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## ABSTRACT

### PROJECT LEAD THE WAY AND DEEPER LEARNING: AN EVALUATION STUDY

For the past several decades governmental, educational, and philanthropic entities have endeavored to respond to the national STEM gap directing tremendous amounts of resources in response. During this time a specific STEM intervention, Project Lead the Way, a K12 program with a purpose to address the STEM gap, has spread across the country. This study investigates whether Project Lead the Way is delivering on its promise. Project Lead the Way exhibits many of the characteristics recommended by leading experts to reform traditional education into one that stresses deeper learning and the acquisition of 21<sup>st</sup> Century Skills. The central question of this study was to determine whether exposure to Project Lead the Way curriculum does indeed lead to deeper learning as evidenced through the acquisition of 21<sup>st</sup> Century Skills, specifically problem solving, critical thinking, and creativity. Further, are the recommendations of researchers who intend to more fully integrate deeper learning into the fabric of high school coursework validated by the effects of a program that follow those recommendations. The results suggest that the answer is maybe to both questions.

## CHAPTER I

### PROJECT LEAD THE WAY AND DEEPER LEARNING

#### **Introduction**

A current topic of public concern in the United States is the American education system's success related to Science, Technology, Engineering and Math (STEM) education and the career fields that education leads to. One reason for the concern is a belief that United States businesses have a greater demand for STEM workers than is currently being supplied domestically (Center on Education and the Workforce, 2011; Charette, 2013). This gap in workforce supply and demand is assumed to be the result of inadequate mathematics and science preparation in K-12 schooling, a general resistance for American students to choose and ultimately persist in STEM degree programs in college, and a lack of gender diversity in these fields of study (Metcalf, 2010; States News Service, 2011). Sensing the urgency to address this problem, decision makers at the local, state, and federal levels have aggressively directed massive resources to improve STEM education outcomes for decades (Congressional Research Service, 2008; Sanders, 2008). After years of prioritization in the form of funding from government and industry, it is appropriate to consider the following questions: Have the interventions helped? Maybe more importantly, can we show that any one particular intervention has been successful?

The United States has enjoyed a rich history of prosperity due in part to its international contributions to STEM career fields (Congressional Research Service, 2012), though most believe America's worldwide prominence in STEM work is declining. Because these STEM careers historically provide a rewarding wage relative to

other careers in the domestic economy, it follows that a reduced American involvement in STEM work will adversely affect the American standard of living (Augustine, 2005; National Commission on Excellence in Education, 1983). There are several reasons posited that endeavor to explain why the American STEM workforce may be losing its preeminence on the world stage.

One possible explanation is American students' declining worldwide standing on international math and science achievement tests (Congressional Research Service, 2008; Congressional Research Service, 2012). On the 2015 Programme for International Student Assessment (PISA) test, American students ranked 31<sup>st</sup> of 35 participating countries in math and 19<sup>th</sup> of 35 participating countries in science (OECD, 2016). This result is worse than 2009 when American students ranked 25<sup>th</sup> in math and 17<sup>th</sup> in science (OECD, 2011). American student's international position in science and math achievement has declined steadily since 2000, (OECD, 2004; OECD, 2007). Similar trends are found upon analysis of both the National Assessment of Educational Progress and Trends in International Mathematics and Science Study assessments (Congressional Research Service, 2008).

Perhaps not surprisingly, as American students have performed more poorly in math and science relative to the world, the proportion of worldwide STEM degrees that are awarded to them has declined as well (Congressional Research Service, 2008; Congressional Research Service, 2012; Freeman, 2006; Tai, 2012; The National Academies National Research Council Board of Science Education, 2008). Researchers point to a myriad of factors that contribute to this. The National Research Council Board of Science Education reports a decline in American students pursuing undergraduate and

postgraduate STEM degrees (The National Academies National Research Council Board of Science Education, 2008). As the number of American students enrolled in STEM degree programs domestically has declined, foreign student participation in these programs has increased. Recent analysis found that foreign students earn half or more of the engineering, physics, computer science, and economics doctoral degrees conferred in America (Congressional Research Service, 2012).

Even though it can be argued that students' educational characteristics including math and science achievement and motivation to enter and persist in STEM degree programs are the major factors related to American loss of STEM education and work preeminence (Congressional Research Service, 2008; Congressional Research Service, 2012; Freeman, 2006; The National Academies National Research Council Board of Science Education, 2008; Tai, 2012), other contributing factors have been identified. First, the relatively new ability to communicate worldwide nearly instantaneously has allowed American businesses to outsource STEM work. Prior to the Internet and the ability to transmit data through wires, American STEM work had to be performed by a highly paid domestic workforce (Augustine, 2005). In today's world that same work can be performed more economically by members of a foreign workforce. Second, an aging and retiring American STEM workforce is increasing the frequency at which business must identify and hire STEM employees (Tran & Nathan, 2010). The increasing number of STEM positions opening, the decreasing motivation to be trained in STEM majors by the domestic workforce, and the ability to outsource STEM work worldwide combine to put the United States in a precarious economic position (Augustine, 2005; Congressional Research Service, 2008; Congressional Research Service, 2012; Freeman, 2006; The

National Academies National Research Council Board of Science Education, 2008; Tai, 2012).

American policy makers have aggressively addressed these concerns in recent years with the aim of reversing the aforementioned trends. The origin of this particular concern and intervention may have occurred when the acronym STEM was developed by the National Science Foundation in the 1990's. Since that time, attention and funding for STEM education has grown rapidly (Sanders, 2008). Though calculations differ depending on how you define "STEM programs", the US federal government spent \$3.4 billion on 250 STEM programs distributed throughout fifteen federal agencies in fiscal year 2010 (Congressional Research Service, 2012). President Obama's administration put increased focus on STEM education through incentivizing STEM programs and activities when allocating Race to the Top money, pursuing a 2011 State of the Union pledge to develop 100,000 quality STEM teachers in the following decade, and hosting the nation's first White House science fair (Committee on STEM Education, 2013). Additionally, the America COMPETES reauthorization act of 2010 called for the creation of a federal committee, CoSTEM, to coordinate federal STEM efforts and develop a five year national STEM strategic plan (Committee on STEM Education, 2011).

Much of the governmental focus has been on improving K-12 STEM access and student performance. These efforts span a wide range of activities and intensities. They include traditional or STEM specific elective project-based coursework, weeklong summer STEM camps, and STEM related hobbies and clubs (Fantz, Siller, & DeMiranda, 2011). These programs universally attempt to motivate and prepare American high school students who wouldn't otherwise choose and persist in STEM

career paths. This is often referred to as “enlarging the pipeline” (Congressional Research Service, 2008; The National Academies National Research Board of Science Education, 2008; Sanders, 2008). Other initiatives seek to improve the quality of math and science instructors, improve American student performance in math and science assessments, or present various integrated or project-based STEM learning environments to high school students (Congressional Research Service, 2008; Sanders, 2008).

### **Statement of the Problem**

This proliferation of K-12 STEM initiatives over the past thirty years provides a rich environment for inquiry. Have these initiatives worked as intended? Are these initiatives preparing this generation of American high school graduates to be more successful in STEM career majors than prior generations? Has the effect been worthy of the expense? Which of these initiatives is most effective? Currently these questions remain largely unanswered by research.

From an extremely broad perspective it is simple to generate conclusions regarding the effectiveness of these efforts. As mentioned previously, one need only point to negative national trends in student’s math and science test scores and the percentage of college graduates attaining a STEM degree, relative to other countries, to come to the conclusion that these initiatives have been largely ineffective. National data, however, mask performance realities at the local level. Like with most initiatives one can find cases where outcomes are being realized and cases where they are not.

Currently, there exists a gap in the literature exploring the effects of K-12 STEM programs. Extant research primarily explores the connection between membership in K-12 STEM initiatives and either math and science achievement test scores or enrollment in

collegiate STEM degree programs. Such evidence attempts to probe the general effectiveness of K-12 STEM initiatives in preparing students for success in STEM majors and improved access to the domestic STEM workforce. Unfortunately, achievement test scores do not fully capture the effects K-12 STEM initiatives have on a broader set of competencies more closely aligned with the modern workforce. One unexplored outcome is how modern STEM education is related to the advancement of deeper learning and 21<sup>st</sup> Century Skills. As described in the literature review, deeper learning competencies have become the expectation for STEM fields specifically and the modern workforce more generally.

Given the lack of attention to deeper learning as an outcome, this study was conducted to (1) examine features of a particular STEM program – Project Lead the Way – in relation to deeper learning process and outcomes, and (2) empirically test the relationship between participation in Project Lead the Way and a cognitive dimension of deeper learning. Project Lead the Way is a project-based pre-engineering curriculum administered as an elective in middle schools and high schools across the nation (Blais & Adelson, 1998; Tai, 2012) . Current research evaluating Project Lead the Way’s effectiveness in enlarging and enriching the STEM pipeline concentrate on a few specific measures. These include math and science achievement test scores and college persistence (Project Lead the Way, 2006; Schenk, Rethwisch, Chapman, Laanan, Starobin & Zhang, 2011; Rethwisch, Chapman, Schenk, Starobin, & Laanan, 2013; Southern Regional Education Board, 2005; Southern Regional Education Board, 2007; Tai, 2012; Tran & Nathan, 2010; Van Overschelde, 2013). Though these indicators

capture an aspect of STEM preparation, an equally appropriate outcome involves the thinking and problem-solving capacity of students.

### **Statement of Purpose**

Demonstrating the degree to which Project Lead the Way adds value to a students' education and prepares them for college level STEM degrees is vitally important. As we continue to focus funding and energy on improving and increasing our domestic STEM workforce, it is prudent to investigate the effects of the programs we are using to achieve these outcomes. Researching the effects of Project Lead the Way coursework on students provides evidence measuring how effectively the program equips students with valuable 21<sup>st</sup> Century skills. Further, conducting this research provides a unique set of information for decision makers who are considering selecting, adopting, or funding STEM programs in their individual context. Finally, this evaluation could lead to future research. If students in Project Lead the Way are engaging with STEM coursework at a deeper level and acquiring 21<sup>st</sup> Century Skillsets, researchers will want to explore if they are more successful in their collegiate studies, if they are more likely to graduate with a STEM degree, and if they are more successful in their careers compared to their peers. Additionally, this type of study could be replicated with other STEM initiatives to compare relative effectiveness.

Specifically, this research investigated whether Project Lead the Way students display heightened levels of problem solving and creativity skill as compared to their peers. Students' problem solving and critical thinking skills were measured with the systems thinking test, originally developed by Kahneman (Kahneman, 2011) and recently



expanded (Toplak, West, & Stanovich, 2014). Additionally, student creativity was measured by the Remote Associates test first used by Mednick (Mednick, 1968).

### **Definitions of Terms**

The following definitions are provided to assist in interpretation and to explain terms used in this study.

**21<sup>st</sup> Century Skills.** The 21<sup>st</sup> Century Competencies suggested by the work of the National Research Council and the Hewlett Foundation organize six 21<sup>st</sup> Century competencies into three broad domains (Huberman, Bitter, Anthony, & O’Day, 2014). In the cognitive domain content knowledge and critical thinking / problem solving are identified. The interpersonal domain consists of collaboration and communication. And finally, the intrapersonal domain is populated by academic mindset and learning to learn.

**Creativity.** Creativity was defined by Mednick as the “forming of associative elements into new combinations which either meet specified requirements or are in some way useful” (Mednick, 1968). It is common for more modern treatments of the construct of creativity to differentiate between convergent and divergent thinking (Brophy, 2000). This study was conducted to measure the convergent element of learner’s creativity.

**Deeper Learning.** The Hewlett Foundation defines deeper learning as the ability to master rigorous academic content through the application of higher-order skills, including critical thinking and problem solving, communication, collaboration, learning to learn, and the development of an academic mindset.” (William and Flora Hewlett Foundation, 2013). A slightly different definition posited by the National Research Council emphasizes the learner’s ability to use knowledge gained from one situation in a different situation, referred to as transfer (Huberman, Bitter, Anthony, & O’Day, 2014).

**Problem Solving.** According to The William and Flora Hewlett Foundation (2013) critical thinking and problem solving occur when “Students apply tools and techniques gleaned from core subjects to formulate and solve problems. These tools include data analysis, statistical reasoning, and scientific inquiry as well as creativity, nonlinear thinking, and persistence.” (p. 2).

**Project Lead the Way.** According to Blais & Adelson (1998) “Project Lead the Way (PLTW), is a national program that has formed partnerships among public schools, institutions of higher education, and industry to increase the quantity and quality of students graduating from engineering and engineering technology institutions” (p. 40). Project Lead the Way pursues this mission by facilitating the inclusion of project-based pre-engineering curriculum into the many schools in its network.

### **Organization of the Study**

The research study is divided into five chapters. Chapter I includes an introduction, statement of the problem, statement of purpose, definition of terms, and organization of study. Chapter II includes a review of the literature regarding three topics; general K-12 STEM initiatives, Project Lead the Way and improved math and science achievement, and Project Lead the Way and positive college effects. Chapter Three includes an introduction, a discussion of deeper learning and 21<sup>st</sup> Century Skills, and concludes with the study’s theory of action for Project Lead the Way. Chapter Four discusses research methods including an introduction, descriptions of the design, population and sample, procedure, analytical technique, and study limitations. Chapter Five reports results including the testing for the significance of possible confounding variables, the analysis of differences in problem solving and creativity by Project Lead the Way membership,

and a summary of the findings. Chapter Six concludes the dissertation with discussion of deeper learning, Project Lead the Way, implications of the study, and a final conclusion.

## CHAPTER II: REVIEW OF LITERATURE

### **Introduction**

The literature review contained in this chapter is comprised of four sections. The first reviews the existing literature regarding characteristics and effects of K12 Science, Technology, Engineering and Math (STEM) initiatives. The second section details the characteristics of a specific initiative, Project Lead the Way. The third and fourth sections review existing literature regarding the effects of Project Lead the Way membership on student's math and science achievement and positive college effects respectively. The chapter concludes with a summary of the evidence.

### **K12 STEM Initiative Analysis**

Though there seems to be universal agreement that enriching and enlarging the K12 STEM pipeline through intervention is necessary, there has been very little analysis of the effects of current interventions. Fantz, Siller, and DeMiranda (2011) investigated the relationship between college engineering students' self-efficacy and K12 formal and informal STEM preparation. They categorized K12 STEM activities in four broad categories. These included pre-engineering or technology related coursework, multi-day STEM camps, high school STEM extracurricular activities, and individual student hobbies. Only a few of these categories exist at a coordinated national level. The ones that do include Project Lead the Way pre engineering coursework, the FIRST Robotics extracurricular program, the Junior Engineering Technical Society (JETS) extracurricular program, and the Lego Engineering extracurricular program. The study found that formal pre engineering or technical coursework led to the highest levels of college student self-efficacy, though the effect was not statistically significant.

In 2004 the American Society for Engineering Education (ASEE) released the results of their analysis of K12 STEM initiatives (Douglas, Iverson, & Kalyandurg, 2004), possibly the most comprehensive review of K12 STEM outreach available. To conduct their analysis ASEE surveyed 300 STEM outreach program leaders of whom 66 responded. The results illuminate some common themes in K12 STEM outreach. First, K12 STEM intervention is recent. When surveyed in 2004, 41% of responding programs had been founded since 2000 and 75% since 1990. Second, K12 STEM initiatives are largely local and not coordinated nationally. 46% of responding leaders reported reaching fewer than 100 students, 72% reported reaching fewer than 1000, and only four reported reaching more than 10,000 students. Third, K12 STEM initiatives tend to reach the same demographic of students as are seen in the current engineering profession. Programs that reach African-American, Hispanic, Asian, and Native American students only enroll 15%, 5%, 3%, and 2% membership respectively. Further, K12 STEM initiatives reach seems to be disproportionately at the high school level. The study found that 77% of responding programs have high school students, 49% middle schoolers, and 21% elementary students. Finally, in conjunction with reach, the vast majority of K12 STEM initiatives utilize from one to 150 instructors with Project Lead the Way being an outlier using over 1000 instructors.

The research of the effectiveness of K12 STEM outreach is hindered by the characteristics of the outreach. Because programs tend to be local, informal, and unique to their own situations, it is difficult to measure effects on a large scale. Though current initiatives are undoubtedly well intentioned, the lack of scale and voluntary nature of most programs prohibits researchers from studying effects and generalizing findings to a

larger population of students. These characteristics have resulted in few attempts to quantify the effects of specific K12 STEM initiatives. As will be detailed in the following section, the Project Lead the Way initiative has several characteristics that make it a logical subject for inquiry regarding the effectiveness of K12 STEM initiatives while having the ability to generalize findings to a larger population of students.

### **Project Lead the Way**

Project Lead the Way presents an ideal case study for the effectiveness of a particular K12 STEM initiative with the ability to generalize to larger populations of K12 STEM programs for several reasons. First, unlike most current American K12 STEM initiatives, Project Lead the Way is a widely deployed national program, allowing researchers to replicate research in multiple settings (Blais & Adelson, 1998; Van Overshelde, 2013). According to the Project Lead the Way website, their program is currently in all 50 states and used with over 10,000 schools. The website also claims Project Lead the Way has trained in excess of 55,000 teachers and reached over two million students to date. The website explains that students are exposed to a structured curriculum delivered by instructors who have all completed rigorous mandatory training. This consistency allows the researcher to generalize findings inside of the Project Lead the Way network of schools. Finally, Project Lead the Way curriculum is similar to many other STEM initiatives, focusing on immersing students in hands on project-based learning related to math and science (Southern Regional Education Board, 2005; Blais & Adelson, 1998). These characteristics may allow the researcher to not only generate knowledge regarding the effectiveness of Project Lead the Way, but generalize this knowledge to other similar STEM initiatives.

According to its founder Richard Blais, Project Lead the Way is a national pre-engineering sequence of courses that introduces pre-college students to engineering (Blais & Adelson, 1998). PLTW has two primary goals. It endeavors to increase the number of domestic students who choose engineering and engineering tech degree programs and to reduce the attrition rates of American students once in those degree programs.

Project Lead the Way coursework is different than traditional science, math, or engineering coursework in four distinct ways (Blais & Adelson, 1998). First, Project Lead the Way courses are intended to be roughly one third theory and two thirds application. This specific allocation of class time seems to emphasize hands on project work more than a traditional schedule. Second, the curriculum requires students to engage in problem solving, collaboratively with peers, in a project-based learning environment. Third, in most instances, there is an expectation that students will concurrently complete a college level math and science sequence in their other coursework. Finally, Project Lead the Way teachers attend intensive professional development prior to being certified to teach a course. In this professional development, teachers are taught how to properly use the prescriptive Project Lead the Way curriculum. This training, ultimately, is very hands-on, as instructors complete the majority of the yearlong curriculum in an intensive two-week professional development under the tutelage of an experienced PLTW master teacher (Southern Regional Education Board, 2005).

## **Effects of Project Lead the Way**

To date, studies regarding the effect of membership in Project Lead the Way coursework center around two measures. First, researchers have measured the change in students' math and science achievement test scores as an effect of PLTW coursework. These studies have mixed results. Additionally, a strand of educational research investigates the existence of positive college effects as a result of taking PLTW coursework prior to entering a STEM related degree program. These results are more consistent, finding that PLTW alumni are more resilient in college STEM programs.

### **Project Lead the Way and Improved Math and Science Achievement**

The following three studies explore the relationship between membership in Project Lead the Way coursework and mathematics and science achievement test scores. Their relevance centers on the stipulation that Project Lead the Way coursework more adequately prepares its students for the rigor of college level math and science coursework than the alternative or traditional high school experience. This is one of two stated claims Project Lead the Way makes regarding positive effects of its curriculum. Though different researchers draw different conclusions, it would be appropriate to contend that outstanding math and science scores or accelerated growth in scores is the result of the project-based application of theory that defines the structure of Project Lead the Way courses.

Schenk, Rethswisch, Chapman, Laanan, Starobin, and Zhang (2011) researched math and science achievement test improvement for PLTW students. Their study utilized the state of Iowa's longitudinal educational data system to classify and compare science and math achievement test score growth of over 25,000 high school students on their state



mandated achievement tests in the 8th and 11th grades. The researchers used a propensity score matching technique to derive comparable groups of students to compare, namely those who enrolled in Project Lead the Way coursework and those who did not. They concluded that Project Lead the Way students increased their math and science test scores at a level that was statistically significant compared to non-Project Lead the Way students. The researchers concluded that Project Lead the Way membership resulted in small or moderate test score effects. The researchers contend that this finding validates the effectiveness of the project-based learning model in secondary education.

Tran and Nathan (2010) also conducted research concerning the levels of math and science achievement of PLTW students. Using multilevel statistical modeling, they selected a group of 140 Project Lead the Way and non-PLTW students for comparison, controlling for prior achievement in math and science, teacher experience, gender, and socio-economic status. Evaluating the results of achievement tests given in the eighth and tenth grades, the researchers found smaller math gains for the Project Lead the Way students than the control group and surprisingly no measurable science gains for the Project Lead the Way students. The authors point to the lack of traditional science and math content in standard Project Lead the Way courses as a possible reason for the disappointing math and science achievement scores. The researchers also call for the standard technical education model that is used in Project Lead the Way coursework to consider integrating a more traditional liberal arts treatment of math and science concepts.

The Southern Regional Education Board has also studied the performance of Project Lead the Way students compared to a control group on their 2004 and 2006 High Schools

that Work assessment, a NAEP-referenced test that measures student proficiency in math, science, and reading (Southern Regional Education Board, 2005; Southern Regional Education Board, 2007). After controlling for gender, ethnicity, and parental educational attainment, Project Lead the Way students performed significantly better in math than students in similar career and technical fields in 2004. In 2006, Project Lead the Way students performed significantly better than students in similar career and technical fields of study in both math and science.

Each of the preceding studies suffer from some sort of limitation. Holistically, the comparison of Project Lead the Way students and their peers as they relate to common math and science achievement testing may not be sensitive enough to ascertain with certainty individual gains in the type of knowledge Project Lead the Way coursework is designed to convey. Specifically, Project Lead the Way eschews the practice of covering vast quantities of mathematical and science knowledge in favor of covering fewer concepts in more depth. Because of this, comparing the relative ability of students to call upon a wide variety of mathematical and scientific procedures runs counter to the philosophy of the coursework.

On a more granular level, two of the preceding studies suffer from unequal group comparisons. The comparison groups used in the Schenk, Rethswisch, Chapman, Laanan, Starobin, and Zhang (2011) study fail to account for a very powerful difference between Project Lead the Way students and their peers. Though the researchers used propensity score matching to develop their groups they failed to account for prior achievement. Considering the types of students who likely are drawn to secondary pre-engineering coursework, it is likely that these students view themselves as appropriately equipped to

engage in math and science work with their elective courses. This type of student has likely arrived at this conclusion due to their prior success with math and science coursework and testing. Further, students who choose to take Project Lead the Way coursework are more likely to take rigorous math and science courses regardless of their prior testing. Therefore, it is not surprising that they demonstrate greater math and science growth measured by achievement test score during their high school years.

The limitations of the SREB studies are even more egregious. Though the studies controlled for gender, ethnicity, and parental educational attainment, they did not control for the assumed growth of students participating in more rigorous math and science elective courses compared to their peers who choose not to participate in these courses. Even if we concede that these groups begin with relatively similar scores, the fact that one group is engaging in rigorous math and science work with their elective choices will certainly propel them to higher scores in subsequent testing.

Even with limitations, these studies are instructive. Two of the three studies find PLTW students either outperforming or outgrowing their peers on math and science achievement tests. These results lend credibility to claims that PLTW membership enriches the college STEM pipeline and prepares students for rigorous STEM coursework in college. Whether these gains are activated directly through Project Lead the Way coursework or indirectly through requiring college prep math and science coursework to be taken concurrently with PLTW courses, most studies find PLTW students outperforming their peer group.

## **Project Lead the Way and Positive College Effects**

In the previous section I explored research that measured the connection between Project Lead the Way membership and increased math and science achievement or growth. The following four studies have been conducted in hopes of establishing a connection between membership in Project Lead the Way coursework and college readiness or success. If that connection is established it would support the second principal claim that Project Lead the Way makes, specifically that exposure to its coursework leads to greater success in STEM degree programs in college.

In 2006 the Chief Learning Officer, Douglas Walcerz, of True Outcomes, the company responsible for providing PLTW's end of course assessments and student online survey, released the results of that assessment, a survey of current students, and college transcript review of PLTW alumni (Project Lead the Way, 2006). The study found that of the PLTW alumni that were attending college, 40% of them were majoring in engineering or technology degree programs. When compared to the 4.3% of all college freshmen majoring in engineering or technology degree programs, the authors argue that this is validation of the effectiveness of the PLTW coursework. Of those PLTW students still in high school, 80% intended to attend college and 60% of those intended to major in a STEM degree program. Over 80% of PLTW seniors reported that they felt that their PLTW coursework would increase their ability to succeed in college. Finally, PLTW alumni were found to have a .2 point higher GPA in college than the average student. Taken together, these findings support the premise that PLTW coursework encourages more students to take challenging STEM coursework in college, increases their self-efficacy, and prepares them to be more successful than their peers.

A 2010 study compared the persistence rates of PLTW alumni with students in general. The author found that PLTW coursework was associated with above average persistence in an engineering degree program (McCharen & High, 2010). The study focused on engineering students at Oklahoma State University who had participated in Oklahoma Career and Technical Education Project Lead the Way programs. The most powerful finding was that in the four year period prior to the study Oklahoma State's Career Tech Project Lead the Way alumni demonstrated a 93% retention rate at the end of their first year compared with 79% for the student population at large. Though it isn't explored in this research it is worthwhile to consider what mechanisms and emotions are in place that result in this difference. Seymour and Hewitt (1997) find that engineering students who change majors aren't different than students who stay in terms of grades or engagement, yet they do perceive that they are not being successful. It is plausible that pre-engineering coursework in high school acclimates students to challenging content and allows them a safe environment to develop self-confidence prior to college. It is important to note, though, the differences in retention rate for PLTW alumni and the average student shrink to around 2% after four years.

A 2013 study furthered the case that PLTW participation makes a positive contribution to the STEM pipeline (Rethwisch, Chapman, Schenk, Starobin, & Laanan, 2013). In this study, researchers used several data sources to track and compare the postsecondary transition rate of PLTW alumni and non-PLTW alumni. Using propensity score matching, the study's authors were able to control for prior achievement, gender, ethnicity, and socioeconomic status, more accurately measuring the differences accountable to PLTW coursework. The study found that 70% of PLTW alumni

immediately transitioned to post-secondary education compared to 50% in their peer group. The researchers found that PLTW participation increases the likelihood of transitioning into higher education by nearly 11 percent. This bolsters the claim that PLTW is helping to address the national pipeline issue.

A final study for review compared Project Lead the Way students to non Project Lead the Way students in an effort to establish whether membership in PLTW prepares students for college (Van Overshelde, 2013). The author used six years of testing data from the state of Texas to compare Project Lead the Way student outcomes to non Project Lead the Way students. The study generated matched cohorts for comparison controlling for prior achievement, demographics, and program participation variables. The study found that PLTW students were better prepared for college than the control group. PLTW students scored higher on the state's math assessment and were more likely to meet both the state's minimum and college ready math standard than non PLTW students. Further, PLTW students were more likely than their matched peers to attend college and had higher salaries after college. This study presents strong evidence that Project Lead the Way meets the needs of high school students, preparing them mathematically for college, sending them at higher rates to college, and even increasing their salary post college graduation.

Two of the previous studies suffer from limitations. The Walcerz study suffers from group comparison. In a broad fashion the study compares former PLTW students in college with the average college student and finds small academic differences. It is impossible to determine whether this difference is due to PLTW membership or whether the type of student that self selects into PLTW membership in high school might be

slightly more academically inclined naturally. The McCharen and High study suffers from a small sample size with most of the five years studied involving fewer than thirty students.

Though there are relatively few studies investigating the relationship between Project Lead the Way membership and positive college effects, their results tend to point to a positive effect. This should not come as a surprise. Familiarity and practice with STEM work in high school should prepare students to the degree they are not overwhelmed when they attend STEM courses in college. As one study suggests engineering persistence rates are more motivated by the student's perception of their performance than their actual ability to handle their courses (Ohland, Sheppard, Lichtenstein, Eris, Chachra, & Layton , 2008). By providing students early access and building their confidence with their ability to handle STEM content in high school, Project Lead the Way sends more prepared students into the college end of the STEM pipeline.

### **Summary of the Evidence**

In summary, regarding preparing students for STEM coursework in college, some researchers have found PLTW students to have improved math and science achievement test scores, while some researchers have found the exact opposite. There is little doubt that students who electively choose to enroll in applied math and science coursework such as PLTW classes outperform their peers on academic assessments of math and science. What remains a mystery is if this performance is strengthened and improved due to PLTW courses. Using math and science achievement test data to measure the effectiveness of PLTW coursework is misleading at best. PLTW courses are delivered in a project-based learning setting. Classes are designed to engage students in creative

problem solving not rote memorization. A more appropriate measurement to evaluate the effectiveness of PLTW courses in advancing student knowledge would include more sensitive measures including higher order thinking skills, the acquisition and development of 21st Century Skillsets, and the ability to transfer information to novel situations due to levels of deeper learning.

Regarding increasing the STEM pipeline to college STEM majors the evidence is stronger. Regardless of control criteria or measurement instrument, every study reviewed in this literature review concludes that PLTW students are more likely to attend college than their peers and are more likely to enroll in STEM majors. Further, the evidence indicates that PLTW students' persistence rates in STEM majors exceeds those of their peers. Project Lead the Way students are a self selecting group that by enrolling in elective applied science and math coursework in high school illustrate a willingness to engage with rigorous math and science coursework and display a tendency to outscore their peers on math and science achievement tests. Further, by voluntarily enrolling in pre engineering coursework, these students are seemingly considering attending post-secondary education.

Unfortunately, it is possible that even though PLTW coursework is preparing students for, delivering students to, and encouraging persistence in postsecondary STEM majors, they may not be graduating at a higher rate. Studies show that the persistence rate of PLTW students is greater initially, but reverts to the mean over time (McCharen & High, 2010). Further, though the number of STEM graduates has risen in America over the past few decades, their proportion relative to all graduates has remained fixed (Congressional Research Service, 2008).



Perhaps the mixed results regarding the effectiveness of the Project Lead the Way initiative to improve science and math achievement is due to the testing instruments not being sufficiently sensitive to the multitude of factors that either help or hinder postsecondary student success. While mastering content knowledge is an important element of the cognitive domain, so too is problem solving, critical thinking, and creativity (William and Flora Hewlett Foundation, 2013). Further, those elements not researched may be of increasing value in today's changing world (Darling-Hammond, & Conley, 2015).

## CHAPTER III: CONCEPTUAL FRAMEWORK

### **Introduction**

Today's world is changing rapidly. Much of the change can be attributed to differences in how we access, communicate, and store information (Trilling, 2015). Today's teenager lives in a radically different world than his or her parents. Perhaps due to this, the American educational system has increased the number of reforms of its system, with mixed results (Wagner, 2015). Many researchers posit one way to improve our future educational system is to require students engage with concepts more deeply and develop 21st Century skillsets (Bellanca, 2015; Chow, 2015; Pellegrino, 2015). Deeper learning and 21st Century Skills prioritize knowledge application, critical thinking skills, collaboration and communication over memorizing facts and procedures (William and Flora Hewlett Foundation, 2013). Because Project Lead the Way coursework is developed with these principles in mind, deeper learning provides a useful conceptual framework to evaluate the effectiveness of Project Lead the Way equipping its students with 21<sup>st</sup> Century Skills.

### **Modern Learning**

The traditional American educational system, specifically the structure of teaching and learning, was designed to supply the American workforce of the past (Zhao, 2015; Fullan, 2015) when graduates filled mass production positions that don't exist in the same numbers today (DuFour, & DuFour, 2015). Characteristics of this traditional model are information transfer through instructor lecture and student note taking, memorization of rote facts, and the distribution and subsequent assignment of reading from a textbook. Further, the traditional system includes formative assessment of ability through

worksheets and multiple choice, fill in the blank, or constructed response quizzes.

Summative assessment comes at the end of chapters, the term, and the year and also includes multiple choice, fill in the blank, or constructed response questions. Students are silently indoctrinated into a system where they work primarily in isolation, are rewarded for following explicit directions, and believe there to be only one right answer. The current and future American workforce needs a different system that leads to different skill sets (DuFour & DuFour, 2015; Zhao, 2015; Wagner, 2015).

A fundamental way modern society differs from the past is the Internet and our changing interaction with information. Facts were once the exclusive property of libraries and teachers. Information retrieval was time-consuming which made memorization a time saving skill. Today's students need not prioritize the skill of memorization, anyone with a smartphone and a signal can access the world's information (Trilling, 2015). For the modern learner internal information warehousing is less important than the ability to productively use technology to find the latest information and apply it to novel situations (Fadel, 2015).

It isn't simply the way we retrieve information that is rapidly evolving. Today's learners will work in an environment of perpetually changing tools (Vander Ark, 2012). For nearly the first two centuries of America's history there was no such thing as a computer in the workforce. In the past sixty years computers have gone from machines the size of conference rooms to so small and inexpensive that most workers have their own personal devices. Computer software has evolved from internally written, to commercially produced, to nearly universally free. Data storage has evolved from magnetic tape, to floppy disks, to USB drives, to cloud storage.

This new frontier of burgeoning technological innovation and application must be considered when developing training and education for the workforce of tomorrow. In the 1800's a blacksmith could learn his trade from an expert, work in that trade for a lifetime and pass that same information to an apprentice. Conversely, there is no doubt that the future workforce doesn't have the luxury of learning all the procedures and processes they will need for a lifetime of work before they leave school (Schleicher, 2011). No longer is education about what you know, it is about how you use your knowledge. Therefore the American educational system should focus less on facts and procedures and more on teaching students how to problem solve (Wagner, 2015). The modern American worker needs to be a lifelong learner.

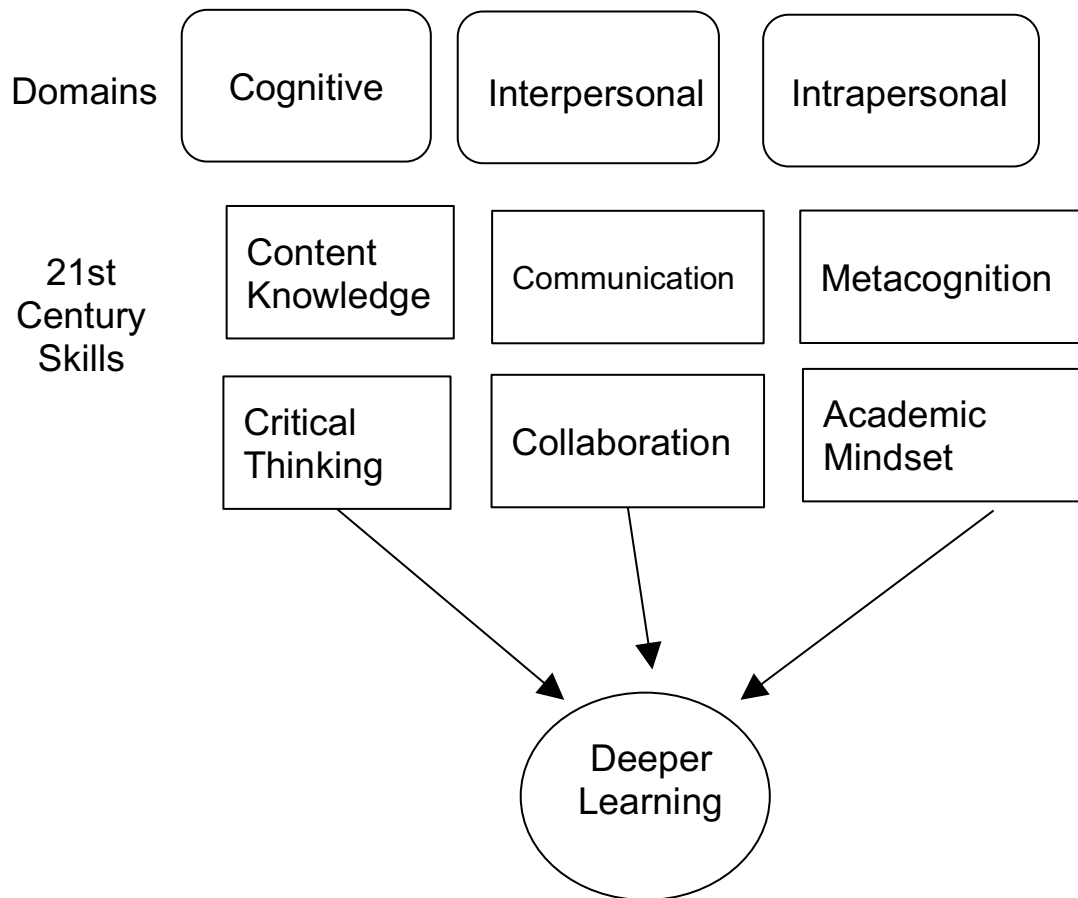
Further, American learners need to be able to do more than simply follow directions (Darling-Hammond, & Conley, 2015). The emergence of a global economy has allowed multinational corporations more varied choice of production workforce. America's high standard of living relative to other parts of the world precludes our workforce from being competitive economically in a mass production environment (Fadel, 2015). Further, ever cheaper computers and improved robotics have led to the American workforce losing jobs due to automation (Wagner, 2015). The modern American worker needs to be skilled beyond following directions and performing scripted tasks, needs to work with others productively, and needs to be capable of creative problem solving and effective communication and collaboration (Darling-Hammond, & Conley, 2015).

### **Deeper Learning and 21st Century Skills**

One way to more adequately meet the needs of the modern student is utilization of the deeper learning framework and 21st Century Skills in curriculum design. Deeper learning

challenges students to apply new information to varied situations (Pellegrino & Hilton, 2013). To do this, students draw on a variety of competencies spanning cognitive capacity, social skills, and psychological traits. Pellegrino and Hilton (2013) advance a definition of deeper learning outcomes that most scholars in this field accept. They argue that deeper learning and 21<sup>st</sup> century skills include cognitive, interpersonal, and intrapersonal domains (see Figure 1).

**Figure 1 – A Model for Deeper Learning and 21<sup>st</sup> Century Skills**



Pellegrino and Hilton (2013) define cognitive skills as cognitive processes and strategies, knowledge, and creativity. The American Institutes for Research adds to this

general definition by further distinguishing cognitive skills as student mastery of academic knowledge and development of critical thinking skills (Huberman, Bitter, Anthony, & O'Day, 2014). Mastery of academic knowledge is one traditional goal of education, understanding and recalling facts and procedures related to an academic area of study. To activate deeper learning, students should move beyond simple mastery of academic knowledge. Students should understand the principles of their academic knowledge and be able to apply that knowledge to situations not encountered previously (Schleicher, 2011). Critical thinking skills relate to the ability students have to view problems flexibly and formulate solutions. Students with excellent critical thinking skills have the ability to catalog their knowledge and apply it when posed with a novel problem. In this regard, knowledge transcends classification into subjects and becomes useful in all applications. 21st Century Skills from the cognitive domain can be developed in students more effectively through the liberal use of project-based learning, real world connections in instruction and problem solving, and assessments that go beyond recall of fact including projects, portfolios, and exhibitions (Darling-Hammond, & Conley, 2015).

Pellegrino and Hilton (2013) define the interpersonal domain as the skills of teamwork, collaboration, and leadership (Pellegrino & Hilton, 2013). Interpersonal skills relate to how effectively and efficiently students interact with others. The American Institutes for Research classify two broad skill sets into the interpersonal domain, communication and collaboration (Huberman, Bitter, Anthony, & O'Day, 2014). While these are very simple terms, both communication and collaboration consist of a number of competencies.

According to the American Institutes for Research (2014), communication is the ability to express oneself and to interpret the communications of others. Student communication skills include the ability to present information to others clearly in written and oral form. This includes formal presentations to a group or feedback to a peer, in addition to presenting one's own perspective in a conversation. Effective communication includes arranging written or spoken words and images in a manner that effectively represents the underlying thoughts and intentions.

According to the American Institutes for Research (2014), collaboration is teamwork. Collaboration includes the ability to be open minded and consider all perspectives in a situation, to cooperate to achieve a mutual goal, listen to others, generate and act on solutions collectively, and be responsible to a group. Each of these skills in the interpersonal domain can be addressed and developed more effectively and efficiently in instruction using group work.

Pellegrino and Hilton define the intrapersonal domain of 21st Century Skills as skills that involve internal disposition including intellectual openness, work ethic and conscientiousness, and positive core self-evaluation (Pellegrino & Hilton, 2013). The American Institutes for Research categorize intrapersonal 21st Century Skills into two broad categories metacognition and academic mindset (Huberman, Bitter, Anthony, & O'Day, 2014).

Metacognition is frequently labeled "learning to learn" (Trilling, 2015). While this is accurate, it is vague. According to the American Institutes for Research (2014), metacognition involves the processes a learner engages with while assessing and making decisions regarding learning. This includes evaluating the depth of learning and making

adjustments if needed to deepen understanding, being aware of personal strengths and weaknesses, using failures as evidence regarding strategies to adjust, and being personally responsible for their own learning.

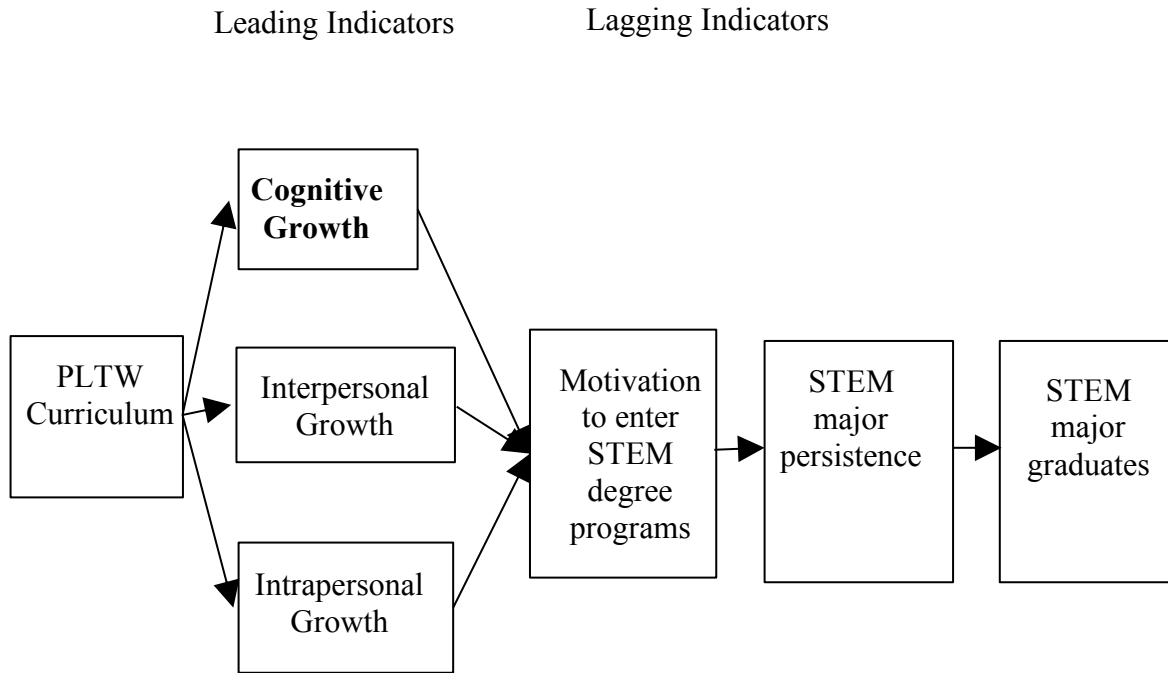
According to the American Institutes for Research (2014), academic mindset includes internal perceptions that influence success and failure academically. These include self-confidence in learning environments, level of engagement with learning, internal motivations, intellectual curiosity, valuation of the worth of intellectual pursuits, etc. Both metacognition and academic mindset skills can be more effectively and efficiently developed by allowing students more freedom in academic pursuits through collective group decision making regarding content and/or individualized learning opportunities.

### **Theory of Action for Project Lead the Way**

Project Lead the Way's stated goal is to inspire more high school students to select, persist, and ultimately graduate college STEM degree program. Left unstated, but undeniable when the curriculum is scrutinized, is the desire to accomplish this goal by activating deeper learning and improving Project Lead the Way students' 21st Century skill set. I propose that as seen in Figure 2 Project Lead the Way seeks to achieve the aforementioned goals of increasing student motivation to enter, persist, and complete STEM major degree programs by fostering improved 21st Century skillsets through a deeper learning experience. These 21st Century skillsets include cognitive, interpersonal, and intrapersonal skills.



**Figure 2 – Theory of Action**



Project Lead the Way curriculum activates deeper learning of STEM concepts in students. The primary means for achieving this is the project-based nature of the coursework. According to Project Lead the Way, direct instruction constitutes approximately one third of class time. The other two thirds is spent engaging engineering problems and projects. For example, in one of the early PLTW courses students are taught free body diagrams. This begins with a brief lecture reviewing forces, vectors, and resolution of vectors into components leveraging trigonometry skills. After some guided practice students are given multiple class periods to design and build the strongest balsa wood truss they are able to. The open ended nature of class projects similar to these require students to apply the knowledge gained through instruction in unique and varying ways. Using Webb’s Depth of Knowledge scheme, these activities are classified as levels three and four meeting the definition of deeper learning.

In addition, Project Lead the Way curriculum is positioned to activate and improve student's 21st Century cognitive skills. Cognitive skills include mastery of academic content and critical thinking skills. As mentioned previously, mastery of academic content in the deeper learning framework means more than simply memorizing facts or committing procedures to short term memory. Instead, deeper learning requires students to apply their knowledge in novel situations. Critical thinking skills are activated when students are asked to view problems flexibly and are required to formulate solutions. Project Lead the Way's course structures overwhelmingly emphasize application and critical thinking over traditional lecture, allowing for two-thirds of class time to be hands-on student projects or problem solving.

Project Lead the Way's curriculum is delivered in a way that develops student's interpersonal skills. Interpersonal skills are defined as communication and collaboration. Collaboration in the form of group work is a requirement of most Project Lead the Way work. Project Lead the Way students are routinely asked to cooperate with and be responsible to fellow students. Another feature of successful group work is effective communication amongst members of the group, though Project Lead the Way course work promotes the use and improvement of student's communication skills in two other ways. First, every Project Lead the Way student is required to maintain an engineering journal, documenting their project experiences. Second, most projects in Project Lead the Way classes culminate in the development and deployment of a class presentation. This presence of persistent group work, engineering journals, and class presentations, makes a strong case that Project Lead the Way courses develop students interpersonal skills.

Though more difficult to quantify, it is believed that Project Lead the Way courses activate and develop individual students' intrapersonal skills. Intrapersonal skills are categorized into metacognition and academic mindset. Giving students and groups of students autonomy to direct the majority of their class time to work on an open ended project or problem brings these skills to the forefront.

Project Lead the Way courses are structured to access and improve deeper learning of STEM concepts and 21st Century Skills in students. Because of this, I stipulate that students who have participated in Project Lead the Way coursework will exhibit more advanced 21st Century Skills than a fair peer group that has not participated in Project Lead the Way courses. Deeper learning and 21st Century Skills have been presented previously in this paper as one method of modernizing our educational system. Acquiring or developing these skills should also improve student performance in difficult STEM degree programs. The proposed research will specifically investigate the degree to which Project Lead the Way coursework strengthens student problem solving skill and creativity.

Therefore, the following hypotheses are advanced.

H1 - Students exposed to Project Lead the Way coursework will demonstrate higher levels of problem solving and critical thinking than comparable non Project Lead the Way peers.

H2 - Students exposed to Project Lead the Way coursework will demonstrate higher levels of creativity than comparable non Project Lead the Way peers.

## CHAPTER IV: RESEARCH METHODS

### **Introduction**

This study was conducted with the administrative data of high school students who attend a medium sized technology center in Oklahoma. The study investigated whether students who had been exposed to Project Lead the Way coursework demonstrated higher levels of certain 21<sup>st</sup> Century Skills (problem solving and creativity) than peers who were not in Project Lead the Way courses.

### **General Description of the Design**

This study was of a simple ex post facto design that compared group means. The exposure to Project Lead the Way curriculum was not a consequence of the study or controlled by the researcher. Therefore, from a research perspective, the study tested the possible effects of an experience rather than a treatment (Leedy & Ormrod, 2005). This is consistent with existing literature regarding the possible effects of exposure to Project Lead the Way coursework. Limitations with the research design can be described in terms of two types of validity, internal and external. Internal validity refers to the accuracy of conclusions about the primary relationship in the study. For this study, internal validity considerations address factors or conditions that may confound the relationship between exposure to PLTW and problem solving and creativity. Project Lead the Way students and non-Project Lead the Way students are self-selecting groups. In the absence of random assignment, there may exist differences in the two groups that are not explained by the curriculum they choose to engage with. Further, due to the ex post facto design structure, the most we can conclude from the research is that certain characteristics are more strongly associated with the different groups and experiences, not that the

characteristics are caused by the experience itself. Future studies should consider testing Project Lead the Way students using a pre and post treatment design. Regarding external validity, the Project Lead the Way curriculum and teacher training program is highly structured. This suggests that all students regardless of location will be given mostly similar experiences as it relates to curriculum and instruction. This standardization suggests a possible level of external generalizability to other Project Lead the Way programs.

### **Population and Sample**

The data used in this study was collected as part of the school's student satisfaction survey procedure. Participants in this research were high school students who attend a medium sized technology center in Oklahoma. This technology center provides service to students from each high school in a three county area. The technology center is located in a medium sized Oklahoma city. Morning students come exclusively from smaller rural high schools and afternoon students come exclusively from the more urban medium sized city in which the technology center is physically located. These students elect to spend half of their school day away from their home high school to attend this technology center. There are a variety of programs available to students. These programs span a range of purposes from training students for traditional vocational trades to preparing students for college. Six programs prepare high school students for college exclusively including two Project Lead the Way disciplines, pre-engineering and bio-medical sciences. Each of the college preparatory programs delivers STEM curriculum. The administrative data from these STEM based college preparatory program students was

used for this study. In total 62 students participated in the study. Of those 37 were Project Lead the Way students and 24 were not.

For two primary reasons, the sample used in this study should be considered generalizable. As discussed earlier, the rigid framework of the Project Lead the Way curriculum and the formal teacher training that every Project Lead the Way teacher completes suggests that experiences in a single Project Lead the Way classroom may be representative of the experiences Project Lead the Way students experience elsewhere. Further, all of the students analyzed in this study self-selected into an elective college bound program of STEM related study at the technology center they attended. This selection criteria purposely matches these groups to avoid some of the group differences that would be inherent if comparing Project Lead the Way students to all non-Project Lead the Way Students. This suggests that differences in student problem solving and creativity skill may be a result of the Project Lead the Way curriculum itself, since all participants engage in elective STEM coursework.

### **Procedure**

This study measured student problem-solving or critical thinking skill with the use of the Cognitive Reflection Test advanced by Kahneman and colleagues (Kahneman, 2011; Morewedge & Kahneman, 2010) and expanded by Toplak, West, and Stanovich (Toplak, West, & Stanovich, 2014). The Cognitive Reflection Test measures a person's tendency toward one of two thinking dispositions, System One or System Two. Kahneman characterizes System One thinking as reactive, intuitive, and quick. Systems Two thinking is analytical, logical, and reasoned. While System One thinking is intuitive and necessary for human survival, an individual's ability to recognize more complex

situations and switch from intuitive System One thinking to more logical and reasoned System Two thinking is a desired trait for problem solving and critical thinking. For the purpose of this study the exhibition of Systems Two thinking on the Cognitive Reflection Test will be considered the more mature from a critical thinking or problem solving perspective.

The Cognitive Reflection Test has been validated to measure critical thinking in addition to several other desirable qualities. Frederick proposes the test measures “the ability or disposition to resist reporting the response that first comes to mind” (Frederick, 2005). Not surprisingly, this quality of reasoned analysis in individuals correlates positively with other desirable measures. Frederick was able to positively correlate performance on the Cognitive Reflection Test with performance on specific cognitive measures, including the Wonderlic Personality Test, the Need for Cognition scale, and college entrance exam scores including the SAT and the ACT. Further, Frederick found that on average students at more selective universities perform better on the Cognitive Reflection Test than their peers at less selective institutions of higher learning. Finally, Frederick positively correlated performance on the Cognitive Reflection Test with performance on patience and risk preference tasks. Building on the work of Kahneman and Frederick, Toplak, West, and Stanovich more recently expanded the battery of questions in the Cognitive Reflection Test and established positive correlations with fifteen tests of intelligence and executive function while finding the expanded test reliable with a Cronbach’s alpha of 0.72 (Toplak, West, & Stanovich, 2011; Toplak, West, & Stanovich, 2014). In fact, Toplak, West and Stanovich, concluded that the

Cognitive Reflection Test is a better indicator of rational thinking than any of the tests of intelligence and executive function explored.

This study measures creativity in students through use of the Remote Associates Test first posited by Mednick (Mednick, 1968). Creativity is defined by Mednick as the “forming of associative elements into new combinations which either meet specified requirements or are in some way useful” (Mednick, 1968). This test requires subjects to generate the word that connects three other given words together. The specific test given was a battery of thirty Remote Associate Test questions that were a subset of the item bank developed and tested by Bowden and Jung-Beeman (Bowden & Jung-Beeman, 2003) and subsequently tested and validated by a more recent study (Lee, Huggins, & Therriault, 2014).

The Remote Associates Test was designed by Mednick as “an operational statement of the definition [of creativity] in the form of a test” (Mednick, 1968). It is common for more modern treatments of the construct of creativity to differentiate between convergent and divergent thinking (Brophy, 2000). The Remote Associates test differs from many other creativity tests because it measures convergent thinking. This has led some to question whether the Remote Associates test measures creativity or if it measures intelligence more broadly (Laughlin, Doherty, & Dunn, 1968; Taft & Rossiter, 1966). Though questions persist, recent research has suggested that the Remote Associates test is both internally and externally valid and reliable with a reported Cronbach alpha of .82. This research also suggests that the Remote Associates Test is indeed a measure of convergent thinking processes in creativity (Lee, Huggins, & Therriault, 2014).



This data was collected early in the Spring semester so students that participated had either half or one and a half years of experience in their programs. Students were asked to report to a remote location on campus for administration. After directions were read, students were given a three-page packet of questions and asked to complete. The first page was divided into two parts, general information and a three-question implicit theory of intelligence test (Dweck, Chiu, & Hong, 1995) to measure levels of growth mindset in subjects. The second page contained the expanded seven question Cognitive Reflection Test. The third page contained the thirty-question battery of Remote Associate triplets. Students were allowed to work at their own pace but under a thirty-minute deadline to complete all tasks.

Participant responses were scored by hand. A separate person scored the tests a second time and inconsistencies were resolved to ensure accuracy. The classifications and scores for each student were then entered into statistical analysis software. Each participant was coded based on age, gender, political affiliation, program, morning or afternoon student, PLTW membership, implicit theory of intelligence score, Cognitive Reflection test score, and Remote Associates Test score.

The three-question implicit theory of intelligence test was scored as prescribed by the authors who presented it (Dweck, Chiu, & Hong, 1995). Scores were assigned to each question based on where the respondent indicated their judgement on the six point Likert scale provided. The higher the score, the more the respondent tends towards the incremental theory of intelligence and the lower the score the more the respondent tends towards the entity theory of intelligence. For example, a student who responded Strongly Agree to the statement “You have a certain amount of intelligence and you really can’t do

much to change it.” was assigned a one for that question, while a student who responded Strongly Disagree to the same statement was assigned a six. Each step in the Likert scale response of the student was scored as one point greater than the previous possible response. The student’s total implicit theory of intelligence score was the average of their responses on the three questions ranging from a minimum of one to a maximum of six. The Cognitive Reflection test and the Remote Associates Test were easier to score as each of the questions had a correct response. Students were given a score based on how many Cognitive Reflection test questions they responded correctly to (range from zero to seven) and how many Remote Associates Test questions they responded correctly to (range from zero to thirty).

### **Analytical Technique**

The analysis of this study compared two separate group mean scores, namely those for Project Lead the Way and non-Project Lead the Way students, on the Cognitive Reflection Test and the Remote Associates Test. It was not immediately clear which analytical technique would be appropriate for the analysis. This was due to the possibility of confounding factors in the groups, other than group membership, that might contribute significantly to differences in performance on the tests administered.

Because of the possibility of confounding factors, gender, age, political affiliation, and growth mindset, were tested to determine whether they contributed significantly to differences in scores on the two tests administered. In the case of gender, an independent samples t-test was conducted to establish significance in gender differences between the two groups. In the other cases, because the variable did not exhibit a binary classification, one way between-subjects analysis of variance or a bivariate Pearson correlation was

used to quantify the relationships between the possible confounding variables and scores on one or both tests administered, as necessary. The final analysis comparing the scores of Project Lead the Way and non-Project Lead the Way student scores on the two tests administered was performed by one way between-subject analysis of variance.

### **Limitations**

This study did suffer from limitations. One limitation of the study was its design. This study was of a simple ex post facto design that compared group means. The exposure to Project Lead the Way curriculum was not a consequence of the study or controlled by the researcher. Therefore, from a research perspective, the study tested the possible effects of an experience rather than a treatment (Leedy & Ormrod, 2005). Future studies might account for this by testing students pre and post Project Lead the Way exposure. Another limitation of the study is the possibility of selection bias in the sample. Students were not randomly assigned Project Lead the Way coursework, instead they opted in. There may exist differences in the characteristics of students who voluntarily choose to engage with elective math and science curriculum and see themselves as potential candidates for post secondary engineering coursework and careers. Attempts were made in the study to mitigate some of these limitations. Specifically, the study did control for student differences that may have been related to the outcome variables and student sample groups were restricted to programs whose primary mission is to prepare students for college coursework. Even though attempts were made to control for characteristics outside of Project Lead the Way membership that may contribute to group differences in performance on the Cognitive Reflection Test, there are many other confounding variables that were not controlled for.

## CHAPTER V: RESULTS

### **Introduction**

This study was conducted to determine whether student interaction with a curriculum that emphasized deeper learning and the acquisition of 21<sup>st</sup> Century skillsets fostered increased problem solving skill and creative thinking. To validate that differences in the results of the tests were potentially due to differences in group membership, the study investigated the possible existence of confounding variables. Confounding factors analyzed as potentially contributing to differences in group means included gender, age, political affiliation, and growth mindset attenuation. After finding no evidence that confounding variables played a statistically significant factor in test results for either the Cognitive Reflection Test or the Remote Associates Test the decision to not control for any confounding variable was made. After eliminating the need to control for confounding factors, differences in group means regarding performance on the Cognitive Reflection Test and the Remote Associates Tests between Project Lead the Way and non-Project Lead the Way students were compared. For both the Cognitive Reflection Test and the Remote Associates Test, Project Lead the Way students were found to perform significantly better than their non-Project Lead the Way peers.

### **Confounding Variables**

The first step in analysis was to establish whether or not either Cognitive Reflection test scores or Remote Associates Test scores differed significantly based on any of the criterion identified prior to and collected during testing. The purpose of this analysis was to establish whether controls needed to be considered via ANCOVA analysis when

comparing mean scores of the two tests based on Project Lead the Way membership, the ultimate goal of the study.

Differences in Cognitive Reflection and Remote Associates test scores by gender were analyzed first. Descriptive statistics and score distributions by gender as box and whisker plots are presented in Table 1 and Figures 3 and 4. For both the Cognitive Reflection Test (CRT) and the Remote Associates Test (RAT) 23 female and 39 male subjects completed the test. While the median score by gender was exactly the same for each test on average male students performed slightly better on the Cognitive Reflection Test and female students performed slightly better on the Remote Associates Test.

*Table 1 – Cognitive Reflection Test and Remote Associates Test descriptive statistics by gender*

Test	Gender	N	Mean	Median	Std. Deviation
CRT	Female	23	1.6957	2.0000	1.57926
	Male	39	2.5641	2.0000	2.01043
RAT	Female	23	21.3913	21.0000	4.44910
	Male	39	20.2308	21.0000	2.01043

Figures 3 and 4 present box-and-whisker plots of the score distribution on the two tests by gender. As evidenced in Table 1, the two groups medians were the same for both tests. Further, both group’s minimums were the same for both tests. For the Cognitive Reflection Test, male scores had a larger range and maximum than female scores. The opposite is true on the Remote Associates Test as female scores had a larger range and maximum than male scores.

Figure 3 – Cognitive Reflection Test Score Distribution by Gender

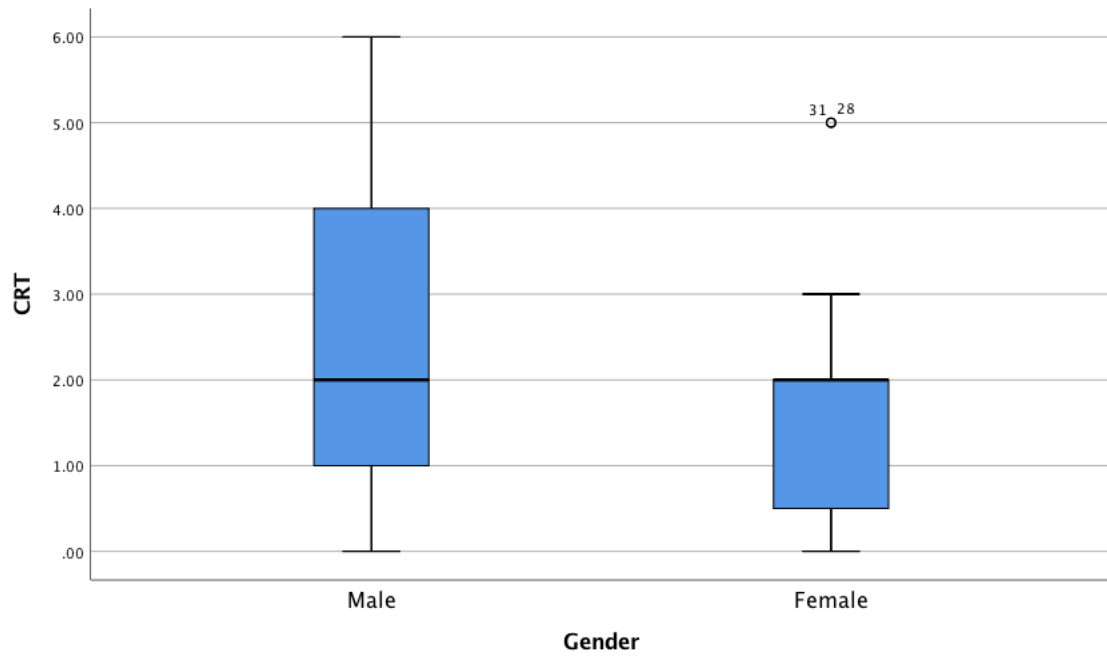
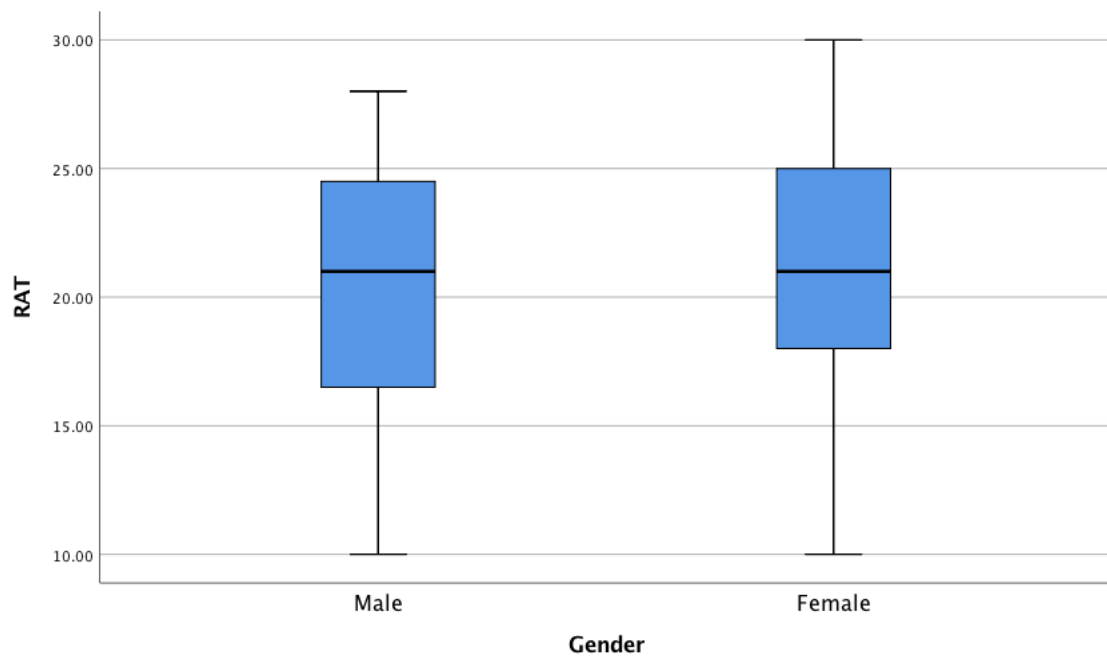


Figure 4 – Remote Associates Test Score Distribution by Gender



Because gender in this study was treated as a binary categorical variable, means were compared using the independent samples t-test. The results of that test are presented in Table 2. For the Cognitive Reflection Test (noted as 1 in Table 2), assuming equal

variance yielded a t-statistic of 1.772, 60 degrees of freedom, and a p-value of .081. Because a significance of .081 is greater than .05, it was determined that differences in group means were not statistically significant. For the Remote Associates Test (noted as 2 in Table 2), assuming equal variances yielded a t-statistic of -.925, 60 degrees of freedom, and a p-value of .359. Once again, because a significance of .359 exceeds .05, group differences were shown to not be statistically significant. Therefore, gender differences did not significantly contribute to either Cognitive Reflection or Remote Associates Test scores and was not included in controls for analysis of differences of mean between Project Lead the Way and non-Project Lead the Way scoring.

*Table 2 – Independent Samples t-test of Scores by Gender*

		LTEV		t-test for Equality of Means					95% CI	
		F	Sig	t	df	Sig	Mean D	SE D	Lower	Upper
1	EVA	5.097	.028	1.772	60	.081	.868	.490	-.111	1.848
	EVNA			1.886	55.041	.065	.868	.460	-.054	1.791
2	EVA	.606	.439	-.925	60	.359	-1.160	1.254	-3.670	1.349
	EVNA			-.951	50.316	.346	-1.160	1.220	-3.610	1.289

*Note: \* implies significance at the p < .05 level.*

*EVA = Equal Variances Assumed*

*EVNA = Equal Variances Not Assumed*

*LTEV = Levene's Test for Equality of Variances*

*CI = Confidence Interval*

*1 = Cognitive Reflection Test*

*2 = Remote Associates Test*

Next, analysis was conducted to determine if age made a significant difference in Cognitive Reflection and Remote Associates test scores. Students who participated in the testing ranged in age from fifteen to nineteen, with at least one subject of each age.

Descriptive statistics and score distribution for both the Cognitive Reflection and Remote Associates Test are presented in Table 3 and Figures 5 and 6. As is shown in Table 3, each age from fifteen to nineteen was represented in the study. For every age with at least three members, means and medians for both tests were similar. Figures 5 and 6 show that though medians remained mostly stable as age increased in both the Cognitive Reflection Test and the Remote Associates test ranges and maximums tended to increase as age increased.

*Table 3 – Cognitive Reflection Test and Remote Associates Test Descriptive Statistics by Age*

Test	Age	N	Mean	Median	Std. Deviation
CRT	15	2	1.5000	1.5000	.70711
	16	20	2.1500	2.0000	1.81442
	17	28	2.4286	2.0000	2.00792
	18	9	2.0000	2.0000	2.06155
	19	1	5.0000	5.0000	NA
RAT	15	2	21.5000	21.5000	4.94975
	16	20	20.3500	20.5000	4.02982
	17	28	21.0000	21.5000	4.58661
	18	9	22.0000	23.0000	5.19615
	19	1	10.0000	10.0000	NA



Figure 5 – Cognitive Reflection Test Score Distribution by Age

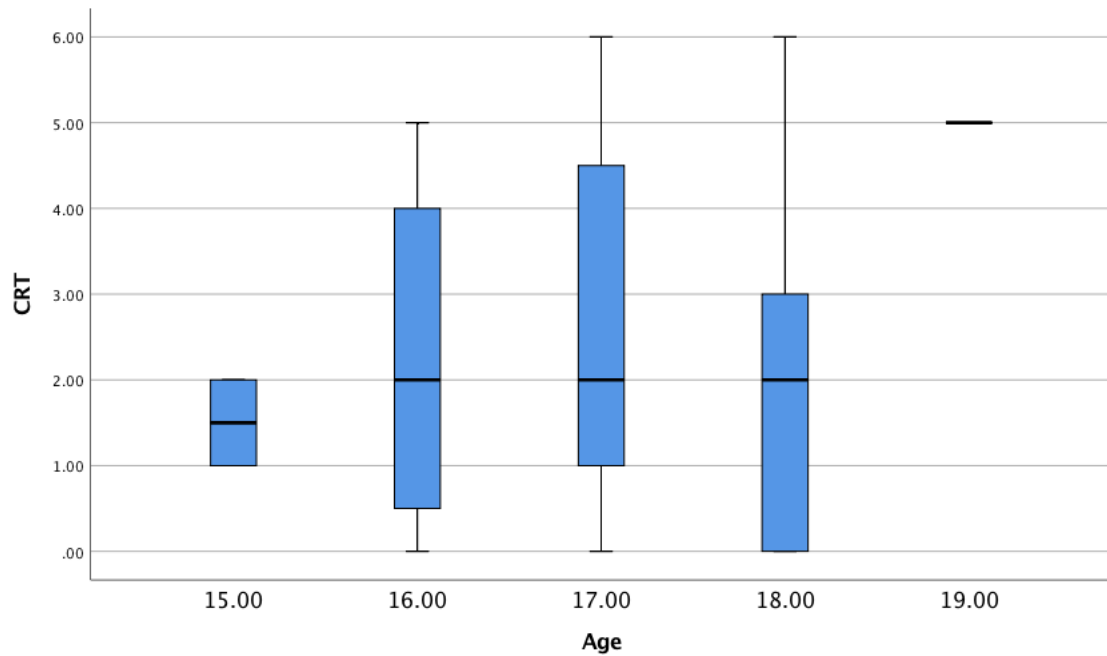
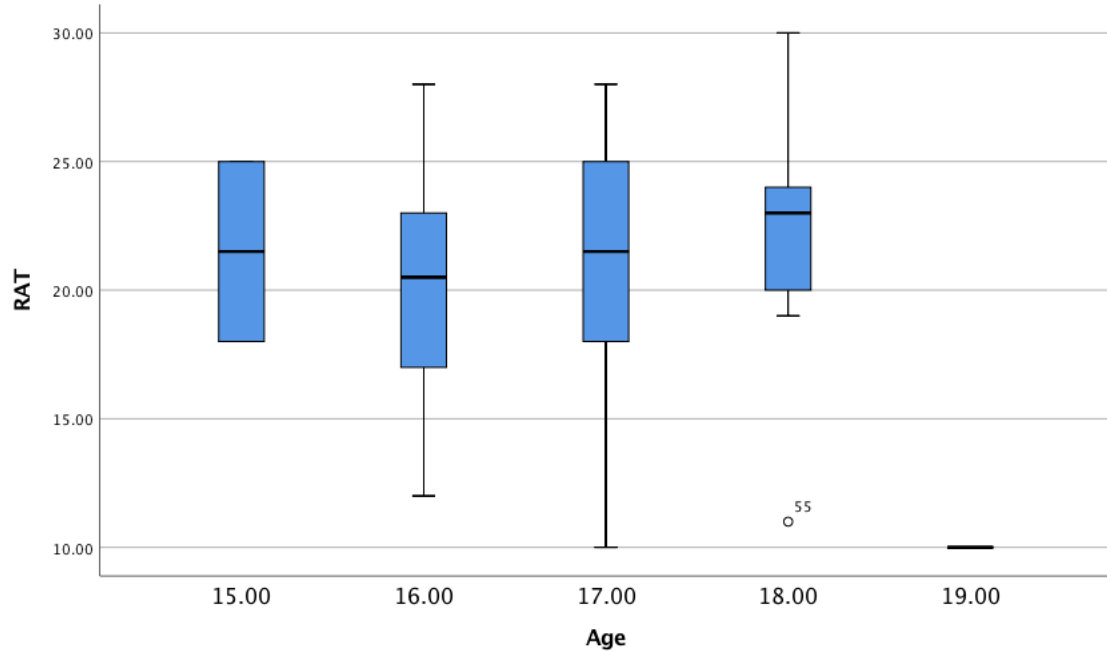


Figure 6 – Remote Associates Test Score Distribution by Age



Because of the existence of five distinct categorical classifications, analysis was performed by applying a one-way ANOVA test. Differences in means classified by age

are reported in Tables 4 and 5. In both cases the degrees of freedom were 4 between groups and 55 within groups. For the Cognitive Reflection Test the F statistic was .686 and the p-value .605. For the Remote Associates Test the F statistic was 1.670 and the p-value .170. Because both test's p-values exceeded the .05 threshold for significance it was determined that age did not play a statistically significant role in differences of means. Therefore, age was not used as a control when comparing Project Lead the Way student's scores on these two tests with non Project Lead the Way students.

*Table 4 – ANOVA analysis of Cognitive Reflection Test Scores by Age*

	df	F	Mean Square	Sig.
Between Groups	4	.686	2.569	.605
Within Groups	55		3.744	
Total	59			
<i>Note: * implies significance at the p &lt; .05 level.</i>				

*Table 5 – ANOVA analysis of Remote Associates Test Scores by Age*

	df	F	Mean Square	Sig.
Between Groups	4	1.670	33.921	.170
Within Groups	55		20.310	
Total	59			
<i>Note: * implies significance at the p &lt; .05 level.</i>				

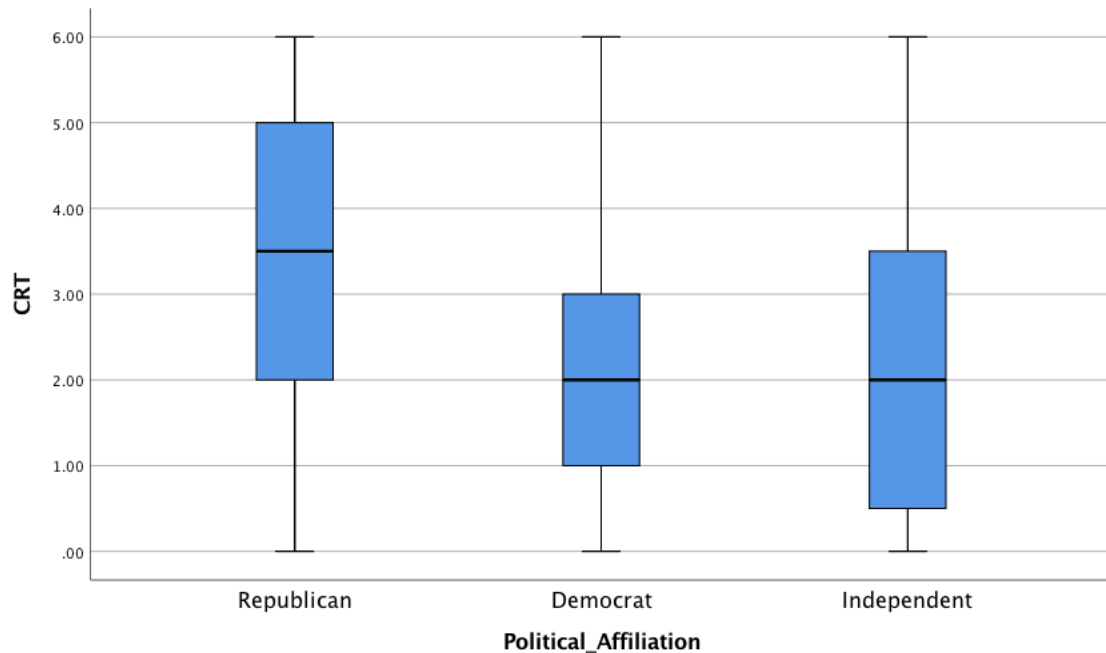
Analysis was conducted to determine if differences in Cognitive Reflection test scores differed significantly due to political affiliation as has been shown to exist in past research (Deppe et al., 2015). Participants were asked to classify their political affiliation

as either Republican, Democrat, or Independent. Descriptive statistics and distribution of scores by political affiliation for the Cognitive Reflection Test is presented in Table 6 and Figure 7 below. Self-identified Republican subjects performed better than their Democrat and Independent peers in regards to mean and median. All three groups exhibited identical ranges, maximums, and minimums on the Cognitive Reflection Test.

*Table 6 – Cognitive Reflection Test Descriptive Statistics by Political Affiliation*

Test	Political Affiliation	N	Mean	Median	Std. Deviation
CRT	Democrat	5	2.4000	2.0000	2.30217
	Independent	24	2.0417	2.0000	1.87615
	Republican	20	3.1500	3.5000	1.98083

*Figure 7 – Cognitive Reflection Test Score Distribution by Political Affiliation*



A one-way ANOVA test with multiple comparisons was used to compare group means. The results of that analysis are presented in Table 7. As discussed previously,

Republican subjects outperformed both Democrat and Independent subjects. Between Democrat and Independent subjects, Democrats outperformed their Independent peers. In each case, significance was found to be either 1.000 or .205. Because none of the tests resulted in significances less than the .05 threshold, it was determined that differences in group means on the Cognitive Reflection Test were not significantly influenced by political affiliation. Due to this, the final analysis of differences in mean scores on the Cognitive Reflection test did not include controls for political affiliation.

*Table 7 – ANOVA Analysis of Difference in Cognitive Reflection Test Scores by Political Affiliation*

I	J	Mean Difference (I – J)	Std. Error	Sig.	Lower	Upper
Republican	Democrat	.75000	.97999	1.000	-1.685	3.185
	Independent	1.10833	.59341	.205	-.366	2.582
Democrat	Republican	-.75000	.97999	1.000	-3.185	1.685
	Independent	.35833	.96351	1.000	-2.035	2.752
Independent	Republican	-1.10833	.59341	.205	-2.582	.366
	Democrat	-.35833	.96351	1.000	-2.752	2.035
<i>Note: * implies significance at the p &lt; .05 level.</i>						

The final analysis conducted prior to comparing means between Project Lead the Way and non-Project Lead the Way students was to correlate student scores on the implicit theory of intelligence, or growth mindset, test with their scores on the Cognitive Reflection Test as prior research points to the possibility of a strong correlation between

both and academic achievement (Dweck, 2006; Frederick, 2005). A Bivariate Pearson Correlation was conducted based on the properties of the variables. Results are reported in Table 8. The calculated p-value between a growth mindset and performance on the Cognitive Reflection Test was .711. Because this p-value was not less than the .05 threshold for significance it was determined that growth mindset did not have a statistically significant effect on Cognitive Reflection Test scores. Because of this, the choice was made not to control for growth mindset when analyzing group differences between Project Lead the Way and non-Project Lead the Way student scores on the Cognitive Reflection Test.

*Table 8 – Bivariate Pearson Correlation between Growth Mindset Index and Cognitive Reflection Test Scores*

		Growth	CRT
Growth	Pearson Correlation	1	.048
	Sig. (2-tailed)		.711
	N	62	62
CRT	Pearson Correlation	.048	1
	Sig. (2-tailed)	.711	
	N	62	62
<i>Note: * implies significance at the p &lt; .05 level.</i>			

**Analysis of Differences in Problem Solving and Creativity Testing by Project Lead  
the Way Membership**

The final analysis conducted was to compare Project Lead the Way student scores on the Cognitive Reflection and Remote Associates Test with non – Project Lead the way students. Descriptive statistics and a distribution of scores based on Project Lead the Way membership is provided in Table 9 and Figures 8 and 9. Thirty-seven subjects were members of Project Lead the Way programs. Twenty-five subjects were not members of Project Lead the Way programs. For both the Cognitive Reflection Test and the Remote Associates Test Project Lead the Way students outperformed their non Project Lead the Way peers in regards to mean and median scores. On the Cognitive Reflection Test, Project Lead the Way students demonstrated a greater range of scores, a higher maximum score, and a concentration of scores at higher levels than their non Project Lead the Way peers. On the Remote Associates test, Project Lead the Way students demonstrated a greater minimum score, a greater maximum score, and a concentration of scores that exceeded their non Project Lead the Way peers.

*Table 9 – Cognitive Reflection Test and Remote Associates Test Descriptive Statistics by Project Lead the Way Membership*

Test	PLTW Membership	N	Mean	Median	Std. Deviation
CRT	Yes	37	2.6757	2.0000	1.91564
	No	25	1.6000	1.0000	1.70783
RAT	Yes	37	22.3514	23.0000	3.93853
	No	25	18.1600	18.0000	4.85352

Figure 8 – Cognitive Reflection Test Score Distribution by Project Lead the Way Membership

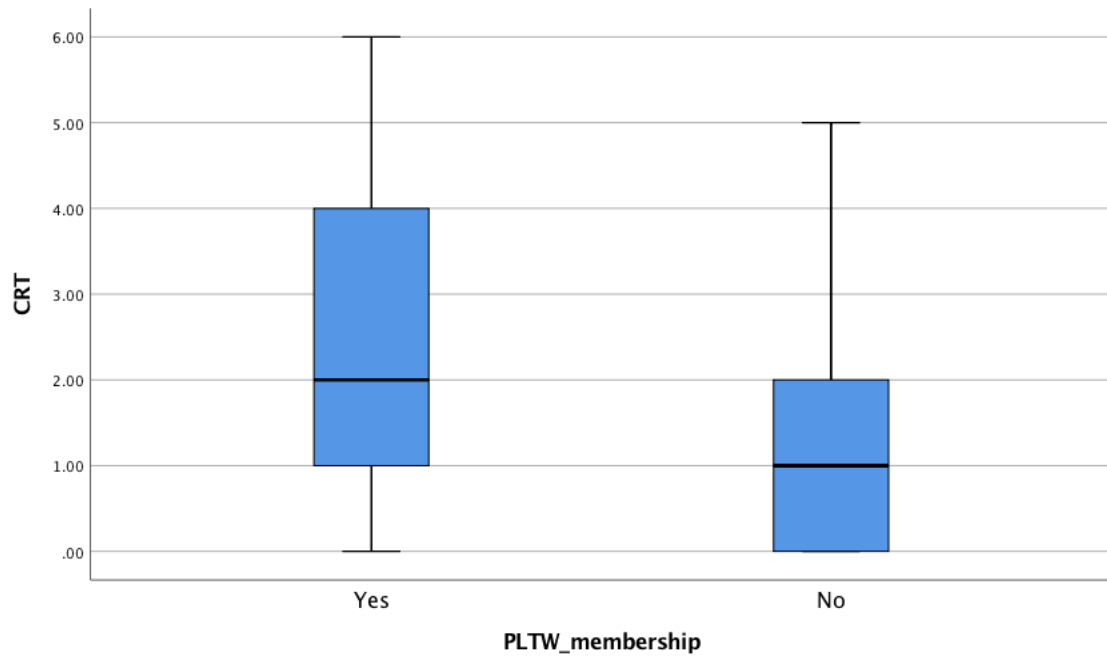
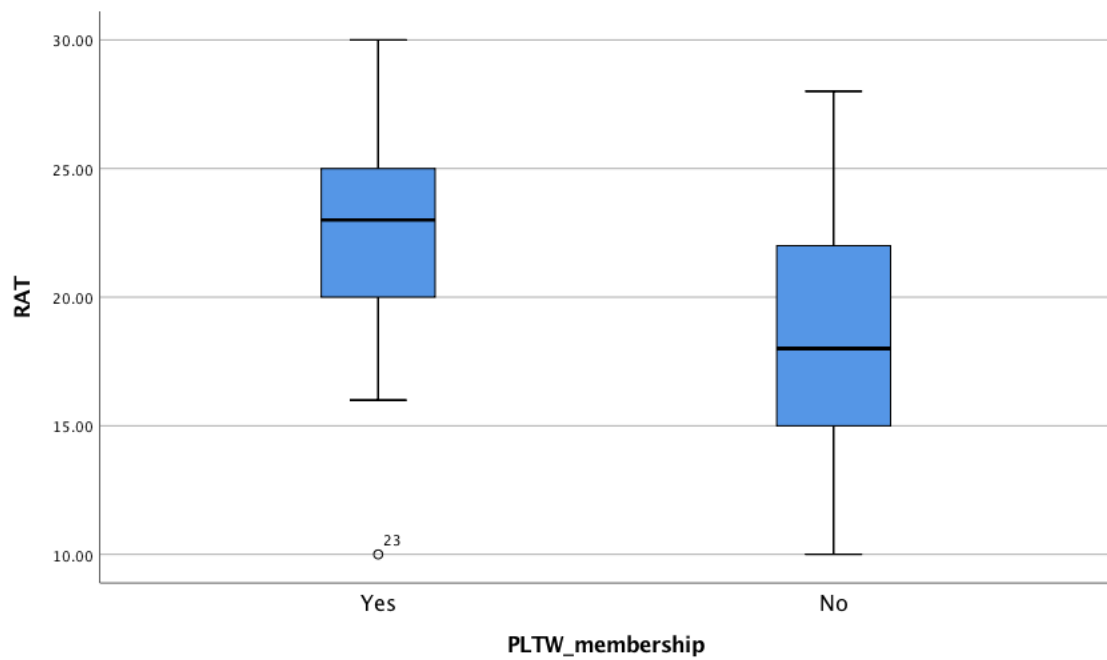


Figure 9 – Remote Associates Test Score Distribution by Project Lead the Way Membership



Because no statistically significant differences existed in Cognitive Reflection Test and Remote Associates Test scores by student characteristics, analysis was conducted through the utilization of an independent samples t-test. Results are reported in Table 10. For the Cognitive Reflection Test, Levene's Test for Equality of Variances provided an F-Statistic of 1.119 which was not found to be significant. Assuming equal variance, analysis of differences in group means produced 60 degrees of freedom, a t-statistic of 2.264, and a p-value of .027. Because this p-value is less than .05 the conclusion was that Project Lead the Way students outperformed their non Project Lead the Way peers by a statistically significant margin. Regarding the Remote Associates Test, Levene's Test for Equality of Variance provided an F-statistic of 1.405 which was not found to be significant. Assuming equal variances, analysis of differences in group means produced 60 degrees of freedom, a t-statistic of 3.741, and a p-value of .000. Because this p-value is less than .05 the conclusion was that Project Lead the Way students outperformed their non Project Lead the Way peers by a statistically significant margin on the Remote Associates Test.



*Table 10 – Project Lead the Way Student Scores Compared to Non Project Lead the Way Student Scores on the Cognitive Reflection and Remote Associates Test*

		LTEV		t-test for Equality of Means					95% CI	
		F	Sig	t	df	Sig	Mean D	SE D	Lower	Upper
1	EVA	1.119	.294	2.264*	60	.027	1.075	.475	.125	2.026
	EVNA			2.315*	55.440	.024	1.075	.464	.144	2.006
2	EVA	1.405	.241	3.741*	60	.000	4.191	1.120	1.950	6.432
	EVNA			3.592*	44.266	.001	4.191	1.166	1.840	6.542

*Note: \* implies significance at the p < .05 level.*

*EVA = Equal Variances Assumed*

*EVNA = Equal Variances Not Assumed*

*LTEV = Levene's Test for Equality of Variances*

*CI = Confidence Interval*

*1 = Cognitive Reflection Test*

*2 = Remote Associates Test*

### **Summary of Findings**

The purpose of this research was to ascertain whether students exposed to Project Lead the Way coursework demonstrated higher levels of problem solving, critical thinking, and creativity when compared to non Project Lead the Way students. Possible confounding variables were assessed to determine if they had statistically significant effect on the tests used to measure problem solving, critical thinking, and creativity. These confounding factors included age, gender, political affiliation, and growth mindset attenuation. In each case, these potentially confounding variables were found to not influence performance on the problem solving, critical thinking, and creativity test in a statistically significant way. After addressing these potential concerns, Project Lead the Way student performance on the selected tests was compared to their non Project Lead

the Way peers. As was hypothesized Project Lead the Way students outperformed their non Project Lead the Way peers by a statistically margin on both the Cognitive Reflection Test and the Remote Associates Test.

## CHAPTER VI: DISCUSSION

### **Introduction**

Substantial public and private resources have and continue to be allocated to initiatives designed to address the American STEM gap (Congressional Research Service, 2008; Sanders, 2008). Many of those resources are focused on K-12 interventions (Congressional Research Service, 2012). The largest such K-12 STEM intervention is Project Lead the Way (Douglas, Iverson, & Kalyandurg, 2004). Project Lead the Way curriculum is comparable to most K-12 initiatives, building curriculum to involve participants in project-based, hands-on, collaborative problem solving. Both its size and its similarity to most other STEM initiatives make it an ideal candidate for research. Current Project Lead the Way research regarding possible effects on student knowledge and skill almost exclusively compares Project Lead the Way student scores to non Project Lead the Way student scores on academic tests of math and science ability (Schenk, et al., 2011; Tran & Nathan, 2010). While beneficial, these studies fail to account for competencies outside of mastering core academic content that may equip students for success in postsecondary STEM programs. This study attempted to measure the possible positive effects of Project Lead the Way coursework in a different manor, by examining the presence of certain 21<sup>st</sup> Century Skills, namely problem solving, critical thinking and creativity in its students.

### **Deeper Learning**

Deeper learning and 21<sup>st</sup> Century Skills provide the conceptual framework for this study. Deeper learning emphasizes student's ability to apply new information to varied situations, to utilize knowledge gained across disciplines and different problems

(Pellegrino & Hilton, 2013). An accepted organization of deeper learning consists of three domains; cognitive, interpersonal, and intrapersonal (Pellegrino & Hilton, 2013). While the deeper learning framework accounts for the importance of mastering core academic knowledge, it balances this competency with others including critical thinking, problem solving, creativity, communication, and collaboration. Deeper learning focuses not simply on recall of fact, but also on the learner's flexibility built through a wide range of learning activities to integrate recall of fact with other skills to solve problems they have not been exposed to previously (Darling-Hammond & Conley, 2015) This study compared Project Lead the Way and non Project Lead the Way student performance on tests of two components of the cognitive domain, namely critical thinking and creativity.

Research suggests that deeper learning and the development of 21<sup>st</sup> Century Skills may improve student outcomes. Pellegrino and Hilton (2013) extensively reviewed research investigating relationships between the subject's strength in deeper learning and 21<sup>st</sup> Century Skills and success in education, work, and other areas of adult responsibility. They found consistent positive correlations between level of 21<sup>st</sup> Century Skills and desirable outcomes. This suggests that educational programs may be well served to consider the recommendations for activities promoting the activation of deeper learning and the acquisition of 21<sup>st</sup> Century Skills when structuring learning environments. It may be reassuring to note that even though positive student outcomes do correlate with IQ and achievement test scores, research suggests that for many outcomes, personality traits can be just as predictive (Almlund, Duckworth, Heckman, Kautz, 2011).

One of the 21<sup>st</sup> Century Skills this study measured was critical thinking and problem solving. The instrument used was the expanded Cognitive Reflection Test (Kahneman,

2011; Morewedge & Kahneman, 2010; Toplak, West, & Stanovich, 2014). This short insight problem solving test measures participant's tendency toward either reactive, intuitive, and quick responses (System One) or analytical, logical, reasoned responses (System Two). For the purposes of this study the measured and deliberate disregarding of an intuitive incorrect answer and the logical determination of the non-intuitive correct answer, System Two response, was considered evidence of heightened critical thinking and problem solving skill. Being able to discern the false positive and logically reason to the correct answer benefits a subject. Research suggests that greater levels of System Two thinking, as measured by the Cognitive Reflection Test, correlate positively with performance on specific cognitive measures, including college entrance exam scores on the SAT and the ACT, and admission to selective institutions of higher learning (Frederick, 2005). Further research positively correlates System Two thinking, as measured by the Cognitive Reflection Test, with intelligence and executive function (Toplak, West, & Stanovich, 2011; Toplak, West, & Stanovich, 2014).

The other 21<sup>st</sup> Century Skill measured in this study is creativity. Research tells us that there are two types of creativity, divergent and convergent (Brophy, 2000). Divergent creativity relates to the number of unique solutions an individual can generate to a question or problem. Convergent creativity relates to the ability to generate a single correct answer. This study used the Remote Associates Test, an instrument both internally and externally validated as a measure of convergent thinking processes in creativity (Lee, Huggins, & Therriault, 2014). Research validates the importance of convergent creativity. Webb, Little, Cropper, & Roze (2017) investigated the relationships between divergent and convergent thinking process and insight and non-

insight problem solving. Insight problems require the participant to think about a problem in a non-standard way to arrive at the correct solution. Non-insight problem solving requires the participant to follow a logical chain of steps to arrive at the correct conclusion. The study found that while both divergent and convergent thinking are correlated with success on insight problem solving, only convergent thinking was significantly correlated with success on non-insight problem solving. By utilizing the Cognitive Reflection Test, an instrument consisting of insight problems, and the Remote Associates Test, a convergent thinking test, this study is able to make claims regarding both insight and non-insight problem solving ability of its subjects.

### **Project Lead the Way**

Most of the current research attempting to quantify effects of Project Lead the Way membership focus on improving math and science ability as measured through achievement tests (Schenk, et al., 2011; Southern Regional Education Board, 2005; Southern Regional Education Board, 2007; Tran & Nathan 2010; Van Overshelde, 2013), increasing the number of students who pursue STEM postsecondary education (Project Lead the Way, 2006; Rethwisch, Chapman, Schenk, Starobin, & Laanan, 2013), or their persistence once there (McCharen & High, 2010). This body of research strives to measure the dual outcomes of Project Lead the Way, both to prepare more students for postsecondary STEM programs while equipping them to be more persistent once there (Blais & Adelson, 1998). This study also measures the success of Project Lead the Way's dual outcomes but approaches it from a different perspective. Specifically, this study attempts to discover how Project Lead the Way coursework may contribute to these goals outside of the traditional increasing of science and math achievement.

Project Lead the Way course and coursework structure follows The Research Alliance for New York City Schools recommendations regarding how to embed deeper learning and 21<sup>st</sup> Century Skills into K-12 curriculum (Huberman, Bitter, Anthony, & O'Day, 2014). In the cognitive domain Project Lead the Way coursework is built on a national curriculum framework, involves real-world problems, is structured as project-based learning, and leverages the use of longer term assessments. From the interpersonal domain, Project Lead the Way coursework contains explicit goals, uses collaborative group work as a common method of task accomplishment, and mostly relies on longer term assessments that students are required to present and provide feedback to others. In the intrapersonal domain Project Lead the Way classes allow for student autonomy to make decisions based on the open ended project structure. Due to these similarities I believe Project Lead the Way to be an appropriate vehicle through which to measure the effects of curriculum designed to promote deeper learning and the acquisition of 21<sup>st</sup> Century Skills.

Using achievement tests as a basis for determining the effectiveness of a deeper learning teaching methodology, as is currently the case for Project Lead the Way research, seems flawed. While deeper learning does indeed reference the need for academic content knowledge, it balances that objective with others including critical thinking, creativity, collaboration, communication, and academic mindset. These other objectives would not necessarily improve student performance on achievement tests of core content they have already covered, it should improve their ability to formulate correct answers in situations that are not familiar, like the Cognitive Reflection Test and the Remote Associates Test. This study is unusual because it chooses to assess the

effectiveness of Project Lead the Way coursework not through math and science achievement test scores but instead how flexibly and accurately Project Lead the Way students can apply their problem solving skills with unfamiliar content.

### **Implications**

The STEM gap and improving STEM education is a current focus of governmental, educational, and philanthropic support. Tremendous resources have been channeled into programs designed to address the problem. Unfortunately, drastically increasing the number of K12 students being exposed to STEM initiatives over the past several decades has not resulted in commiserate increases in American students completing postsecondary STEM degrees (Congressional Research Service, 2012; The National Academies National Research Council Board of Science Education, 2008). Even more unfortunate, the little research that is available regarding STEM programs like Project Lead the Way present conflicting conclusions and little to guide policymakers towards programs and/or qualities of STEM initiatives that work (Tai, 2012). With this in mind three implications emerge from this study.

First, project-based learning structures in general, and Project Lead the Way specifically, should be considered potentially effective methods to improve the cognitive domain of 21<sup>st</sup> Century Skills. Though we can't be certain differences measured in this study are due to Project Lead the Way coursework specifically, the fact remains that Project Lead the Way students performed at statistically significant higher levels of problem solving, critical thinking, and creativity than their non Project Lead the Way peers. This suggests that project-based learning in conjunction with the recommendations



referenced in this study for integrating deeper learning in curriculum might promote the activation of deeper learning through the acquisition of certain 21<sup>st</sup> Century Skills.

Another implication of this study is the introduction of a more sensitive method to investigate the effectiveness of STEM initiatives or any program that is built upon deeper learning foundations. Using achievement test results as an indicator of success does not probe a complete reality of student success. Project Lead the Way coursework will give students valuable content knowledge, but of as much importance it may equip students with the skills necessary to successfully collaborate, communicate, and persist while dealing with difficult and novel problems. These skills simply aren't valued or measured on most academic achievement tests. By testing problem solving and creative ability in the context of Project Lead the Way membership, this study adds to the existing literature an unexplored method to use when evaluating the effectiveness of coursework designed to activate deeper learning and aid the acquisition of 21<sup>st</sup> Century Skills.

A final implication of this study is the possibility that coursework designed upon the recommendations regarding how to embed deeper learning and 21<sup>st</sup> Century Skills into K-12 curriculum might be more effective in empowering students to deal with unique and novel problems more flexibly. Though mastering academic content is undeniably a primary goal of education, so is application and extension of the knowledge gained to new and unique situations. Based on the conclusions of this study, those that design coursework for core subjects, such as mathematics and science, that might benefit from application and extension to future contexts might consider the recommendations regarding how to embed deeper learning and 21<sup>st</sup> Century Skills into their curriculum.

## Conclusion

Visit a Project Lead the Way classroom and you see something different than traditional math and science classes. The instructor may lecture some, but the majority of class time students are engaged in individual or group problem solving activities. There are no textbooks and worksheets generally aren't assigned as homework. Instead of turning in their project, students schedule a time and present the results of their work to their classroom peers. For many projects there is not an answer key, but a competition. I began this research to answer a simple question, how do students who engage with this type of coursework differ from their peers who don't? What possible benefit might this type of coursework afford those that engage with it?

This study found that Project Lead the Way students demonstrated significantly higher levels of problem solving, critical thinking, and creativity than their non Project Lead the Way peers. Because Project Lead the Way coursework is structured in a manner nearly identical to the recommendations of the leading Deeper Learning and 21<sup>st</sup> Century Skill frameworks, this study suggests that those practices may be effective in fostering deeper learning and the acquisition of 21<sup>st</sup> Century Skills. This might also suggest that Project Lead the Way coursework is making progress toward its dual goals of preparing more students for postsecondary STEM programs and preparing those students to be more persistent in those programs by equipping them with skills that will allow them to transfer prior learning to new novel situations.

The primary limitations of this study regard the design. Deciding to compare Project Lead the Way students to non-Project Lead the Way students made it impossible to control for selection effects as students voluntarily choose if they want to enroll in these

programs. It is possible that the self-selected Project Lead the Way cohort would have performed at statistically significant higher levels on the same problem solving, critical thinking, and creativity tests prior to their enrollments. Another limitation of the study design was the ex post facto nature. Because of the one-time test it is impossible to ascertain with certainty if the results are due to the Project Lead the Way treatment specifically. A final limitation of the study is the possibility of confounding variables other than those controlled for contributing significantly to differences in group performance on the Cognitive Reflection Test.

Future research should attempt to replicate the effects found in this study in other contexts, both with general STEM programs and other Project Lead the Way programs. Another future research consideration would be to replicate the testing but to isolate the Project Lead the Way treatment by conducting it with the same subjects both before and after Project Lead the Way coursework. Future research should also consider the addition of additional possible confounding factors that may contribute to differences in group performance on the Cognitive Reflection Test. Finally, future research should consider how to test the Deeper Learning domains untested in this study, namely the inter- and intra- personal domains.

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### Appendix A – Cognitive Reflection Test

A bat and a ball cost \$1.10 in total. The bat costs \$1.00 more than the ball. How much does the ball cost?

\_\_\_\_\_ cents

If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?

\_\_\_\_\_ minutes

In a lake there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?

\_\_\_\_\_ days

If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together?

\_\_\_\_\_ days

Jerry received both the 15th highest and the 15th lowest mark in the class. How many students are in the class?

\_\_\_\_\_ students

A man buys a pig for \$60, sells it for \$70, buys it back for \$80, and sells it finally for \$90. How much has he made?

\_\_\_\_\_ dollars

Simon decided to invest \$8,000 in the stock market one day early in 2008. Six months after he invested, on July 17, the stocks he had purchased were down 50%. Fortunately for Simon, from July 17 to October 17, the stocks he had purchased went up 75%. At this point, Simon has:

\_\_\_\_\_ Broken Even in the Stock Market

\_\_\_\_\_ Is Ahead of Where He Began

\_\_\_\_\_ Has Lost Money

## Appendix B – Remote Associates Test

For each set of three words, find a fourth word that connects them. For example

sun / tail / year = "light" and

yellow / board / credit = "card"

Cottage / Swiss / Cake \_\_\_\_\_

Cream / Skate / Water \_\_\_\_\_

Fountain / Baking / Pop \_\_\_\_\_

Show / Life / Row \_\_\_\_\_

Opera / Hand / Dish \_\_\_\_\_

Safety / Cushion / Point \_\_\_\_\_

Cane / Daddy / Plum \_\_\_\_\_

Duck / Fold / Dollar \_\_\_\_\_

Loser / Throat / Spot \_\_\_\_\_

Aid / Rubber / Wagon \_\_\_\_\_

Flake / Mobile / Cone \_\_\_\_\_

Cracker / Fly / Flight \_\_\_\_\_

Preserve / Range / Tropical \_\_\_\_\_

Dream / Break / Light \_\_\_\_\_

Dew / Comb / Bee \_\_\_\_\_

Sense / Courtesy / Place \_\_\_\_\_

Fish / Mine / Rush \_\_\_\_\_

Political / Surprise / Line \_\_\_\_\_

Worm / Shelf / End \_\_\_\_\_  
Piece / Mind / Dating \_\_\_\_\_  
River / Note / Account \_\_\_\_\_  
Print / Berry / Bird \_\_\_\_\_  
Night / Wrist / Stop \_\_\_\_\_  
Food / Forward / Break \_\_\_\_\_  
Hound / Pressure / Shot \_\_\_\_\_  
Fur / Rack / Tail \_\_\_\_\_  
Basket / Eight / Snow \_\_\_\_\_  
Nuclear / Feud / Album \_\_\_\_\_  
Main / Sweeper / Light \_\_\_\_\_  
Carpet / Alert / Ink \_\_\_\_\_