethnicity, Economic Disadvantage, ELL, Gender) and attendance at MNTH. Including these interaction terms in the model allowed me to identify any possible differences in effects of the demographic characteristics and attendance at MNTH on high school standardized test achievement. For each of the created interaction terms I tested for significant changes in the dependent variables, differences in standardized test scores. If significant interaction terms were identified, I depicted interaction effect by calculating the predicted means for each combination of demographic group by assigned school.

Research Question (3) Methods

In order to answer research question (3), "Does MNTH have a positive effect on students' graduation rates," I developed a Logistic Regression Model. Logistic Regression is a regression analysis in which one can predict the classification of data into defined categories or groups. Logistical Regression allows for a dichotomous (or categorical) indicator variable, y, and the predictor variables, x_i, can take on many different data types (i.e. dichotomous, nominal/categorical, interval, and ratio) (Tate, 1998).

In terms of the data of interest for research question 4, the dichotomous indicator variable, Y_1, was coded as $Y_1 = 1$, for students who were admitted to MNTH and graduated from MNTH in four years or $Y_1 = 0$ for a student who was waitlisted and then admitted to MHS and graduated from MHS in four years. The following predictor variables were included in the model, where necessary, to control for variance between the two samples on the demographic characteristics: economic disadvantage, ethnicity, and prior achievement. In order to control for prior achievement, I used students' 8^{th}-grade math achievement because math and science 8^{th}-grade achievement are highly correlated and 8^{th}-grade achievement, as shown in research question two results, is a significant predictor of high school TAKS achievement. I also chose to continue to use 8th-grade achievement, instead of using 11th grade, exit level, TAKS score because many students that do not graduate have left high school by the administration of the exit level TAKS, so that missing data would have masked this effect on my graduation variable.

Logistical regression was chosen over other statistical tests for multiple reasons. The main reason was that logistical regression allows for a dichotomous indicator variable. Logistic regression also provides an opportunity to create a clear model that calculates the effects of attending MNTH on a students' likelihood of graduating, while controlling for demographic characteristics that differ between the two samples. Comparing two populations could also be done with multiple, univariate, Analysis of Variance (ANOVA) tests, but ANOVA assumes that the dependent variable is either interval or ratio. Also, conducting multiple ANOVA tests would inflate the chance of Type I error, which is the likelihood of rejecting the null when it is in fact true (i.e. false positive).

In order to use Logistic Regression methods, the following assumptions must be met (Tate, 1998):

1. The residuals are independent
2. The logistic function is the appropriate functional model of the probability that Y=1 across the predictor variables
3. Validity is ensured for large sample sizes, error rates may not be accurate for small sample sizes.

All of these assumptions were met for these data. The "rule of thumb" for sample size when using logistic regression methods is 10 cases per predictor variable, since the maximum number of predictor variables included in the model was six (i.e. Special

Education, Gifted and Talented, ELL, Economic Disadvantage, Ethnicity, Gender), my sample size of 131 students that applied to MNTH meets the fourth assumption for using logistic regression. In order to ensure no violations of the second assumption, the Hosmer and Lemeshow Test was used in SPSS to determine how well the logistic function fit these data, and a non-significant p-value implied that the logistic model is the correct fit for these data. Similarly, the Durbin-Watson statistic was used in SPSS to support independence of residuals, where a value approximately equal to two shows no serial correlation.

The Logistic Regression equation calculates the odds ratio, $P_r(Y = 1)$, which is the probability of "success" divided by the probability of "failure," (see Equation 1), where β_i are the coefficients of the predictor variables x_i for *i*=0,1,2,3…n, where n is the number of predictor variables. Developing this Logistic Regression equation allowed me to determine any effect of attendance to MNTH on students' likelihood of graduating in four years, while controlling for demographic differences between the two groups.

$$P_r(Y=1)=\frac{e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\ldots+\beta_i x_i}}{1+e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\ldots+\beta_i x_i}} \quad (1)$$

The hypothesis testing when using the Logistic Regression model looks at the coefficients of the predictor variables, β_i. The null hypothesis is that the coefficient, β_i, is zero, which would imply that there is no difference between the groups with regard to the indicator variable (Tate, 1998). For the data of interest, the null hypothesis assumed that there was no difference in graduation rate for students that attend MNTH and the control group that were waitlisted and instead attended MHS. After developing the Logistic regression equation, I used the Wald statistic and determined the statistical significance of the predictor variable, thus rejecting or failing to reject my null hypothesis.

Research Question (4) Methods

In order to answer research question (4), “How do college enrollment rates and first-year college GPA distributions differ between New Tech schools and compare with state and national averages?” I again used the χ^2 Test for Homogeneity to identify any significant difference between the two New Tech schools. These findings were then compared to the descriptive enrollment and first year GPA national and state averages. The χ^2 Test for Homogeneity allows one to determine whether there is a difference between two populations on a single categorical variable (Yates et al., 2002). A benefit of the χ^2 Test is that it allows us to compare proportions. Again, the χ^2 Test for Homogeneity requires that the following assumptions be met to ensure validity of the statistic:

1. Samples are independent
2. The variable being studied is categorical
3. No more than 20% of expected frequency count for each cell can be less than five

Provided that students are only able to graduate from a single high school, the first assumption was not violated. The college enrollment and first year GPA data used to answer this question are both categorical (ordinal or nominal), so the second assumption was met with these data. There were times when more than 20% of the expected frequencies were less than five, and in these cases the Monte Carlo method (described in Research Question 1 Methods) was used to calculate the p-value for χ^2.

In order to use the χ^2 Test, I identified the null hypotheses for this question. For the college enrollment data, the null hypothesis was that there is no difference between Manor New Tech High School and each New Tech School in Texas for type of college enrollment (2-year, 4-year, Texas independent colleges & universities, not trackable, and not found). Similarly, the null hypothesis for the first year GPA data, was that there is no difference between Manor New Tech High School and each New Tech School in Texas for the distribution of 1^{st} year college GPA at either a 2-year or 4-year public Texas college (<2.0; 2.0-2.49; 2.5-2.99; 3.0-3.49; >3.5).

A significance level $\alpha = 0.05$ was chosen to use while testing the null hypothesis with the χ^2 Test of Homogeneity. Again the χ^2 Test determined whether the sample frequencies that were observed differ significantly from the expected frequencies based on the defined null hypothesis. Since these data had more than one degree of freedom, Cramer's *V* was used to determine the magnitude of the effect size, and *V*=0.06 is considered small effect, *V*=0.17 is a medium effect, and *V*=0.29 is considered a large effect.

I used SPSS to calculate the χ^2 test statistic and found the resulting p-value. The calculated p-value provided the probability that the rejection of the null hypothesis happened by chance, for research question four that is, the likelihood that MNTH differs from other New Tech schools on different levels of GPA distribution and type of college enrollment. When faced with a significant p-value, I combined some of the categorical groups in hopes of identifying the potential culprit for the difference between groups.

CHAPTER 4: ANALYSIS RESULTS

This chapter explains the results from the research conducted on the effects of project-based learning and teaching methods on student outcomes while also determining demographic characteristics of students that choose to apply to a non-traditional high school that only teaches through project-based learning. This chapter is split into four sections that correspond with each of the following four identified research questions:

4.1 Applying to MNTH	How are the students who apply to MNTH different demographically from other students in the district?
4.2 STEM Achievement	Does MNTH have a positive effect on students' achievement in STEM? If so, is there evidence that MNTH is effective at reducing achievement gaps between demographic groups?
4.3 High School Graduation	Does MNTH have a positive effect on students' graduation rates?
4.4 College Enrollment	How do college enrollment rates and first-year college GPA distributions differ between New Tech schools and compare with state and national averages

4.1: Applying to MNTH

I answered this question by first looking at the descriptive statistics for all 8th grade students in Manor Independent School District in 2008 for the following demographic variables: Special Education, Gifted & Talented, ELL Status, Economic Disadvantage, Ethnicity, Gender, 8th Grade Math and Science standardized test achievement. Tables 2 and 3 show the average proportion of 8th grade students, for each of the identified demographic and achievement predictor variable groups (Special Education, Gifted & Talented, ELL Status, Economic Disadvantage, Ethnicity, Gender, and Prior Achievement) that applied to MNTH and chose not to apply.

	Applied	Didn't Apply	Total
Special Education	.10	.15	.13
Gifted & Talented	.06* ($\Phi = .121$)	.01	.03
ELL	.04 *** ($\Phi = -.216$)	.19	.14
EconDis	.52 *** ($\Phi = -.257$)	.77	.68
Ethnicity ***	($V = .280$)		
Asian	.03	.01	.02
African American	.27	.30	.29
Hispanic	.43	.63	.55
White	.24	.06	.13
Female	.58 * ($\Phi = .120$)	.46	.50
N	131	226	357

Note: Percentages are displayed for each categorical variable, followed by Φ or Cramer's *V* measure of effect size. Significance levels are marked with asterisks indicating that the given percentage of students that applied to MNTH is significantly different from the percentage for those that did not apply *p<.05, **p<.01, ***p<.001.

Table 2: Descriptive Statistics for Demographic Characteristics

	Applied	Didn't Apply	Total
8^{th} Grade Math TAKS Score	2159 (18.0)***	2054 (14.7)	2095 (11.8)
8^{th} Grade Science TAKS Score	2111 (20.7)***	1967 (19.1)	2023 (14.7)
N	120	187	307

Note: Means are displayed first, rounded to the nearest integer, followed by standard errors rounded to one decimal place in parentheses. Significance levels are marked with asterisks indicating that the given mean for students that applied to MNTH is significantly different from the mean for those that did not apply *p<.05, **p<.01, ***p<.001.

Table 3: Prior Achievement Average Score

APPLYING TO MNTH RESULTS

Looking at the descriptive statistics for the demographic characteristics and achievement scores of students that applied to attend MNTH and compared the averages for the students that chose not to apply (see Tables 2 & 3), the results show that there are differences in percentage of students from each demographic subgroup and prior achievement. To further investigate these initial differences, I calculated χ^2 to see if any of the differences observed were significant (see Table 2). I then ran an ANOVA to see if any of the differences in prior 8^{th} grade achievement were significant (see Table 3). I noted the significant findings in the table with an asterisk for p<.05, two asterisks for p<.01, and three asterisks for p<.001.

I found a small significant difference between the 6% of students identified as Gifted and Talented that applied to MNTH compared to the one percent that did not $\chi^2(1, N = 352) = 5.172, p < 0.05)$. There was no distinguishable difference statistically between the 10% of Special Education students that applied versus those 15%

that didn't apply to MNTH $\chi^2(1, N = 352) = 1.367, p = 0.242$). Significantly fewer students that applied to MNTH are classified as economically disadvantaged (52%) compared with 77% of students that didn't apply $\chi^2(1, N = 352) = 23.392, p < 0.05$). Significantly fewer students that applied to MNTH were labeled English Language Learners (4%) than the 19% of students that didn't apply $\chi^2(1, N = 352) = 16.409, p < 0.05$). Also, significantly more females applied to attend MNTH (58%) than those 46% that chose not to apply $\chi^2(1, N = 352) = 5.066, p < 0.05$).

Based on ethnicity, there was a large significant difference between groups $\chi^2(3, N = 352) = 27.659, p < 0.05$). To further investigate the ethnicity difference, I grouped the Asian and African American students since they had the smallest differences between groups, and re-calculated χ^2. The difference appears to be between the 43% of Hispanic students that apply and the 24% White students among those that applied to MNTH, compared with the 63% of Hispanic students and 6% White students among those that did not apply $\chi^2(2, N = 352) = 26.258, p < 0.05$).

In terms of previous academic achievement, students that applied to MNTH scored significantly higher ($\bar{x}$ =2159, $p < 0.05$) on their 8th-grade math standardized TAKS test than students that didn't apply ($\bar{x}$ =2054, $p < 0.05$). Similarly, students that applied to MNTH scored significantly higher on their 8th-grade science TAKS ($\bar{x}$ =2111, $p < 0.05$) than the students that didn't apply ($\bar{x}$ =1967, $p < 0.05$).

4.2: STEM Achievement

In order to answer this question, I developed multiple linear regression models to compare the predicted scaled score on math and science standardized tests for students that attended MNTH with those that were waitlisted. MNTH uses a lottery to accept students to attend the school. One girl and one boy are picked until a class of 100 students is chosen. Before developing any models, I ran χ^2 for each of the demographic characteristics and an ANOVA for achievement scores of students that were accepted through the lottery to attend MNTH compared to those that applied, but were waitlisted.

Then, for each standardized math and science assessment, I developed a model of the average scores for students that attended MNTH versus those that were waitlisted, and then developed a second and third model that controlled for the significantly different demographic variable subgroups.

LOTTERY DEMOGRAPHIC MAKE-UP RESULTS

Looking at the demographic make-up of students, there are differences between those that were accepted to MNTH and those that were waitlisted (see Tables 4 & 5). I ran χ^2 tests to see if the differences observed were significant for the categorical demographic characteristics and found that significantly fewer students identified as economically disadvantaged were chosen in the lottery to attend MNTH $\chi^2(1, N = 127) = 6.464, p < 0.05)$. There was also a significant difference in levels of the ethnicity variable accepted to MNTH $\chi^2(1, N = 127) = 18.073, p < 0.05)$.

	Accepted	Waitlisted	Total Applied
Special Education	.07	.17	.10
Gifted & Talented	.07	.02	.06
ELL	.02	.07	.04
EconDis	.44 ($\Phi = -0.226$)*	.68	.52
Ethnicity ***	($V = 0.377$)		
Asian	.04	.00	.03
African American	.18	.48	.27
Hispanic	.43	.43	.43
White	.31	.07	.24
Female	.59	.56	.58
N	86	41	127

Note: Percentages are displayed for each categorical variable, followed by Φ or Cramer's *V* measure of effect size. Significance levels are marked with asterisks indicating that the given percentage of students that applied to MNTH is significantly different from the percentage for those that did not apply *p<.05, **p<.01, ***p<.001.

Table 4: Descriptive Statistics for MNTH Lottery

	Accepted	Waitlisted	Total Applied
8th Grade Math TAKS Score	2182 (24.0)	2110 (21.7)	2159 (18.0)
8th Grade Science TAKS Score	2136 (26.8)	2049 (26.5)	2111 (20.7)
N	85	35	120

Note: Means are displayed first, rounded to the nearest integer, followed by standard errors rounded to one decimal place in parentheses. Significance levels are marked with asterisks indicating that the given mean for students that applied to MNTH is significantly different from the mean for those that did not apply *p<.05, **p<.01, ***p<.001.

Table 5: Prior Achievement Averages for MNTH Lottery

I then ran an ANOVA to look at differences in demographic make up for the continuous, prior-achievement variables. The differences on the 8th-grade math (*p*=0.064) and science TAKS (*p*=0.054) were borderline significant. To further investigate these potential differences, I transformed the scaled scores to *met standard* (scaled score > 2100) and *commended* (scaled score > 2400) for both the science and math 8th-grade TAKS exam. These cut-offs were defined by the Texas Education Agency as successfully meeting the expectations for understanding the math and science content standards. I then calculated χ^2 for these four categorical demographic variables and found that students accepted in the lottery to attend MNTH were more likely to have received a commended score on the 8th-grade math TAKS $\chi^2(1, N = 120) = 3.873, p < 0.05)$ and met standard on the 8th-grade science TAKS $\chi^2(1, N = 120) = 4.740, p < 0.05)$.

I controlled for these demographic differences between the sample that attended MNTH and the control group that were waitlisted by creating multiple linear regression models of students' math and science TAKS scores that included prior 8th-grade achievement in the second step of the model, and included the ethnicity variable and economic disadvantage variable in the third step of the model.

HIGH SCHOOL MATH STANDARDIZED TEST SCORE RESULTS

Ninth-Grade Math TAKS Results. The linear regression model (see Table 6) shows an approximately 111 point higher test score for students that attended MNTH compared to those students that were waitlisted, which has a significant p-value (B=111.317, t=-2.671, p<.05). Then in the second model that controls for 8th grade math achievement, the difference is still significant but decreases the predicted difference in score from 111 to 70 points (B=69.955, t=2.145, p<0.05). Finally, the last step of the model that, in addition to prior math achievement, controls for ethnicity and economic disadvantage, the difference is 57 points for students that attend MNTH and this result is no longer significant (B=56.715, t=1.576, p=.118).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2071.696	36.619		56.575	.000
	MNTH_Accepted	111.317	41.669	.259	2.671	.009
2	(Constant)	2099.393	28.523		73.604	.000
	MNTH_Accepted	69.955	32.620	.163	2.145	.034
	M_SSC_2008_mc	.557	.068	.624	8.215	.000
3	(Constant)	2151.862	45.598		47.192	.000
	MNTH_Accepted	56.715	35.990	.132	1.576	.118
	M_SSC_2008_mc	.549	.068	.615	8.054	.000
	EconDis	-19.456	28.998	-.054	-.671	.504
	Asian	-12.440	82.869	-.012	-.150	.881
	AfricanAmerican	-24.208	41.840	-.060	-.579	.564
	Hispanic	-59.016	35.276	-.163	-1.673	.098

a. Dependent Variable: M_SSC_2009

Table 6: Linear Regression Output Math Scaled Score 9th Grade (2009)

10th Grade Math TAKS Results. Although the linear regression model (see Table 7) shows an approximately 57 point higher TAKS score for students that attended MNTH, this difference is not significant (B=57.339, t=1.382, p=.170). The second model, that controls for prior math achievement, shows a difference that is approximately 10 points lower for students that attended MNTH that is not significant (B=10.247, t=.346, p=.730). Finally, the final model that controls for ethnicity, economic disadvantage, and prior achievement, is approximately 11 points lower for students that attended MNTH, but still these differences are not significant (B= -10.821, t=-0.331, p=0.741).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2107.808	35.742		58.973	.000
	MNTH_Accepted	57.339	41.477	.138	1.382	.170
2	(Constant)	2141.711	25.411		84.284	.000
	MNTH_Accepted	10.247	29.600	.025	.346	.730
	M_SSC_2008_mc	.637	.063	.715	10.068	.000
3	(Constant)	2179.184	42.342		51.466	.000
	MNTH_Accepted	-10.821	32.664	-.026	-.331	.741
	M_SSC_2008_mc	.625	.064	.702	9.827	.000
	EconDis	23.776	27.374	.065	.869	.387
	Asian	1.058	78.588	.001	.013	.989
	AfricanAmerican	-76.501	39.608	-.188	-1.931	.056
	Hispanic	-29.009	33.899	-.079	-.856	.394

a. Dependent Variable: M_SSC_2010

Table 7: Linear Regression Output Math Scaled Score 10^{th} Grade (2010)

11^{th} Grade Math TAKS Results. In the first linear regression model, although the difference observed was not significant, students that attended MNTH scored approximately 62 points higher on the exit level TAKS (B=62.253, t=1.296, p=.198). Similarly, the second model that controlled for prior achievement found that students who attended scored about 43 points higher than students that were waitlisted (B=42.865, t=0.934, p=.198). Then the third model that also controlled for ethnicity and economic disadvantage found that the difference in score for students that attended MNTH decreased to about 40 points and the difference was not significant (B=39.750, t=0.782, p=.437) (see Table 8).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2207.565	41.370		53.362	.000
	MNTH_Accepted	62.253	48.040	.138	1.296	.198
2	(Constant)	2219.440	39.380		56.360	.000
	MNTH_Accepted	42.865	45.916	.095	.934	.353
	M_SSC_2008_mc	.314	.096	.334	3.291	.001
3	(Constant)	2206.494	66.988		32.939	.000
	MNTH_Accepted	39.750	50.850	.088	.782	.437
	M_SSC_2008_mc	.310	.098	.330	3.169	.002
	EconDis	-11.640	43.221	-.029	-.269	.788
	Asian	59.532	142.181	.045	.419	.677
	AfricanAmerican	-.335	63.813	-.001	-.005	.996
	Hispanic	42.980	54.705	.108	.786	.434

a. Dependent Variable: M_SSC_2011

Table 8: Linear Regression Output Math Scaled Score 11th Grade (2011)

High School Science Standardized Test Score Results

10th Grade Science TAKS Results. All three models for the 10th grade science TAKS exam found a significant effect of attending MNTH on students score ($p<0.05$) (see Table 9). The first linear regression model shows that attending MNTH is associated with a test score that is almost 143 points higher than students that were waitlisted for MNTH, and the difference is significant (B=143.237, t=3.678, $p<.05$). When the prior achievement is controlled for in the second model, there is still a significantly higher score of approximately 109 points for students that attended MNTH (B=108.871, t=3.068, $p<.05$), and when economic disadvantage and ethnicity are included in the model, the difference in science TAKS scores increases to approximately 119 points for students that attended MNTH (B=119.281, t=3.012, $p<.05$).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2099.231	33.669		62.349	.000
	MNTH_Accepted	143.237	38.941	.344	3.678	.000
2	(Constant)	2122.044	30.455		69.678	.000
	MNTH_Accepted	108.871	35.486	.261	3.068	.003
	S_SSC_2008_mc	.342	.067	.435	5.114	.000
3	(Constant)	2095.490	51.117		40.994	.000
	MNTH_Accepted	119.281	39.597	.286	3.012	.003
	S_SSC_2008_mc	.348	.070	.443	4.983	.000
	EconDis	11.335	33.109	.031	.342	.733
	Asian	63.318	95.356	.059	.664	.508
	AfricanAmerican	29.114	48.497	.072	.600	.550
	Hispanic	7.418	41.627	.020	.178	.859

a. Dependent Variable: S_SSC_2010

Table 9: Linear Regression Output Science Scaled Score 10^{th} Grade (2010)

11^{th} Grade Science TAKS Results. The models developed showed a 71 point higher score for students that attended MNTH, but this difference was not significant (B=71.130, t=1.369, p=.174) (see Table 10). When prior achievement is added to the model, the difference for students that attended MNTH decreases to a 46 point higher score on the science TAKS (B=45.860, t=0.918, p=0.361), then when economic disadvantage and ethnicity are included, the difference increases to about 57 points higher, but still these differences are not significant (B=57.285, t=1.039, p=0.302).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2205.304	44.983		49.025	.000
	MNTH_Accepted	71.130	51.942	.143	1.369	.174
2	(Constant)	2221.606	43.043		51.613	.000
	MNTH_Accepted	45.860	49.970	.092	.918	.361
	S_SSC_2008_mc	.295	.090	.327	3.262	.002
3	(Constant)	2175.594	72.441		30.033	.000
	MNTH_Accepted	57.285	55.127	.115	1.039	.302
	S_SSC_2008_mc	.314	.095	.349	3.305	.001
	EconDis	-4.224	46.634	-.010	-.091	.928
	Asian	67.097	154.492	.045	.434	.665
	AfricanAmerican	45.237	70.210	.093	.644	.521
	Hispanic	54.838	60.197	.127	.911	.365

a. Dependent Variable: S_SSC_2011

Table 10: Linear Regression Output Science Scaled Score 11th Grade (2011)

Identify Achievement Gaps

Achievement Gap Results. In order to answer this follow-up research question on achievement gaps, I created interaction variables between the MNTH_Accept variable and each of the following demographic characteristics: English Language Learner, Economic Disadvantage, Ethnicity, and Gender. Then I created 20 linear regression models including the appropriate interaction variable to identify whether any of the achievement gaps for the 9th, 10th, and 11th Grade Math TAKS exams, as well as, the 10th and 11th grade Science TAKS exams increased, decreased, or were maintained when students had attended MNTH. In the 20 linear regression models, there was not a single significant interaction.

4.3: High School Graduation

In order to answer this question, I defined *graduation* as whether a student that was accepted to MNTH and attended MNTH their freshman year of high school, went on to graduate from MNTH in four years. Similarly, a student that was waitlisted from MNTH and instead attended MHS their freshman year was labeled as *graduated* if after four years at MHS they graduated. Note that one major limitation to these data is that a student that is labeled not graduated could have transferred to another school out of district and instead graduated from there. Therefore these data do not indicate the actual graduation rate for the students, but instead the graduation from the school that they were admitted to their freshmen year.

In order to answer the question of whether attendance at MNTH has an effect on students' likelihood of graduating, I created a logistic regression model. Since the demographic make-up of students that were accepted versus waitlisted to attend MNTH (see Tables 4 & 5) was significantly different for students labeled economically disadvantaged, African American, as well as, prior 8th-grade standardized test achievement, I controlled for these differences in my logistic regression model by creating a multi-step model, where the first model included the accepted variable, and the second model controls for prior 8th-grade math achievement, and the last model controls for economic disadvantage status and ethnicity (see Tables 11, 12, & 13).

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	MNTH_Accepted	-.448	.498	.811	1	.368	.639
	Constant	.999	.442	5.100	1	.024	2.714

a. Variable(s) entered on step 1: MNTH_Accepted.

Table 11: Logistic Regression Output Model 1

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	MNTH_Accepted	-.740	.526	1.974	1	.160	.477
	M_SSC_2008	.004	.001	6.792	1	.009	1.004
	Constant	-6.487	2.890	5.039	1	.025	.002

a. Variable(s) entered on step 1: M_SSC_2008.

Table 12: Logistic Regression Output Model 2

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	MNTH_Accepted	-.802	.597	1.805	1	.179	.449
	M_SSC_2008	.004	.001	6.794	1	.009	1.004
	EconDis	-.372	.464	.642	1	.423	.690
	Asian	-.630	1.109	.323	1	.570	.532
	AfricanAmerican	.066	.661	.010	1	.920	1.068
	Hispanic	.436	.565	.597	1	.440	1.547
	Constant	-6.570	3.029	4.704	1	.030	.001

a. Variable(s) entered on step 1: EconDis, Asian, AfricanAmerican, Hispanic.

Table 13: Logistic Regression Output Model 3

There were no significant differences observed with respect to likelihood of graduation between students that attended MNTH and those that were waitlisted. Step 1 of the model shows that students that attend MNTH are actually .639 times as likely to graduate from the school where they enrolled in ninth grade as students that attend MHS ($\beta = -.448$, p=.368). Controlling for prior achievement, the likelihood of decreases to .477 times as likely for students that attend MNTH to graduate ($\beta = -.704$, p=.160). Then in the third model, controlling for prior achievement, ethnicity, and economic disadvantage the model shows that students that attend MNTH are .449 times as likely to graduate compared to students that attend the traditional school, MHS ($\beta = -.802$, p=.179). The lack of a significant p-value means these differences observed are likely to have happened by chance.

4.4: College Enrollment

College Enrollment Results

Only one other New Tech High School had a graduating class in 2012, New Tech @Coppell in located in Coppell, TX. Seventy percent of 2012 New Tech @Coppell graduates enrolled in a Texas institute of higher education in 2013 and 83% of Manor New Tech High graduates enrolled in a Texas institute of higher education. Both of these PBL school graduates had higher post-secondary enrollment percentages than the 51% of graduates in the state of Texas and 66% of the graduates in the nation (see Table 14).

Manor New Tech	New Tech @Coppell	Texas	United States
83%	70%	51%	66%

Table 14: Percent of 2012 High School Graduates Enrolled in College

Of the 111 students that graduated New Tech @Coppell, 41 went on to enroll in a 4-year institution of higher education in Texas, and 24 went on to enroll in a 2-year college in Texas. Of the 69 students in this research study that graduated from MNTH in 2012, 28 went on to enroll in a 4-year college in Texas and 25 enrolled in a 2-year institution. Four of the 69 MNTH graduates went on to enroll in a Texas independent college, compared to 13 of the 111 New Tech @Coppell graduates.

In order to determine if any of these differences in college enrollment type were statistically significant, I used SPSS to calculate χ^2 for the data in the college enrollment contingency table (see Table 15). The results led me to reject the null hypothesis, meaning that there is a significant difference between the type of college distribution for Manor New Tech High School and New Tech @Coppell students $\chi^2(4, N=180)=9.89$, p=0.04.

	4-Year	2-Year	Independent College	Not Trackable	Not Found	Total
MNTH	28	25	4	4	8	69
NT @Coppell	41	24	13	4	29	111
	69	49	17	8	37	180

Table 15: College Enrollment Contingency Table

In order to further investigate this significant difference I first created a table with the percentages of students' post-secondary enrollment types to see where there were the largest differences (see Table 16). I did this in hopes of identifying the factor responsible for this significant difference observed. I immediately noticed that MNTH had about 15% more students enrolling in 2-year colleges, and NT @Coppell had about 15% more students labeled "Not Found."

	4-Year	2-Year	Independent College	Not Trackable	Not Found	Total
MNTH	40.5%	36.2%	5.8%	5.8%	11.6%	69
NT @Coppell	36.9%	21.6%	11.7%	3.6%	26.1%	111

Table 16: Enrollment Contingency Table

Next I isolated the 2-year college enrollment and "Not Found" and then combined the other types of enrollment (see Table 17) and re-calculated χ^2. In this simpler model, I again rejected the null hypothesis, finding that there is a significant difference in post-secondary enrollment types for students that graduated from one of the two schools $\chi^2(2, N=180)=7.71$, p=0.02. The p-value decreased from 0.04 to 0.02 with this simpler model, suggesting that the students graduating from MNTH are more likely to enroll in 2-year colleges and students graduating from New Tech @Coppell are more likely to be "Not Found."

	2-Year	Not Found	Other	Total
MNTH	25	8	36	69
NT @Coppell	24	29	58	111
	69	49	17	8

Table 17: Combined Enrollment Contingency Table

GPA Distribution Results

The grade point average (GPA) for a student receiving the minimum grade to receive credit 'C' is GPA=2.0. Sixty-six percent of Texas high school graduates in 2012 that enroll in Texas 2-year or 4-year institutions of higher education the following year receive a first year GPA of 2.0 or higher. Manor New Tech High graduates outperform this state average with 78% of their students receiving a first year GPA greater than 2.0. Similarly, New Tech @Coppell students outperform the state average with 83% of their students above a 2.0 first year grade point average. The specific GPA distribution for graduates from MNTH and New Tech @Coppell for students attending 2-year and 4-year can be found in tables 18 and 19 respectively.

	<2.0	2.0-2.49	2.5-2.99	3.0-3.49	>3.5	Total
MNTH	6	6	6	8	2	28
NT @Coppell	6	10	7	9	9	41
	12	16	13	17	11	69

Table 18: 4-Year College GPA Contingency Table

	<2.0	2.0-2.49	2.5-2.99	3.0-3.49	>3.5	Total
MNTH	5	7	7	2	1	22
NT @Coppell	5	3	5	5	6	24
	10	10	12	7	7	46

Table 19: 2-Year College GPA Contingency Table

4-Year GPA Distributions. χ^2 was calculated in SPSS to determine if differences in GPA distributions at 4-year institutions were significantly different for the two high schools. I found a χ^2 smaller than the critical value, which caused me to fail to reject the null hypothesis, meaning that there is no significant difference between Manor New Tech High School and New Tech @Coppell for the distribution of 1st year college GPA at a 4-year public Texas college $\chi^2(4, N = 180) = 3.26, p = 0.52$.

2-Year GPA Distributions. When the expected frequencies were calculated in SPSS for students' GPA distributions at 2-year institutions, more than 20% of the expected values were below five (see Table 20). Therefore the Monte Carlo simulation method, described in Chapter 3, was used to calculate χ^2. The calculated χ^2 resulted in failing to reject the null hypothesis, meaning that there is no significant difference between Manor New Tech High School and New Tech @Coppell for the distribution of 1st year college GPA at a 2-year public Texas college $\chi^2(4, N = 180) = 6.716, p = 0.15$.

	<2.0	2.0-2.49	2.5-2.99	3.0-3.49	>3.5	Total
MNTH	4.78	4.78	5.74	3.35	3.35	22
NT @Coppell	5.22	5.22	6.26	3.65	3.65	24
	10	10	12	7	7	46

Table 20: 2-Year College GPA Expected Frequency Table

CHAPTER 5: DISCUSSION AND CONCLUSION

The purpose of this study was to investigate whether teaching through project-based methods has effects on students' high school math and science achievement, high school graduation, and college enrollment and first year grade point average. The first part of the study is unique and adds to the educational literature because it compares students that attend a school taught solely through project-based methods with a control group that applied to the PBL school, but were waitlisted and instead attended a school that uses traditional teaching methods. Since students that attend project-based schools are taught all four years of high school through these methods, it lends another interesting opportunity in the second part of this study, which was to explore initial college outcomes (i.e. enrollment type and GPA) for students taught solely through project-based pedagogies.

This chapter first discusses the findings from the research conducted on the effects of project-based learning teaching methods on various high school and college student outcomes separated into four research questions. The discussion and conclusion are split into sections that correspond with each of the four identified research questions. Then, in closing, a section on limitation, implications, and opportunities for future research are discussed in detail.

5.1: Discussion and Conclusion

APPLYING TO MNTH

The research found that the population of students that apply to an alternative school that teaches all courses through project-based instruction, MNTH, is different demographically from other students in the district. These students are more likely to be labeled gifted and talented, and are more likely to have scored higher on both their 8th grade math and science TAKS exam. Significantly fewer economically disadvantaged and ELL students apply to MNTH. Fewer Hispanic students and more white students apply to MNTH than do not. Also, females are more likely to apply than males.

The study conducted by Murnane, Newstead, & Olsen, (1985) that found significant gains in students' achievement when attending Catholic schools compared to traditional public schools, but later it was realized that their results were invalid since they had assumed random selection for attendance to the schools. This problem shows the importance of uncovering selection-bias and controlling for it in the design of a study. Since students that apply to MNTH are significantly different from the population of Manor ISD, we now know that selection bias is occurring, therefore simply comparing MNTH to MHS violates the assumption of random sampling.

The findings that these students are more likely to be from a higher socio-economic status and more likely to be white are very important because these demographic characteristics historically are predictive of high school and college student success (NRC, 2011). Then finding that the students that apply are also more likely to have been successful on their 8th grade math and science standardized tests only further supports this achievement pattern.

Since Manor New Tech High School is part of the T-STEM initiative and offers a variety of integrated science, math, engineering, and technology courses as part of this initiative, it aligns with the literature that students from low-SES and ethnic minorities are underrepresented in STEM fields (DOE, 2011). The finding that females are more likely to apply to MNTH contradicts this literature though, since females are also underrepresented in STEM careers and majors. Finding that white students and students from higher socio-economic status are more likely to apply, also aligns with the literature on school choice that claims that students with these demographic characteristics are more likely to choose a school that has higher academic performance (Weiher & Tedin, 2002).

STEM ACHIEVEMENT

Overall results from this research showed that students that attended the project-based school, MNTH, performed as well or significantly better on high school math and science Texas Assessment of Knowledge and Skills (TAKS) than those that were waitlisted and instead attended the traditional school, while controlling for ethnicity, SES and prior achievement. Although all of the linear regression models created showed a positive difference in scores for students that attended the project-based MNTH, the only significant difference in achievement observed was for the 10^{th} grade science TAKS test. Specifically, students attending MNTH scored an average of 119 points higher on the 10^{th} grade science TAKS than their matched counterparts ($B= 119.281$, $t=3.012$, $p<0.05$).

Finding significant gains in standardized test achievement on the science TAKS aligns with the studies reviewed in Chapter 2. Geier et al. (2008) found that students engaged in the project-based LeTUS science curriculum outperformed the rest of the Detroit public school population on the science MEAP standardized exam. Similarly, Schneider et al. (2002) found that students taught through project-based science (PBS) curriculum outperformed the national average performance on the NAEP standardized exam. This finding also aligns with studies that found increased performance in science when taught through inductive teaching methods similar to PBL (Anyafulude, 2012; Kolodner et al., 2003; Lynch et al., 2005; Schwartz et al., 2011).

Of the empirical studies discussed in Chapter 2 that found an increased performance on standardized exams for students taught through PBL, Boaler (2012) was the only study conducted that found significant increases in math performance on a European standardized exam when taught through PBL. Finkelstein et al. (2010) found significant gains in economics achievement for students taught through problem-based economics curriculum, whereas (Mergendoller et al., 2006) found that students taught through problem-based methods performed as well as their traditionally taught counterparts on microeconomics exams. This aligns with the findings of this dissertation research, that students taught through project-based curriculum had a non-significant positive increase in performance on the 9th, 10th, and 11th grade math TAKS exams. Lastly, finding that attending the project-based MNTH school did not harm students' performance on the math TAKS aligns with the research on anchored instruction conducted by Cognition and Technology Group at Vanderbilt (1992).

Difference in Math and Science Performance

Although there was an increased performance on both the math and science TAKS for students that attended the project-based MNTH, the only significant difference observed was for the science TAKS exam. This aligns with the empirical studies reviewed in the literature. A possible explanation of this difference in performance could be due to differences between the two TAKS exam question types.

As discussed in Chapter 2, both the math and science TAKS exams consist of primarily multiple-choice questions aligned with content specific learning objectives. One main difference between these two sets of learning outcomes is that the math learning outcomes could be assessed using mostly abstract equation or calculation questions, without situation in a verbal or story context. Science is itself a context, therefore word problems that are situated in the context of science, often depend on a student understanding the context and making connections between the context and the content being assessed.

One possible explanation for the significant increase in science TAKS score in 10th grade could be that the type of story problems given on the science TAKS often require an understanding of the context in order to successfully solve them. For example, the released science TAKS question below is a question assessing students' understanding of the fifth science objective, Motion, Forces, and Energy, and is situated in the context of a motor (see Figure 6). In order to successfully answer this question, students will need at least a rudimentary understanding of the basic properties of a motor.

A motor produces less mechanical energy than the energy it uses because the motor —

F gains some energy through motion

G stores some energy as electrons

H converts some energy into heat and sound

J uses some energy to increase in mass

Figure 6. Problem 28 from the Released 2009 11th grade Science TAKS Test
http://tea.texas.gov/student.assessment/taks/released-tests/

The mathematics TAKS exam does include many story and verbal equation word problems. Koedinger & Nathan (2004) found that all students, regardless of type of instruction, perform better on story problems compared with matched, abstract equation problems. So finding that there was no significant effect of instructional method on mathematics TAKS performance aligns with this literature.

Some mathematics story problems that are situated in a context are used on TAKS (see Figure 7). In this problem, the introduction of an algebraic expression is not an authentic approach to solving that problem. This arbitrary use of an algebraic expression to solve an unrealistic context problem often distracts the student from successfully solving the problem (Walkington et al., 2012). Although a student may enjoy playing the guitar, knowledge of the guitar is not necessary for correctly answering this question. Walkington et al. (2012) found that providing a story problem customized to a students' personal interest still required additional student support to make necessary connections to the algebraic and arithmetic reasoning.

During the second week of summer vacation, Reuben practiced his guitar for 10 minutes less than twice the amount of time he practiced the first week. If he practiced m minutes the first week, which of the following expressions represents the number of minutes that Reuben practiced during the second week?

A $2 - 10m$

B $10 - 2m$

C $2m - 10$

D $10m - 2$

Figure 7. Problem 23 from the Released 2009 11th grade Math TAKS Test
http://tea.texas.gov/student.assessment/taks/released-tests/

Students taught through anchored instructional methods, such as project-based instruction, that focus on solving complex, authentic problems possess an increased ability to solve complex, single and multi-step story problems (CTGV, 1992). The mathematics TAKS exam is lacking in these types of complex problems, therefore may not be sensitive to measuring students' increased problem-solving ability. However, the science TAKS does have complex, story problems (see Figures 8 and 9), so perhaps the inclusion of these multi-faceted story problems on the science TAKS explains the difference between performance on math and science TAKS for students that attended a project-based school.

Use the information below and your knowledge of science to answer questions 17–20.

Fireworks

Fireworks displays are often associated with celebrations. Some fireworks are rockets that can be fired into the air, producing colorful patterns of bright light. One rocket design involves a cardboard tube, a propellant, and a fuse. A cap on the tube contains metal salts and explosive powder with a second fuse. The propellant consists of a mixture of carbon (C), sulfur (S), and potassium nitrate (KNO_3). Potassium nitrate is a potassium ion (K^+) bonded to a nitrate ion (NO_3^-).

A long cardboard tube is filled with the propellant. When a lit fuse ignites the propellant, the propellant releases oxygen, produces flames, and forces gas out the bottom of the rocket. These actions cause the rocket to rise high into the air.

As the rocket reaches its maximum height, a second fuse ignites an explosion that heats and burns the metal salts. This heating and burning of metal salts produces large colorful flashes. Many people enjoy watching these colorful displays against the night sky.

The use of fireworks can be dangerous. Professionals who use fireworks take many safety precautions while setting up and igniting the displays.

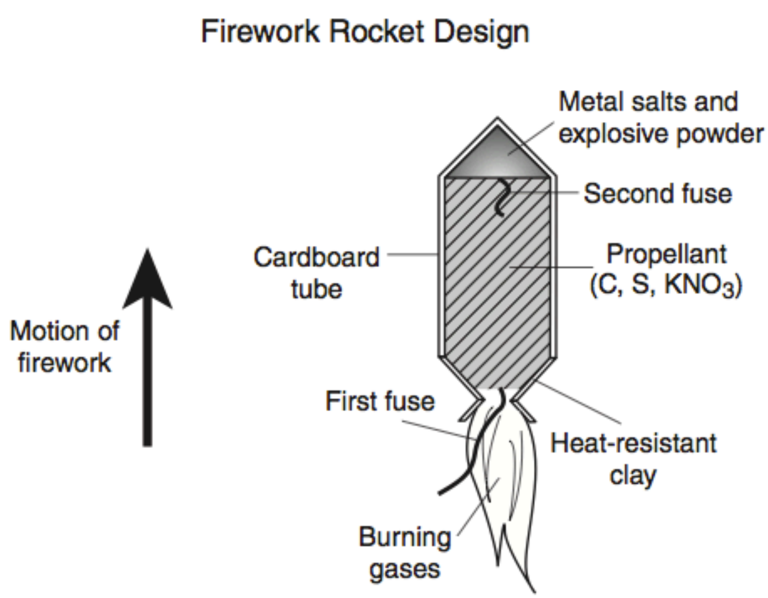

Figure 8. Firework Context Provided to Students on the Released 2009 11th grade Science TAKS Test http://tea.texas.gov/student.assessment/taks/released-tests/

17 Which of the following information would allow the most direct calculation of the average speed of the rocket on its upward flight?

A Thrust force and wind speed

B Maximum height and the time it takes the rocket to reach it

C Rocket mass and the time it takes the rocket to reach the highest point

D Thrust force and the time it takes the rocket to fall to the ground

18 As a rocket rises, its kinetic energy changes. At the time the rocket reaches its highest point, most of the kinetic energy of the rocket has been —

F permanently destroyed

G transformed into potential energy

H converted to friction

J stored in bonds between its atoms

19 When the fuse ignites the contents of a firework, oxygen is consumed as a result of which type of change?

A Mass

B Phase

C Nuclear

D Chemical

20 A scientist hypothesizes that the use of a propellant other than the traditional mixture of C, S, and KNO_3 will cause a rocket to rise higher into the air. The researcher builds a rocket that uses an alternate propellant. A proper control for the experiment would be an identical rocket that uses —

F the traditional propellant

G the alternate propellant

H no propellants

J a mixture of both propellants

Figure 9. Problems #17-20 from the Released 2009 11th grade Science TAKS Test
http://tea.texas.gov/student.assessment/taks/released-tests/

Achievement Gaps

There were no findings in my analysis to imply that PBL decreases any achievement gaps between the following demographic characteristics performance on the math or science TAKS exam: English Language Learner, Economic Disadvantage, Ethnicity, and Gender. It is important to note that the ethnicity variable and the ethnicity interaction variable were significantly correlated, which resulted in my needing to exclude pairwise cases to include the ethnicity variables in the analysis.

As explained in Chapter 2, the empirical studies that look at how PBL impacts achievement gaps are scarce. Boaler (2002) found that being taught through project-based instruction in math classrooms removed the gender achievement gap. Similarly, Kolodner et al. (2003) found that students taught science through their Learning by Design (LBD) curriculum closed the gender achievement gap on the post assessment. Although these studies find that inductive teaching methods minimize the gender gap, Table 21 shows that the TAKS exam used in this analysis did not possess a significant gender gap for the class of 2012 cohort in Manor ISD on TAKS performance, so there was no gap to close.

Gender	**M (2009)**	**M (2010)**	**S (2010)**	**M (2011)**	**S (2011)**
Male	2067 (235)	2069 (240)	2143 (207)	2177 (300)	2221 (182)
Female	2089 (205)	2108 (219)	2162 (172)	2184 (285)	2207 (246)
Total	2078 (221)	2088 (230)	2153 (190)	2181 (292)	2214 (217)

Note: Means are displayed first, followed by standard deviation in parentheses and all values are rounded to the nearest integer. Significance levels are marked with asterisks indicating that the given mean TAKS scores for the district differed based on gender *$p<.05$, **$p<.01$, ***$p<.001$.

Table 21: Average TAKS Scores for Class of 2012 Manor ISD Cohort by Gender

Lynch et al. (2005) found that being taught through PBL maintained the English-language learner gap, which aligns with my findings that the ELL gap is maintained since there was not a significant interaction between MNTH attendance and ELL status. R. M. Schneider et al. (2002) found that White and non-economically disadvantaged students, outperformed a matched national sample on the NAEP, but did not further investigate how project-based instructional methods may have impacted ethnic or SES achievement gaps.

HIGH SCHOOL GRADUATION

Students that attend MNTH are just as likely to graduate from high school as students that instead received more traditional instruction at MHS. Differences observed between the two graduation rates were not statistically significant. Due to limitations of the data, *graduation* was defined for this study to be students that applied to MNTH and were admitted to either MNTH or MHS and went on to graduate from the school they were admitted to, these findings might not explain whether the students actually graduated. For example, it is possible that students from MNTH left and attended another high school in or outside of district. Similarly, students that left MHS could have left the district and successfully graduated from another school. Unfortunately one limitation to the data available for use in this study is an inability to determine if students that did not graduate from MNTH or MHS actually dropped out of school or transferred to another school.

Since research on the effectiveness of project-based learning is often conducted on a micro-level, with one course or one year of instruction taught through project-based methods, there is a gap in the literature in regards to potential long-term student success outcomes (e.g. high school graduation, college enrollment, college graduation) for students taught solely through PBL in high school.

Asian or Pacific Islanders and White students have the highest graduation rates among American students. The high school dropout rate is highest for Hispanic and Black students, students from a low socioeconomic status, and male students (NCES, 2009). This suggests that ethnicity, SES, and gender might be significant predictors of high school graduation. Students in this research study that were accepted to MNTH and the control group that were waitlisted were similar on these demographic characteristics, or any differences were controlled for in the models created. Since these demographic characteristics are associated with higher high school graduation rates, the research design allowed us to isolate the potential effect from attending the project-base school. Since no significant difference was found for students that attended the project-based school, MNTH, and students that instead attended the traditional school, the results found in this research align with what is already known about graduation, and add to the scholarship by suggesting that attendance at a project-based school does not have an effect on graduation rates.

COLLEGE ENROLLMENT AND PERFORMANCE

Seventy percent of New Tech @Coppell graduates and 83% of Manor New Tech graduates went on to enroll in Texas institutions of higher education. These percentages are greater than both the state of Texas and national averages for post-secondary enrollment in 2013. Graduates from MNTH were more likely to enroll in 2-year colleges and students graduating from New Tech @Coppell are more likely to be "Not Found" [$\chi^2(2, N=180)=7.71$, $p<0.05$]. Also, there were no significant differences between GPA distribution at both 2-year and 4-year institutions for the graduates from each New Tech school, meaning that graduates from MNTH performed as well as New Tech @Coppell graduates their first year in Texas 2-year [$\chi^2(4, N = 180) = 6.716, p = .16$] and 4-year institutions of higher education [$\chi^2(4, N = 180) = 3.26, p = .52$].

New Tech @Coppell is a school in Coppell Independent School District has a much different demographic make-up than Manor New Tech High School (see Table 22).

	Manor New Tech High	New Tech @Coppell
Asian	1.9%	13.5%
African American	21.9%	3.6%
Hispanic	44.1%	8.3%
Native American	0%	0.3%
White	13.2%	74.3%%
EconDis	56.9%	4.9%
ELL	6.1%	0%

Table 22: 2012 Demographic Makeup for MNTH and New Tech @Coppell http://www.texastribune.org

College Enrollment. Recall from Chapter 2, students from low SES are less likely to attend college, but when they do, they are more likely to attend 2-year colleges (Walpole, 2003). So finding that students that attended MNTH, a school with 56.9% students labeled economically disadvantaged, are more likely to attend a 2-year college aligns with this literature. The finding that students from MNTH were just as likely as students from New Tech @Coppell to enroll in 4-year and Independent/Private institutions suggests an increase in college outcome for students that graduated from MNTH. Since economically disadvantaged students are usually less likely to enroll in 4-year institutions of higher education, this finding of no difference between these two PBL schools with very different demographic make-ups, suggests that being taught through PBL minimizes these college enrollment gaps.

Students that are from a more affluent background like the students at New Tech @Coppell are more likely to attend college out of Texas. One limitation of the data set from THECB is that it cannot track students that do not enroll in Texas institutes of higher education; therefore it is likely that the significantly more students that were "not found" attended schools out of Texas.

GPA Distributions. Students from both PBL schools, Manor New Tech High and New Tech @Coppell, outperformed the state of Texas percentage of students receiving a first year GPA greater than 2.0. Finding that there was no significant difference between first year college GPA for students from MNTH and the more affluent, New Tech @Coppell could suggest that being taught through PBL in high school minimizes achievement gaps in college performance. Successful college performance, could be due retaining knowledge for a longer duration, therefore this finding aligns with research that suggests students taught through inductive teaching methods retain information longer than their traditionally taught counterparts (Dochy et al., 2003; Prince & Felder, 2006; Schmidt et al., 2006).

5.2: Limitations

The primary assumption made for this research is that MNTH teaches all courses through project-based learning. Although a case study and the school's website claim that this is the case, there is not any observational data confirming fidelity of implementation of the New Tech Model. Similarly, an assumption is that MHS is using traditional instruction and not PBL or another research-based effective pedagogical approach. Since this research attempts to isolate any effect of project-based learning, it is important to keep in mind the assumption that MNTH is indeed teaching all of their classes through PBL and what that means in terms of implications of the findings.

A limitation to the graduation data is that students that do not graduate from the school in which they were admitted after four years are labeled as “not graduated.” It is very possible that these students did not drop out of high school, but instead transferred to another school within or outside of the district.

A major limitation to the college outcome data (e.g. 1st year GPA, College enrollment type) is that the data are given at the school level, instead of by student. This makes it very difficult to control for differences between the schools and imply any type of causal relationship. One result from this research was that students from New Tech @Coppell were more likely to be labeled “not trackable,” which could imply that they enrolled out of state or did not enroll in college at all. Therefore, a limitation to the data for first-year GPA did not include students that went out of state for college, which were likely the higher-performing students. In order to compare MNTH and New Tech @Coppell appropriately, the first-year GPA for students attending college outside of Texas would need to be included.

5.3: Implications and Recommendations

Finding that more females apply to MNTH is very interesting, since females are historically underrepresented in STEM careers and fields. This could imply that something in the recruitment efforts for MNTH, a project-based and STEM focused school, is especially appealing to female students. Perhaps the focus of learning content through projects engages females by showing them how STEM content could be relevant to their lives. I recommend that PBL schools might be used as a mechanism for engaging more females in STEM fields.

This research implies that attending the project-based school, MNTH, does not harm students' standardized test performance in math or their likelihood to graduate, and enhances students' performance in science. One implication could be that project-based learning has a limited effect on students' high school outcomes, particularly in mathematics. Another explanation for this finding could be that PBL is actually not occurring at MNTH or conversely PBL could also be occurring at MHS. One major limitation to this study is a lack of data supporting that the claim that PBL is actually occurring at MNTH and "traditional" instruction is the main mode of delivery at MHS.

Literature on project-based learning approaches suggests that students taught through these methods outperform students on non-content specific skills (e.g. task completion skills, problem-solving skills, collaboration skills) (CTGV, 1992; Petrosino, 1998; Schmidt et al., 2006; Yilmaz et al., 2010). Also, students taught through project-based instruction show an increased interest in and motivation to pursue STEM fields (Pryor, 1996; Tate, 1998; Verma et al., 2011; Yilmaz et al., 2010). Another implication could be that the TAKS standardized exams may not be capturing all the skills developed when a student is taught through PBL. Further it could be that unobservable characteristics, such as parental support and student motivation, have the largest effect on students' standardized test achievement and high school graduation, regardless of school attendance.

College outcomes such as first year GPA and type of enrollment in higher education for students taught at New Tech high schools, through project-based methods, suggests that students are performing well regardless of the demographic makeup of the school. Also, both schools taught through PBL outperformed the state averages for first year GPA and state and national averages for college enrollment. Since MNTH and New

Tech @Coppell are different demographically, one implication is that teaching through PBL merits further research looking at PBL effects on minimizing achievement gaps in college enrollment type and first year performance.

5.3: Recommendations for Future Research

The literature suggests that students taught through inductive teaching methods such as project-based learning develop high-order thinking skills and other non-content specific skills (e.g. oral communication, technology literacy, critical thinking). The instrument used to measure achievement was the TAKS standardized math and science exam. Since these exams are predominantly multiple-choice exams, they may not be sensitive to some higher order skill development that may occur when taught through project-based methods. Therefore, future research should be conducted to create new high school success outcome measures that will capture more robust learning than traditional standardized tests. Using these instruments further analysis of difference in students performance when taught through inquiry methods will be conducted. It would also be interesting to follow up with students and capture qualitative data on students' perceived college preparedness.

Since the college enrollment and first year GPA distributions suggested that students could retain knowledge longer when taught through PBL, future research should be conducted looking at potential effects of PBL on other college success outcomes such as STEM major choice, college retention, college graduation, and overall GPA.

REFERENCES

Abdulkadiroglu, A., & Sönmez, T. (2003). School Choice: A Mechanism Design Approach. *The American Economic Review*, *93*(3), 729–747. http://doi.org/10.1257/000282803322157061

Anyafulude, J. C. (2012). Effects of Problem-Based and Discovery-Based Instructional Strategies on Students' Academic Achievement in Chemistry. *International Journal of Social Sciences & Education*, *2*(4), 554–554.

Archambault, I., Janosz, M., Fallu, J.-S., & Pagani, L. S. (2009). Student engagement and its relationship with early high school dropout. *Journal of Adolescence*, *32*(3), 651–670. http://doi.org/10.1016/j.adolescence.2008.06.007

Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., & Bransford, J. D. (1998). Doing With Understanding: Lessons From Research on Problem- and Project-Based Learning. *Journal of the Learning Sciences*, *7*(3-4), 271–311. http://doi.org/10.1080/10508406.1998.9672056

Bell, C. A. (2009). All Choices Created Equal? The Role of Choice Sets in the Selection of Schools. *Peabody Journal of Education*, *84*(2), 191–208. http://doi.org/10.1080/01619560902810146

Bell, S. (2010). Project-Based Learning for the 21st Century: Skills for the Future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *83*(2), 39–43. http://doi.org/10.1080/00098650903505415

Blumenfeld, P. C. S., ElliotMarx, Ronald W.Krajcik, Joseph S.Guzdial, MarkPalincsar, Annemarie. (1991). Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist*, *26*(3/4), 369.

Boaler, J. (2002). Paying the Price for "Sugar and Spice": Shifting the Analytical Lens in Equity Research. *Mathematical Thinking and Learning*, *4*(2-3), 127–144. http://doi.org/10.1207/S15327833MTL04023_3

Bonser, F. G. (1921). Dangers and Difficulties of the Project Method. *Teachers College Record*, *19*(2), 297–305.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, *18*(1), 32–42. http://doi.org/10.3102/0013189X018001032

Carnevale, A. P., Smith, N., & Strohl, J. (2010). *Help Wanted: Projections of Jobs and Education Requirements through 2018. Executive Summary*. Georgetown University Center on Education and the Workforce.

Casey, B. (2012). *STEM education: Preparing for the jobs of the future*. Washington, DC: US Congress Joint Economic Committee.

Cognition and Technology Group at Vanderbilt (CTGV). (1992). The Jasper Series as an Example of Anchored Instruction: Theory, Program Description, and Assessment Data. *Educational Psychologist*, *27*(3), 291–315. http://doi.org/10.1207/s15326985ep2703_3

Collins, A., Greeno, J. G., & Resnick, L. B. (1992). Cognition and learning. In *Handbook of Educational Psychology*. New York: Simon & Shuster MacMillan.

Cullen, J. B., Jacob, B. A., & Levitt, S. D. (2005). The impact of school choice on student outcomes: an analysis of the Chicago Public Schools. *Journal of Public Economics*, *89*(5–6), 729–760. http://doi.org/10.1016/j.jpubeco.2004.05.001

DeBerard, M. S., Spielmans, G., & Julka, D. (2004). Predictors Of Academic Achievement And Retention Amongcollege Freshmen: A Longitudinal Study. *College Student Journal*, *38*(1), 66–80.

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: a meta-analysis. *Learning and Instruction*, *13*(5), 533–568. http://doi.org/10.1016/S0959-4752(02)00025-7

Eslami, Z., & Garver, R. (2013). English Language Learners and Project-Based Learning. In R. M. Capraro, M. M. Capraro, & J. R. Morgan (Eds.), *STEM Project-Based Learning* (pp. 119–128). SensePublishers. Retrieved from http://link.springer.com/chapter/10.1007/978-94-6209-143-6_13

Finkelstein, H., Hanson, T., Huang, C. W., Hirschman, B., & Huang, M. (2010). *Effects of Problem Based Economics on High School Economics Instruction*. National Center for Education Evaluation and Regional Assistance.

Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E., & Clay-Chambers, J. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching*, *45*(8), 922–939. http://doi.org/10.1002/tea.20248

Gourgey, H., Asiabanpour, B., Crawford, R., Grasso, A., & Herbert, K. (2009). *Case study of manor new tech high school: promising practices for comprehensive high schools*. Retrieved from http://www.newtechnetwork.org/sites/default/files/dr/manornewtechcasestudy.pdf

Hastings, J. S., Kane, T. J., & Staiger, D. O. (2006). *Preferences and Heterogeneous Treatment Effects in a Public School Choice Lottery* (Working Paper No. 12145). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w12145

Hennes, M. (1921). Project Teaching in an Advanced Fifth Grade Classroom. *Teachers College Record*, *19*(2), 137–148.

Jennings, L. B., & Mills, H. (2010). Inquiry-Based Learning. In *Encyclopedia of Educational Reform and Dissent* (Vol. 1, pp. 468–470). Thousand Oaks, CA: SAGE Reference.

Kilpatrick, W. (1918). The project method. *The Teachers College Record*, *19*(4), 319–335.

Kilpatrick, W. (1925). *Foundations of Method: Informal Talks on Teaching*. New York: Macmillan.

Koedinger, K. R., & Nathan, M. J. (2004). The Real Story Behind Story Problems: Effects of Representations on Quantitative Reasoning. *Journal of the Learning Sciences*, *13*(2), 129–164. http://doi.org/10.1207/s15327809jls1302_1

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., … Ryan, M. (2003). Problem-Based Learning Meets Case-Based Reasoning in the Middle-School Science Classroom: Putting Learning by Design(tm) Into Practice. *Journal of the Learning Sciences*, *12*(4), 495–547. http://doi.org/10.1207/S15327809JLS1204_2

Krajcik, J., & Blumenfeld, P. C. (2006). Project-Based Learning. In *The Cambridge handbook of the Learning Sciences* (pp. 317–333). New York: Cambridge Press.

Kuehler, C. P., Marle, P. D., Decker, L. L., & Khaliqi, D. H. (2012). *Gender differences in high school students' science interests and attitudes: Scenario-based STEM education*.

Ladson-Billings, G. (1997). It Doesn't Add up: African American Students' Mathematics Achievement. *Journal for Research in Mathematics Education*, *28*(6), 697–708. http://doi.org/10.2307/749638

Lynch, S., Kuipers, J., Pyke, C., & Szesze, M. (2005). Examining the effects of a highly rated science curriculum unit on diverse students: Results from a planning grant. *Journal of Research in Science Teaching*, *42*(8), 912–946. http://doi.org/10.1002/tea.20080

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education*, *95*(5), 877–907. http://doi.org/10.1002/sce.20441

Manor New Tech. (2015). Retrieved April 15, 2015, from http://mnths.manorisd.net/apps/pages/index.jsp?uREC_ID=172752&type=d&pREC_ID=356303

McKenna, A., McMartin, F., Terada, Y., Sirivedhin, V., & Agogino, A. (2001). A Framework for Interpreting Students' Perceptions of an Integrated Curriculum. Presented at the 2001 ASEE Annual Conference and Exposition.

Mergendoller, J., Maxwell, N., & Bellisimo, Y. (2006). The Effectiveness of Problem-Based Instruction: A Comparative Study of Instructional Methods and Student Characteristics. *Interdisciplinary Journal of Problem-Based Learning*, *1*(2). http://doi.org/10.7771/1541-5015.1026

Mills, J. E., & Treagust, D. F. (2003). Engineering education—Is problem-based or project-based learning the answer? *Australasian Journal of Engineering Education*, *3*, 2–16.

Moss, D., & Van Duzer, C. (1998). Project-Based Learning for Adult English Language Learners. ERIC Digest. Retrieved from http://eric.ed.gov/?id=ED427556

Murnane, R. J., Newstead, S., & Olsen, R. J. (1985). Comparing Public and Private Schools: The Puzzling Role of Selectivity Bias. *Journal of Business & Economic Statistics*, *3*(1), 23–35. http://doi.org/10.2307/1391686

Nathan, M. J., Long, S. D., & Alibali, M. W. (2002). The Symbol Precedence View of Mathematical Development: A Corpus Analysis of the Rhetorical Structure of Textbooks. *Discourse Processes*, *33*(1), 1–21. http://doi.org/10.1207/S15326950DP3301_01

Nathan, M. J., & Petrosino, A. (2003). Expert Blind Spot Among Preservice Teachers. *American Educational Research Journal*, *40*(4), 905–928. http://doi.org/10.3102/00028312040004905

National Academy of Engineering. (2008). *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. Washington, DC: The National Academies Press. Retrieved from http://www.nap.edu/catalog/12187/changing-the-conversation-messages-for-improving-public-understanding-of-engineering

Olson, L. (2006). Views Differ on Defining College Prep: How to Gauge Readiness Sparks Vexing Questions. *Education Week*, *25*(33).

Pellegrino, J. W., & Brophy, S. (2008). From Cognitive Theory to Instructional Practice: Technology and the Evolution of Anchored Instruction. In D. Ifenthaler, P. Pirnay-Dummer, & J. M. Spector (Eds.), *Understanding Models for Learning and Instruction* (pp. 277–303). Springer US. Retrieved from http://link.springer.com/chapter/10.1007/978-0-387-76898-4_14

Petrosino, A. J. (1998). At-risk children's use of reflection and revision in hands-on experimental activities. *ProQuest Dissertations And Theses; Thesis (Ph.D.)--Vanderbilt University, 1998.; Publication Number: AAI9827617; ISBN:*

9780591798975; Source: Dissertation Abstracts International, Volume: 59-03, Section: A, Page: 0725.; 248 P. Retrieved from http://adsabs.harvard.edu/abs/1998PhDT.......171P

Prince, M. J., & Felder, R. M. (2006). Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. *Journal of Engineering Education*, *95*(2), 123–138.

Pryor, A. Z. (1996). Putting Trust in Change: A Partnership for Better Science Education. *T.H.E. Journal*, *24*(3), 74–76.

Ravitz, J. (2008). *Project Based Learning as a Catalyst in Reforming High Schools*. Buck Institute for Education.

Rivet, A. E., & Krajcik, J. S. (2004). Achieving standards in urban systemic reform: An example of a sixth grade project-based science curriculum. *Journal of Research in Science Teaching*, *41*(7), 669–692. http://doi.org/10.1002/tea.20021

Sadler, P. M. ., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education*, *96*(3), 411–427. http://doi.org/10.1002/sce.21007

Sander, W. (2001). Catholic Grade Schools and Academic Achievement. In *Catholic Schools* (pp. 13–22). Springer US. Retrieved from http://link.springer.com/chapter/10.1007/978-1-4757-3335-8_2

Schmidt, H. G., Vermeulen, L., & Van Der Molen, H. T. (2006). Longterm effects of problem-based learning: a comparison of competencies acquired by graduates of a problem-based and a conventional medical school. *Medical Education*, *40*(6), 562–567. http://doi.org/10.1111/j.1365-2929.2006.02483.x

Schneider, M., & Buckley, J. (2002). What Do Parents Want From Schools? Evidence From the Internet. *Educational Evaluation and Policy Analysis*, *24*(2), 133–144. http://doi.org/10.3102/01623737024002133

Schneider, R. M., Krajcik, J., Marx, R. W., & Soloway, E. (2002). Performance of students in project-based science classrooms on a national measure of science achievement. *Journal of Research in Science Teaching*, *39*(5), 410–422. http://doi.org/10.1002/tea.10029

Schwartz, D. L., & Bransford, J. D. (1998). A Time For Telling. *Cognition and Instruction*, *16*(4), 475–5223. http://doi.org/10.1207/s1532690xci1604_4

Schwartz, D. L., Chase, C. C., Oppezzo, M. A., & Chin, D. B. (2011). Practicing versus inventing with contrasting cases: The effects of telling first on learning and transfer. *Journal of Educational Psychology*, *103*(4), 759–775. http://doi.org/10.1037/a0025140

Shyu, H.-Y. C. (2000). Using video-based anchored instruction to enhance learning: Taiwan's experience. *British Journal of Educational Technology*, *31*(1), 57–69. http://doi.org/10.1111/1467-8535.00135

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and Science Achievement: Effects of Motivation, Interest, and Academic Engagement. *The Journal of*

Educational Research, *95*(6), 323–332. http://doi.org/10.1080/00220670209596607

Tate, R. L. (1998). *An Introduction to Modeling Outcomes in the Behavioral and Social Sciences* (2nd ed.). Edina, MN: Burgess International Group, Inc.

Texas Education Agency. (2015a). Retrieved April 13, 2015, from http://ritter.tea.state.tx.us/perfreport/src/2014/campus.srch.html

Texas Education Agency. (2015b). Retrieved April 13, 2015, from http://tea.texas.gov/student.assessment/taks/released-tests/

Tytler, R., Osborne, J., Williams, G., Tytler, K., & Cripps Clark, J. (2008). Opening up pathways: Engagement in STEM across the Primary-Secondary school transition.

Verma, A. K., Dickerson, D., & McKinney, S. (2011). Engaging Students in STEM Careers with Project-Based Learning--MarineTech Project. *Technology and Engineering Teacher*, *71*(1), 25–31.

Wagner, T. (2010). *The Global Achievement Gap: Why Even Our Best Schools Don't Teach the New Survival Skills Our Children Need--and What We Can Do about It*. Basic Books.

Walkington, C., Sherman, M., & Petrosino, A. (2012). "Playing the game" of story problems: Coordinating situation-based reasoning with algebraic representation. *The Journal of Mathematical Behavior*, *31*(2), 174–195. http://doi.org/10.1016/j.jmathb.2011.12.009

Walpole, M. (2003). Socioeconomic Status and College: How SES Affects College Experiences and Outcomes. *The Review of Higher Education*, *27*(1), 45–73. http://doi.org/10.1353/rhe.2003.0044

Weiher, G. R., & Tedin, K. L. (2002). Does choice lead to racially distinctive schools? Charter schools and household preferences. *Journal of Policy Analysis and Management*, *21*(1), 79–92. http://doi.org/10.1002/pam.1041

Yates, D., Moore, D., & Starnes, D. S. (2002). *The practice of statistics: TI-83/89 graphing calculator enhanced*. Macmillan Publishing.

Yilmaz, M., Ren, J., Custer, S., & Coleman, J. (2010). Hands-On Summer Camp to Attract K #x2013;12 Students to Engineering Fields. *IEEE Transactions on Education*, *53*(1), 144–151. http://doi.org/10.1109/TE.2009.2026366