CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

Using Project Based Learning to Engage Third -Fifth Grade Students in Robotics Education

A project submitted in partial fulfillment of the requirements
For the degree of Master of Arts in Education, Elementary Education

By
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May 2015

The project of Oscar Cesar Rios Jr. is approved:

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DEDICATION

This graduate project is dedicated to:

My Family, Shirley, Cesar Luis, Alejandro, Oscar C. Rios Sr., Teresa Rios, my sisters Jennett and Jessica, Martha Rodriguez, Rudy Rodriguez, The Felix Family, The Vanegas Family, all of my friends, family, my fifth- grade team, and my Stanley Mosk Elementary Family.

I want to thank everyone whom supported me during my journey of earning my Masters in STEM Instruction. Your encouragement, love, support and understanding during a momentous part of my educational career will never be forgotten.

ACKNOWLEDGMENT

I would like to thank my committee members who supported my efforts in writing this graduate project.

To my chair, Dr. Susan Belgrad,

To Dr. Raymond Brie,

To Barbara Friedrich,

To David Garringer

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Abstract

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Students in Robotics Education

By

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The purpose of this graduate project was to examine the engagement of third through fifth grade students using Lego® robotics as the catalyst in project based learning. Robotics educations has been on the rise in the last 10 years, but in the elementary schools it has been the driving force for many teachers on how to engage students in todays' technological advances. Using project based learning and Lego® robotics creates an engaging environment for students and teachers to cover Common Core States Standards along with the Next Generation Science Standards. This project was created to help guide teachers, administrators and after school counselors with the materials and resources needed in order to start a robotics program at their own location.

Chapter 1: INTRODUCTION

The purpose of this Project is to provide upper elementary grade teachers a Resource Guide the applies principles of Project Based Learning (PBL) as they plan to introduce LEGO® platform robotics as the catalyst for providing rich, STEM-integrated learning experiences girls and boys in grades three-five. Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with the concepts and practices of technology and/or engineering education. Integrative STEM education may be enhanced through further integration with other school subjects, such as language arts, social studies, art, etc. (Sanders & Wells, 2010). This Guide is structured to provide concrete, authentic, accessible and motivating sequence of lessons and activities that will invite, welcome and retain students from Minority Serving Elementary (MSE) schools into the rich curriculum and instruction that assures student achievement in the important twenty-first century STEM disciplines (James, 2002).

Many dedicated elementary educators throughout the past decades have worked tirelessly to find new and exciting ways to promote their students' engagement and success in science and mathematics. From themed teaching to cooperative learning groups, teachers have continuously searched for new and innovative ways to not only inspire students to achieve in these disciplines but to keep students motivated to learn while concurrently delivering rigorous, content-rich lessons. (Cannon, 2007, p 74). Many of these teachers strive to address the needs of students in MSE schools where the reality is that many have become underachievers. In reality their students whom are capable of achievement in science and math but are likely not receiving the right challenges in the classroom or home that would inspire them to high levels of achievement. (Sanders, 2010)

As critics of the test-driven curricula and assessment programs of the past decade have noted (Darling Hammond 2008, Kohn, 2007) teachers have been known to result to bribery in order to keep students engaged and on task--using countless strategies such as stickers, snacks, or even offering in-class “play time.” Alfie Kohn, states, “Rewards are most damaging to interest when the task is already intrinsically motivating. That may be simply because there is that much more interest to lose when extrinsic are introduced; if you're doing something boring, your interest level may already be at rock bottom. What kids deserve is an engaging curriculum and a caring atmosphere so they can act on their natural desire to find out about stuff. No kid deserves to be manipulated with extrinsic so as to comply with what others want. All these methods have been deployed in attempts to keep unmotivated students engaged in a lesson.” Now with the introduction of Common Core State Standards (CCSS) along with the California adoption and imminent implementation of Next Generation Science Standards (NGSS) the elementary school content, curriculum and context is shifting. With business and industry’s expectations that public school education aligns with the present and emerging workforce needs teachers’ must have access to resources that assist them in preparing minority students to access high-tech, high-knowledge jobs and careers (Lough & Fett, 2002). For example, the Partnership for 21st Century Skills asserts that there are four “C’s” of the Common Core State Standards. These are: Communication, collaboration, critical thinking and creativity. This immense shift now requires in teaching and learning that students actively rather than passively participate in their learning process, as the need for scientists, mathematicians, engineers and computer scientists continues to advance at the local, state and national levels.

This Project presents a Resource Guide to address the important concern as to how educators might successfully introduce and integrate STEM education in MSE schools, which promotes student engagement. It responds to the need for upper elementary teachers to create curriculum and instruction characterized by content-rich learning opportunities in STEM. It focuses on assuring that more students develop knowledge, skill and ability across all content areas as they become more positive and productive students performing at their grade level.

The Resource Guide begins with a promising methodology that is being advanced by many stakeholders including Bill and Melinda Gates: Project based learning (PBL). This learning platform has been found to be an effective means to launch both in-and out-of-school robotics, become a key workforce component of global manufacturing, including the aerospace industry and NASA. Robotics, a form of engineering has rapidly gained global manufacturing popularity in the last decades. It has similarly found its way into K-12 education. Robotics has become a curriculum that attracts K-12 educators' interest as a somewhat affordable implementation of computer technology (coding and engineering—The "T" and "E" of STEM). Educational robotics can be used as a method for integrating STEM learning in the everyday classroom. Depending on the intended instructional use of robotics, (Catlin 2012), states that "it can be found at the middle and high school levels and that its application has grown in popularity as demonstrated by the spread of national and international robotics competitions, such as VEX Robotics® (VEX), FIRST Robotics Competition (FIRST), Boosting Engineering, Science, and Technology (BEST), and First LEGO® League (FLL)". Typically, many of the robotics activities offered in schools today are offered after school and are geared towards these student competitions (Rusk, N., Resnick, M., Berg, R., & Pezalla-Granlund, M., 2008, pg. 63). Studies have shown that the use of robotics, can improve students' personal skills dispositions and mindsets, such as self-confidence, problem solving, communication, creativity, decision making, and team work. (Akey 2006).

This Project will identify how PBL methods and strategies can be used to introduce upper elementary school robotics program that address the need for our students to become creative, positive, productive, and focused STEM achievers.

Chapter 2: LITERATURE REVIEW

As robotics have begun to enjoy entry into in-school curricula through such programs as Project Lead the Way and Engineering is Elementary, it becomes important to place the knowledge, skills and dispositions acquired by students in this engineering process within an integrated STEM-learning context. Teachers of elementary school girls and boys—especially in minority-serving schools need to know: What are the real-world applications of robotics? Are they used in industries: which ones manufacturing? Health Services? Business? Entertainment? Science? Aerospace?

How are important social dispositions and "soft" skills as well as the visual and performing arts integrated during the designing, building, programming and operating of robots? How is mathematical knowledge integrated and developed? How are Common Core State Standards in Language and literacy advanced through robotics curricula and instruction? How is the engineering design process that is now incorporated in CCSS and NGSS introduced, implemented and assessed in robotics?

It has been argued, that at the elementary level STEM education should be experimental and offer students the opportunity to experience appropriate science, technology, engineering and mathematical applications they can relate to, which serve as a catalyst for awareness of the career and workforce-related fields they may later decide to explore and pursue. (Connors, 2011) Educational robotics offer an alternative to traditional teaching methods in elementary curricula while addressing and advancing the new standards that call for STEM-integrated applications.

The goal of this project is to create a coherent framework in which elementary-level teachers understand how age appropriate robotics can be placed within PBL lesson structures to meet the diverse student learning needs for the diverse students they serve. This Project will provide teachers with background and implementation strategies that assist them in promoting the engineering design process of robotics and the accompanying disciplines of science, technology, mathematics language, literacy, and the arts in the fifth-grade classroom? In the next chapter a review of the literature will provide teachers with awareness and understanding of how an elementary school-based model of robotics engagement can be integrated within a PBL unit of study that assures deep and dimensional, student engagement. This project will meet a significant need to better understand the process of implementing a STEM-integrated PBL that introduces and extends robotics curriculum on to the third through fifth grade classroom.

What is engagement?

It is well recognized that student engagement is fundamentally important in promoting achievement (Akey, 2006; Patrick, Ryan, & Kaplan, 2007; Shernoff & Schmidt, 2008; Shin, Daly, & Vera, 2007) and in retaining students as active achievers within the education system (Fredricks, Blemfield & Paris, 2004; Shin, Daly, & Vera, 2007). However, the multitude of overlapping concepts and definitions about student engagement that have been advanced have not made it easy for K-8 educators to achieve a common understanding about what engagement is. Furthermore, such variability and lack of a common definition about student engagement makes it difficult to know what might be done in classrooms to support students' learning and acheievement (Fredricks Blemfield & Paris, 2004; Shernoff & Schmidt, 2008). For example, engagement and motivation are used interchangeably in some literature or used in different bodies of literature to represent the same construct. (Cannon, 2007). Some cases, engagement is a meta-construct that incorporates a range of factors. In others, engagement is one of a number of factors, such as motivation, that is identified as impacting students' learning at school.

Very few studies have attempted to define engagement and most of those that did failed to provide a definition of student engagement that covered all of the elements that achieves consensus of scholars and researchers. For instance the following definition failed to reflect the notion of students' intentional cognitive learning: Student engagement is "the simultaneous perception of concentration, interest and enjoyment" (Shernoff & Schmidt, 2008, p. 566). This contrasts with the more comprehensive definition provided by (Akey, 2006):

> Student engagement can be defined as the level of participation and intrinsic interest that a student shows in school. Engagement in schoolwork involves both behaviors (such as persistence, effort, attention) and attitudes (such as motivation, positive learning values, enthusiasm, interest, pride in success). Thus, engaged students seek out activities, inside and outside the classroom, that lead to success or learning. They display curiosity, a desire to know more, and positive emotional responses to learning and school.

Engaging students in learning is a demanding yet highly-satisfying professional responsibility. Although engagement is commonly viewed as having three main components: emotional, behavioral and cognitive, it has become evident to this teacher-researcher in both the theoretical and practical sense that attending to students' emotional and behavioral needs is foundational for their authentic cognitive learning. (Leamson, 2000) Similarly it is believed that there are more advanced levels of engaged learning in which students participate in, such as goal-setting, risk taking or experimenting and academic self-regulated learning; each of which are aspects to which teachers aspire to promote in their students.

While making sure that we are engaging our students we must remember that we need to ensure that we are hitting the four "C's" to help drive student engagement. "Using the 'Four Cs' to engage students is imperative. As educators prepare students for this new global society, teaching the core content subjects—math, social studies, the arts— must be enhanced by incorporating critical thinking, communication, collaboration, and creativity. We need new tools to support classroom teachers and education support professionals in their profession, even as they implement new strategies in their classrooms." (Stocks, 2011).

Moore (1999) used robots to teach her fourth-grade students several different topics under the umbrella of examining robots. She used the topic as a "hook" to capture her students' attention; then she weaved other disciplines into this central theme and asked her students to think critically about robots. According to Moore (1999) students built and program robots, understood geometry concepts, wrote and shared stories with peers and compared and contrasted technology systems with human body systems.

While developing or using PBL lessons one must remember to make sure that the lesson is allowing the student to stay engaged with the lesson and make sure that they are learning the lesson and standards at hand. As stated earlier that engagement comes in different forms, teachers must be able to recognize the times that students are not engaged and the teacher must be able to modify the lessons in order to keep the students engaged.

Project Base Learning

What is PBL? PBL today is one of the most recognized acronym in the educational world, but this term has been around for quite some time. Problem-Based Learning (PBL) is a curriculum development and delivery system that recognizes the need to develop problem solving skills as well as the necessity of helping students to acquire necessary knowledge and skills.

The first application of PBL, and perhaps the most strict and pure form of PBL, was in medical schools which rigorously test the knowledge base of graduates. Medical professionals need to keep up with new information in their field, and the skill of life-long learning is particularly important for them. Therefore, PBL was thought to be well suited for this area. Many medical and professional schools, as well as undergraduate and graduate programs use PBL in some form, at varying capacities internationally. But even before medical school some of our older finding of PBL was with world known great thinkers, Confucius and Aristotle were early proponents of learning by doing. Socrates modeled how to learn through questioning, inquiry, and critical thinking, all strategies that remain very relevant in today's PBL classrooms. Move forward to John Dewey, 20th-century American educational theorist and philosopher, and we hear a ringing endorsement for learning grounded in experience and driven by student interest. Dewey challenged the traditional view of the student as a passive recipient of knowledge and the teacher as the transmitter of a static body of facts. Dewey disputed instead for active experiences that prepare students for ongoing learning about a vigorous world. As Dewey pointed out, "Education is not preparation for life; education is life itself." (Boss, 2011)

In PBL, projects requiring students to apply the knowledge and skills they learn are the focus of the curriculum rather than being added as a supplement at the end of traditional instruction. The entire PBL process is organized around an open-ended driving question that teachers use to connect content to current and relevant issues or problems. Through this process, students develop their own questions to drive learning, study concepts and information that answer those questions, and apply that knowledge to products they develop. In addition, PBL encourages more rigorous learning because it requires students to take an active role in understanding concepts and content, and it enables them to develop 21st-century skills, which foster an enduring curiosity and hunger for knowledge. Since students are able to apply classroom content to real-life phenomena, PBL also facilitates career exploration, technology use, student engagement, community connections, and content relevancy (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; The Buck Institute for Education, 2012).

Although project-based instruction continues to gain popularity among educators, not much relevant professional development is available, and the practice remains far from common. As educators we have trouble learning not to obsess about curriculum coverage on a day-to-day basis. Teachers need to become comfortable with the unpredictable nature of this style of teaching and accept that if the teacher doesn’t accomplish everything that they wanted to accomplish that given day, they must understand that it will get accomplished eventually. Successful project-based instruction requires teachers to trust themselves, their students, and the process enough to abandon extensive measures of control over both lesson content and pacing.

Today’s students often find school to be boring and meaningless. In PBL, students are active, not passive; a project fully engages their hearts and minds, and provides real-world relevance for learning. After completing a project, students remember what they learn and retain it longer than is often the case with traditional instruction. Because of this students who gain content knowledge with PBL are better able to apply what they know and can do to new situations. In the 21st century workplace, success requires more than basic knowledge and skills. In PBL, students not only understand content more deeply but also learn how to take responsibility and build confidence, solve problems, work collaboratively, communicate ideas, and be creative innovators. PBL provides an effective way to address such standards.

The use of PBL and modern technology, is a perfect fit with PBL in the classroom. With technology, teachers and students can connect with experts, partners, and audiences around the world, and use tech tools to find resources and information, create products, and collaborate more effectively. PBL allows teachers to work more closely with active, engaged students doing high-quality, meaningful work, and in many cases to rediscover the joy of learning alongside their students.

STEM Pathway

The Noyce Foundation commissioned a 2008 study to review and report on the current state and needs of the after-school science assessment world. The study was conducted by the Program in Education, Afterschool & Resiliency (PEAR) at Harvard University and McLean Hospital. PEAR researchers adapted and modified a framework that has been used by the National Science Foundation (NSF) for evaluating the effect of informal science education programs.

The framework defined five domains in which programs can have an effect on participants. While these domains were originally created to assess the effect of informal science education programs, they have use for programs in technology, engineering and math.

The PEAR researchers have identified components of student outcomes that could be assessed under each domain, then used the domain framework to group and classify instruments commonly used to evaluate informal science education programs. These two domains bring into line most closely with STEM interest. The PEAR study placed the desire to become a scientist under the Attitude and Behavior domain, Pipeline program assessments of the intent to engage in a STEM career or participate in STEM activities were also considered to be measures of student interest under the Attitude and Behavior domain. Assessments of knowledge about STEM careers and pathways remained under the last domain, and were not considered to be assessments of student interest. These clarifications are added in bold italics below.

The two domains that have been chosen from the five were:

● Interest/Engagement

● Attitude/Behavior

Domains:	**Components:**
Interest/ Engagement	Curiosity in STEM–related activities/issues Excitement about / Enthusiasm for engaging in STEM activities Fun / Enjoyment / Interest in STEM Activities
Attitude / Behavior	Desire to become a scientist / ***engage in a STEM career*** Level of Participation ***Intent to Participate in STEM Activities*** Belief that science / math is sensible, useful and worthwhile Belief in one's ability to understand and engage in science and math Reduced anxiety / trepidation around STEM Positive scientific / math identity Pro-social / adaptive learning behaviors in relation to STEM

(PEAR Research, 2008)

STEM education is defined and seen as:

> STEM education, includes the subjects of mathematics, biology, chemistry, and physics, which have traditionally formed the core requirements of many state curricula at the K-12 level. In addition, the report includes other critical subjects, such as computer science, engineering, environmental science and geology, with whose fundamental concepts K-12 students should be familiar. The report does not include the social and behavioral sciences, such as economics, anthropology, and sociology; while appropriately considered STEM fields at the undergraduate and graduate levels, they involve very different issues at the K-12 level.
>
> (Holdren, J. & Lander, E. 2010

21st Century Learning

What is 21st century learning? It has been defined many different ways, the following definition holds well to what our students need in today's learning pathways.

> "The term **21st century skills** refers to a broad set of knowledge, skills, work habits, and character traits that are believed—by

> educators, school reformers, college professors, employers, and others—to be critically important to success in today's world, particularly in collegiate programs and contemporary careers and workplaces. Generally speaking, 21st century skills can be applied in all academic subject areas, and in all educational, career, and civic settings throughout a student's life." (Glossary of Education Reform, 2014)

Robotics in the classroom and the use of PBL lessons is an engaging way to reinforce mathematics, science and technology. Now with the NGSS incorporating engineering in the standards, the use of robotics in the classroom will help support and reinforce the engineering design process along with problem solving skills that is greatly needed in today's and future jobs that students will encounter when they get older. Sixty-five percent of today's children will end up in jobs that haven't been invented yet. (DeJarnette, 2012). Our world and our daily lives are becoming more global. Today's students will be tomorrow's citizens, parents, and employees and must be prepared to be successful in an ever-changing global economy. Every job will require blended abilities across four key areas: Communication, Collaboration, Critical Thinking, and Creativity. If we enable our students today to have strong skills in these four areas, then we are creating a generation that will be effective in working with diverse cultures and geographies in a wide variety of careers and professions.

Robotics in Elementary Education

Today's U.S. economy is decidedly dependent on advanced technology. Technology and related innovation are responsible for at least half of U.S. economic growth (Bonvillian, 2002). Industries that rely on technology need new scientists and engineers every year to help propel their success and it is up to those in our schools to produce these graduates. Regrettably, U.S. students are less prepared than many other first-world countries in terms of science and math. At the fourth grade level, U.S. students are competitive in science but fall behind most first-world countries in math (Gonzales, Guzmán, Partelow, Pahlke, Jocelyn, Kastberg, & Williams, 2004). By age fifteen, U.S. students are still relatively poor math performers and fall behind the international average in science literacy as well (Lemke, Sen, Pahlke, Partelow, Miller, Williams, Kastberg, & Jocelyn, 2004). If innovation is going to continue to drive the United States' economy, its educational system must improve these scores and entice graduates into STEM careers (Bonvillian, 2002).

Until recently educational robotics at the elementary level has been largely ignored (DeJarnette, 2012). However, school districts have begun to target elementary programs in an effort to increase performance and interest in STEM once students enter middle school (National Research Center, (NRC), 2012). The problem is that there is limited time available for teachers to work on projects requiring multiple periods and open-ended solutions given the organization of the elementary school curricula and pressure for content coverage (NRC, 2012). There is the issue of appropriate teacher training in the use of educational robotics to design and implement projects appropriate to elementary school students (Epstein & Miller, 2011). The cost of robotics kits often prevents schools from promoting robotics in the classroom or, in other cases, create unequal opportunities for access in schools (Catlin, 2012). Assuming that educational robotics kits are available for use in elementary schools, and teachers are prepared to use them, two important questions have been posited for effective use: What elementary school curricular content can be taught using robotics-based activities? What types of skills are best promoted through robotics activities in elementary school education?

Here is a chart to help guide that question:

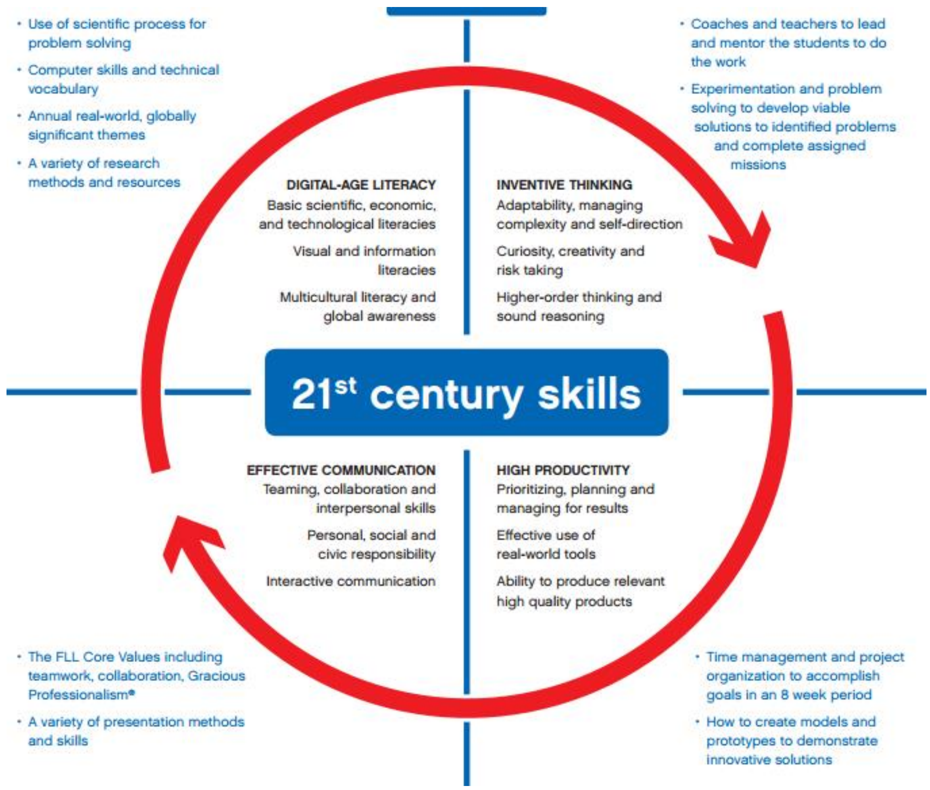


Figure 2.1

Graph Provided by First LEGO League (FLL) 2015

With those questions being asked the PBL lesson with be able to help promote the right activities and subjects to be covered in order to help student engagement to be the main priority in a fifth grade PBL lesson. Engagement for fifth graders is important, and introducing them to robotics at this age is very helpful to promote their possible career choices.

NASA's 5E Lesson Format

In order to have teacher help fulfill the engagement portion of their project based learning lessons, they can follow and use the NASA 5E learning cycle. This model includes Engagement, Exploration, Explanation, Elaboration, and Evaluation.

The point for the engage stage is to get student interest and get them involved in the lesson. During this portion students must understand their instructional task and students make connections between past and present learning experiences.

The advantage for the explore stage is to get students involved in the topic; providing them with a chance to build their own understanding. In the exploration stage the students have the opportunity to get directly involved with the concept and the materials. As they work students they build on experiences which leads them to sharing their ideas and communicate their thinking in their groups.

During the explain stage this allows the students to do exactly that, explain their thinking. Explain is the stage at which learners begin to communicate what they have learned. Language provides motivation for sequencing events into a reasonable format. Also this allows the students to communicate their grasp of the concepts and to share their ideas of what they have learned so far.

The objective for the extend stage is to permit students to use their new knowledge and continue to explore its implications. At this stage students expand on the concepts they have learned, make connections to other related concepts, and apply their understandings to the world around them in new ways. The rational for the evaluate stage is for both students and teachers to define how much learning and understanding has taken place. Evaluate, the final "E", is an on-going diagnostic process that allows the teacher to determine if the learner has achieved understanding of concepts and knowledge. Evaluation and assessment can occur at all points along the, range of the instructional process. Some of the tools that assist in this diagnostic process are: rubrics, teacher observation, student interviews, portfolios, project and problem-based learning products. Students will be excited to demonstrate their understanding through journals, drawings, models and performance tasks. (NASA, 2015)

Next Generation Science Standards (NGSS)

The Next Generation science standards and curriculum frameworks place an emphasis on the importance of design for students. The use of the NGSS with this project will work seamlessly since the NGSS has included an engineering and technology portion in their standards. The design process encourages students to explore and apply their knowledge while gaining skills such as systematic testing, evaluation, and redesign. Often design problems provide students with a rich and engaging context for their knowledge. Robotic design can explore subject areas such as simple machines, sequence and order, and control. Additionally, these elements can easily be integrated into interesting contexts like exploring our environment, creating inventions, or building an artifact from a favorite story. There are several important reasons for exposing young students to robotics. As our world becomes increasingly technological, students need experiences at an early age that enable them to become comfortable with and knowledgeable about technology. Robotics can often do this within a context with what students care about. This is especially critical for female and minority students, as positive early exposure may contribute to persistence in STEM courses and possibly careers (James, 2002). Additionally, including robotics throughout the upper elementary curriculum will help prepare students to enter the workforce as technologically literate (Lough & Fett, 2002).

Robotics is an attractive approach to technology education because of its interdisciplinary nature, requiring expertise in a range of fields from mathematics to aesthetics. This can make STEM subjects engaging for students who are not reached by traditional classroom lessons and make the NGSS standards utilized within the lesson. Work in the area of K through 12th grade robotics began with Seymour Papert's Logo project and continued at the Massachusetts Institute of Technology's Media Lab with LEGO® /Logo projects and the development of a programmable brick (Roth, 1997). The work continued at Tufts University through the CEEO and the LEGO Mindstorm® NXT (Resnick, 1999). These projects explored what could be done with the developing technology, but did not systematically research learning or implement large school change. Projects at these institutions are now aimed at researching children's learning and thinking as well as teacher education and classroom implementation (Resnick, 2002).

Children learning through robotics and applying the NGSS is an area of research that is beginning to develop. One area of interest is what skills children develop using robotics that they would not gain otherwise. For example, Wagner found increases in the areas of science achievement and problem-solving skills with elementary students using robotics as compared to those traditionally taught in a science class (McManara, 1999). Another area of interest is the design process undertaken by students during robotics activities which is greatly covered in the NGSS and NASA's design process. These processes can provide insight into what and how students learn. Studies such as those by Stein and Mc Robbie are providing the foundations of children's design processes (Stein & Mc Robbie, 2002). Students may not be learning explicit science or robotics content during these activities, but rather they are gaining an understanding and appreciation of the process of robotic design and the NGSS (Stein, 2002). While there have been many efforts to bring robotics into schools, there is little knowledge about projects making sustainable systemic changes to introduce an entire school's population to the subject. The use of the NGSS and LEGO® robotics in the classroom will help guide the teacher and student toward a level of comfort knowing that they are covering the NGSS standards and guiding student and teacher to an engaging and fun work environment.

LEGO Mindstorms® and EV3’s® as a Tool for Learning

LEGO Mindstorms NXT ® and LEGO EV3’s ® robots were developed by some of Papert’s students and successors, who saw them as part of a progression from the early work with LOGO towards a world of ubiquitous computing and therefore ubiquitous learning through computing (Lehrer, Guckenberg, & Lee, 1988). In many ways, the LEGO Mindstorms NXT® robots were designed as the intersection between constructionism, distributed constructionism, and tools that can be played with. From the beginning, these devices were seen as being used cooperatively with others, a kind of physical implementation of distributed constructionism. One of the earliest projects with the Programmable Brick involved two children. Andrew and Dennis, ages 11 and 12, were intrigued with the idea of making an “active environment”— making the environment “come alive” and react to people. After some consideration, they decided to make a device to flip on a room’s light switch when people entered the room, and flip it off when people left. (Resnick, Martin, Sargent, & Silverman, 1996).

Several researchers have investigated the use of robotics to teach the STEM areas, especially mathematics (Fernandes, Fermé, & Oliveira, 2006), science (Matson, DeLoach, & Pauly, 2004), and engineering (Wing, 2006). In addition, some studies have explored the use of robotics to affect many comprehensive skills and experiences, such as computational thinking (Wing, 2006) authentic learning (Chang, Lee, Wang, & Chen, 2010; Druin & Hender, 2000), and problem-solving (Lin & Liu, 2012; Mosley & Kline, 2006).

This project seeks to advance the use of a robotics program with third through fifth-grade students in order to deepen their understanding of STEM concepts, engagement in the classroom STEM lessons and their ability to collaborate with one another through PBL.

Problem Solving Using LEGO's®

While using the Lego robotics introduced in this project I found that problem solving was a driving force in many of the student endeavors while working on their robots. As I developed this project I sought to establish a few specific objectives that were integral to the approach to problem solving. This project has been created to help teachers expose elementary level students to the excitement, spirit, and intellectual substance of engineering and the physical sciences through hands-on robotic-design projects. Furthermore this project encourages student explorations that span a wide range of disciplines, including physics, computer science, mathematics, biology, engineering, and art, and is a curriculum that is accessible to all third through fifth-grade students. This project also promotes a civic engagement component that uses the pedagogy of project-based learning to connect students to each other in a group setting while exposing them to the challenges of problem solving. Students are expected to demonstrate abstract robotic concepts acquired through concrete, hands-on robotic manipulation as the work together in their groups. Students and teachers will develop stronger skills in logical thinking, critical analysis, effective team work, and communication skills through oral presentations, as well as increasing their understanding of the value of science, mathematics, engineering and technology. The project is based on the LEGO MINDSTORMS NXT ® and LEGO EV3® robotics technology product, which was designed for individuals aged eight years and up. The use of this equipment has offered young students the opportunity to learn the concepts of robotics technology and computer programming in a fun and engaging environment.

Students today tend have been exposed to the instant gratification that a media-centered society promotes and tend not to have a predisposition to engage in problem solving. By using the LEGO® robotic educational system students are engaged in approaching problem solving through an enjoyable and interactive median. Students become able to transfer the cognitive abilities acquired in robotics so that when they are faced with similar scenarios in other school subjects or even real-life problems, they have a better understanding of how to approach the situation instead of waiting for someone to "spoon feed" the answer to them.

Mathematics in the Classroom Using Robots

Why is robotics in the classroom a motivator to learn, with hands-on learning that links math and science to the real world works best for all students? Online learning and other new technologies show promise but have to be refined and vetted by knowledgeable. Combining good teachers with technology may be the game changer. Robotics promotes a consistent and ongoing opportunity to solve problems. The combination of engineering and software problems and solutions creates a dynamic environment that helps student participants to develop problem-solving skills that involve math, engineering, physics, and logic as they work toward tangible goals. Students that are exposed to math through robotics tend to solve problem as they engage in the following mathematical concepts:

- Proportional relationships.
- Circumference, radius, diameter and even Pi
- Equations and inequalities
- Probability, defining, evaluating, and comparing functions
- Rounding numbers and measures to approximate answers
- Understanding angle measure, area, surface area, and volume
- Understanding and analyzing ratio concepts and developing solutions from there
- Applying and extending previous understandings of arithmetic to algebraic expressions and
- Estimating numbers, measures, and approximate answers, including using these to check other calculation methods.

Teaching engineering through robotics allows students to learn the content of a subject area, such as mathematics, by applying the content in a real-world context. Learning with robots helps teach scientific and mathematic principles through experimentation with the robots. Rogers and Portsmore (2004) reported success in teaching decimals at the second-grade level by making a robot move for a time between one and two seconds. Papert (1980) used robots to teach geometry concepts. Robots helped his students see the relationships between programming, |mathematics, and movement of the robot. Building and programming robots also requires that the students develop problem-solving skills (Beer et al., Mauch, 2001; Nourbakhsh et al., 2005; 1999). Beer et al. (1999) emphasized that designing an entire system that was needed to work in the real world required problem solving skills that would serve them well in their future careers no matter what discipline they chose. Teamwork is another career skill that robots appear to foster. Nourbakhsh et al. (2005) and Beer et al. (1999) identified teamwork as being important outcomes of their robotics courses.

Chapter 3: METHODOLOGY

About Robotics in the Elementary Classroom Resource Guide

In order to support teachers with the use of robotics and project-based learning in the classroom I have developed a manual and a website that will help guide teachers to use the NGS standards and 21st century learning strategies. This Project-Based Learning module, (P.B.L.) will give teachers the lessons needed for student interest in robots to drive the lesson and to help cover the Next Generation Science Standards, (NGSS) for third through fifth grades. The lessons that have been offered on the web site have been carefully selected so that the teacher can use them in a free-standing manner or solely with their LEGO robotic equipment.

The focus of the resource guide is to enable teachers to sustain third through fifth-grade students' engagement during a P.B.L. lesson using LEGO EV3® and LEGO Mindstorms NXT ® robots.

About the Author

A short biography offers readers a glimpse into my background and qualifications to provide this Resource. I have been teaching for over 15 years, and for the last five years I have been co-teaching in an after school LEGO robotics program at Stanley Mosk Elementary, in Winnetka California. In the last year, I have been teaching LEGO robotics in the classroom and incorporating PBL and NGSS into my lessons, while keeping the students fully engaged. I began to regularly use robotics in the classroom because I quickly learned that the high level of engagement that the students demonstrated offered me the opportunity to lead meaningful STEM lessons in which students learned in a fun, yet academically-challenging classroom environment.

About PBL

In this portion of the Resource Guide I have included an abundance of resources that a teacher can use while incorporating robotics in the elementary school classroom. My goal is to make sure that elementary teachers have enough resources that will help inspire and guide them as they seek to implement robotics as part of their integrated STEM curricula. For instance, I have made sure that each of the lesson plans presented are aligned with both CCSS and NGSS, as well as meeting the criteria of inquiry based teaching and learning. The lesson plans, examples and templates address the NASA 5E frameworks, which promote a high level of alignment with each of the STEM disciplines that assure student motivation, engagement and inclusion in the assessment process.

PBL and Robotics in the Classroom

When working with emerging, innovative ideas and concepts in the elementary school classroom, teachers need to make sure that they are presenting authoritative, well researched information aligned with standards. But in addition to this they need to feel confident that they may successfully execute the suggested lessons. With this in mind the "How to Guide" provides many suggested website links that will both support and connect them to materials and resources that are NGSS and CCSS- aligned.

How-to Guide

Creating the right classroom environment to use robotics is very important in order to get the students authentically involved. The use of technology can be second nature to students who have been termed "digital natives" (Prensky, 2001) but the introduction of robotics and the computer science that supports it can be discomforting to veteran educators (digital natives, Prensky, 2001). While the high levels of computer science engagement in coding is especially perfect for those elementary-level students who often have a difficult time focusing on the rigors of mathematics and science in the classroom, the hands-on interaction and group engagement of robotics effectively engages students' interest while motivating them to achieve in their academic work. The Guide is structured to assure a safe and fun learning environment for the educator.

Sample Projects

Many projects can be done in order to engage the students with robotics and teaching many math lesson to help incorporate robots. Check out the following page to see the different projects that can be created using robots in the classroom.

https://stanleymoskes-lausd-ca.schoolloop.com/cms/page_view?d=x&piid=&vpid=1424774898010 (January 2015)

Steps to Starting a LEGO® Robotics Program

The Robotics in the Elementary Classroom Guide provides a logical step-by-step plan to introduce and support educators throughout a robotics instructional process. Each of the steps are relevant to teachers, after-school program leaders, and club leaders. Teachers will need to decide upon the specific educational outcomes they are seeking to achieve as well as how robotics outcomes align with their school or district's Common Core and Next Generation Science standards implementation plans.

Step-by-Step Organizer

An organizer is provided in the Robotics in the Elementary Classroom Guide that enables user to decide what it is that they want to teach about robotics and where this instruction might fit into the curriculum. For example, a teacher might use robotics to promote deeper student understanding of mathematical concepts that extend into the programming, teamwork, problem solving of robotics. Or they may be simply preparing students for robotics competitions. Once the outcome of robotics curriculum is determined the next step is to select the robotics hardware that will be used. This decision will lead to the decision of which programming language will be appropriate for the students' grade and developmental levels. In the elementary school setting robotics is the ideal organizer to support fundamental mathematical and scientific thinking processes. LEGO MINDSTORMS NXT® and LEGO EV3's ® robotics also allow the instructor to learn how the engineering design process concepts of systems integration and digital control, and how they reinforce the NGSS, CCSS for upper- elementary school STEM instruction .
The LEGO MINDSTORMS NXT® and LEGO EV3's both include *Education Base Sets* that will allow teachers to complete all of the lessons in both of their robotics curricula. These can be found on the Guide's Robotics Education Locker page. Instructors will also find instructional budgets recommendations that are structured to recognize the limits of buying power. For example, purchasing at least one *Education Resource Set* for every 3-4 MINDSTORM NXT® or EV3® Education Base Sets is recommended at the outset. While this accessory kit includes many parts and connectors not included in the Education Base Set including tracks, it is not necessary to complete most of the basic lessons. Figures 3.1 and 3.2 shows the recommended LEGO Education® products for the elementary-level classroom.

Figure 3.1

LEGO Mindstorm NXT ®   LEGO Mindstorm NXT ® Expansion Kit

Figure 3.2

LEGO EV3® Core Set   LEGO EV3® Expansion Kit

Available Curriculum, Resources and Research Literature

The Guide includes a helpful section where educators may find curricular support, ideas, and resources and the scholarly, research literature regarding the use of robotics in education.

The *Robotics Education Locker*

https://stanleymoskeslausdca.schoolloop.com/roboticseducation, (January 2015), developed by the author's team of elementary school educators provides examples of robotics curriculum that thousands schools are already using.

Logistical Decision Making

The Guide includes recommendations that instructors apply the processes and tools of cooperative learning in their robotics curricula. Collaboration is one of the Four C's of 21st Century learning outcomes along with communication, critical thinking and creativity. All work in robotics should be done in teams of three or four students per robot. Through this engagement students learn that teamwork is a crucial skill in the modern workplace, as scientists, engineers, as well as industries' workforce floor employees are regularly engaged in the team work and problem solving to meet everyday challenges. Robotics activities in the workplace and in the classroom lend themselves to group solutions so it is important for students acquire the skills of the team player, thinker, designer, collaborator and communicator.

Deciding on the size and number of student teams.

For elementary school classrooms, four students-per-kit is ideal, and for equity purposes (NAPE, 2015) it is recommended that teams be comprised of two girls and two boys. For afterschool programs and clubs it is recommended that three-students-per kit works well because you have less students in the club and easier to manage.

Utilizing cooperative learning structures that define tasks and roles for teams is quite important as it provides a variety of opportunities for students to learn the full range of roles on a rotating basis, allowing them to learn about both individual and shared responsibility for all aspects of the engineering design process that includes building, programming, creating, etc. When working with team of three the suggested roles are (1) Engineer (Builder), (2) Software Specialist (Programmer), (3) Information Specialist (Gets the necessary information for the team to move forward). For teams of four an additional role is that of the (4) Project Manager (thoughtful leader).

Equipping the Robotics Program

When purchasing robotics kits one robot for each team of 3-4 students is generally recommended. Also, the teacher should acquire several backup robots in case of emergency situations, but this is not necessary at the outset. A few updated computers, ideally, one computer for each robotic team of students will be needed as most of the students' activity will be independent and self-directed while programming, testing, and multiple debugging during and after each practice. (Here it is noted that robotics promotes persistence as students must continue this until they reach satisfactory solutions to coding problems. Multiple computers will provide easy access to the programming language, eliminate 'traffic jams' and changing another team's program that can inadvertently occur with few available computers

Providing a Robotics Practice Area

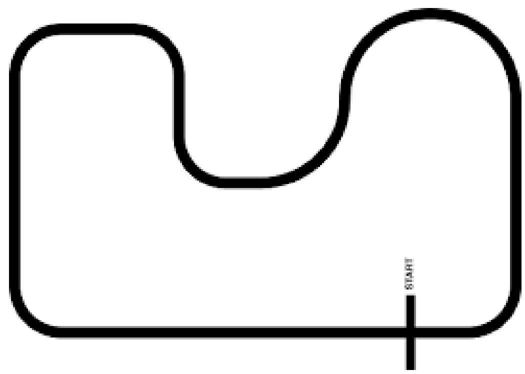
Recommendations are provided in the Guide to arrange for adequate space in the class room that is large enough to accommodate all the student teams, computers, practice tables, projector for lessons, and storage area for the robots. Acquiring access to a multipurpose room or an auditorium is ideal for an after school robotics program. A practice table is not required but providing it will help avoid damage to robots and keep activities accessible to all students. At a minimum, the table should have borders to prevent robots from falling off. Instructors will find a projector to be most valuable in reviewing videos, building instructions, and sample programs with the entire class.

A storage space where parts are easily organized and accessible to teams, is quite necessary. The Guide provides many storage options that include portable organizers, drawer cabinets, boxes, caddies, etc. These can be readily located online and at local hardware and crafts stores.

Figure 3.3

Sample Tables for Robotics

4 foot Diameter Sumo Table



Follow the line table 8x4 foot

Figure 3.4

Samples of ways to organize kits

After downloading the site license that is purchased separately (not provided with the kits) the software and curriculum for robotics will need to be loaded onto the school's network or each computer. The Mindstorm® Programs should be included in the school's regular system backup or the instructor should make a backup to a flash drive or CD.

Addressing Funding Needs

A typical classroom budget will consist of robotics kits, programming language, curriculum, materials, and competition fees. The final cost for your robotics program will depend on the size of your team and activities (competitions and showcases). The Guide provides typical costs to use when calculating an annual budget (all prices subject to change).

As mentioned earlier, when buying the robotic kits the programming software classroom license for the LEGO NXT-G® or the LEGO EV3® must be purchased separately The Guide provides some potential sources of funding for elementary school programs that can come from a wide range of sponsors within the community. These would include (1) the school or school district, (2) local businesses, and (3) local non-profit organizations. It recommends for example that local small and large business within the neighborhood be solicited for supporting the robotics teams for school showcases or for local, state and regional competitions. Being sure to acknowledge sponsors at every opportunity; for example, printing their names on your team shirts, banners, event programs, and flyers is important in both maintaining and growing your robotics support network.

Professional Development and Training

The Guide recommends that at the outset of a robotics program instructors should connect with the robotics-educator community locally and virtually. By finding another robotics team in the school's area and asking to attend their practice sessions it can be very helpful for first-time robotics leaders. Attending robotics academy trainings often offered as colleges and universities or at LEGO® Robotics Educators Conferences are also very helpful. Schools that wish to offer robotics across grade levels might hold a series of professional developments followed by teachers creating a supportive robotics professional learning community in which they support one another with the implementation of robotics.

Chapter 4: RESOURCE GUIDE WEBSITE

While developing this project, I decided to use our school website to develop my robotics resource guide for teachers, I chose to use https://stanleymoskes-lausd-ca.schoolloop.com/ (January 2015).This web site was is a web site that we already use for our school. This site was developed and provided by my school on site technology coordinator, he gave me the necessary access to develop my own pages to incorporate my robotic lessons and resources into the site. My goal was to make sure that the staff and parents were able to access the resources to help them to incorporate more robotic PBL lesson into their classroom and share with the parents what their child is learning at school.

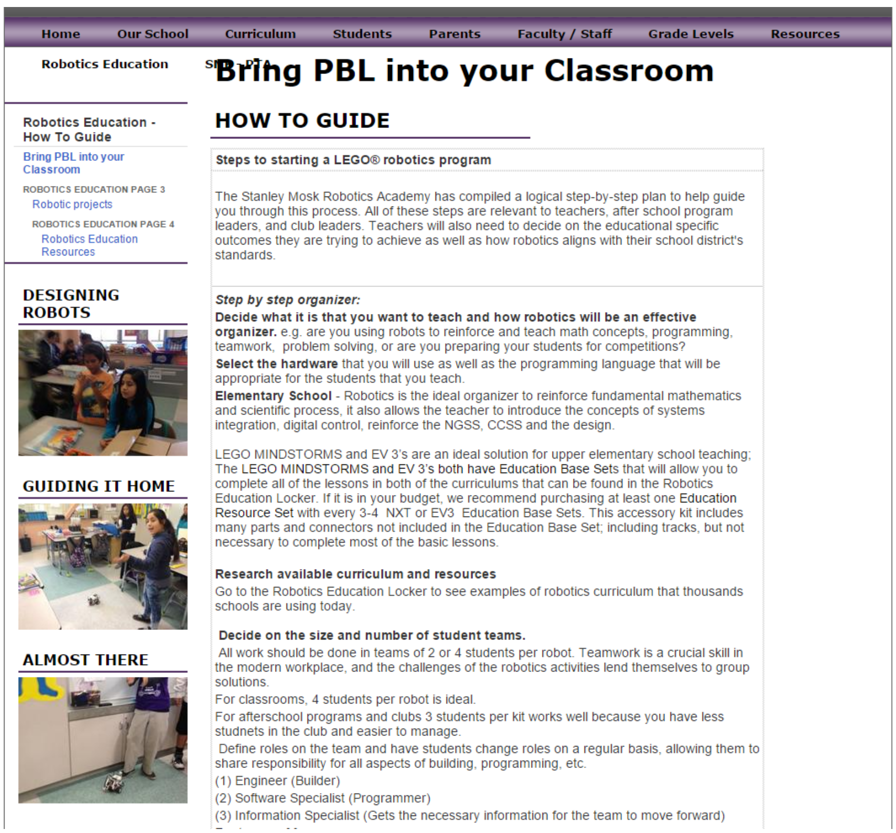


Figure 4.1

Web page Bring PBL in your classroom (May, 2015)

I chose this to use our school site because it is very well established site that is visited very often by our students, parents, staff and community. I wanted the school staff and others have the opportunity to visit a friendly site that has an abundance of resources for several of the robotic kits that we use at our school site. Using this site allowed me to have the capability to house on abundance of resources for our staff and students to use in the classroom, afterschool and at home.

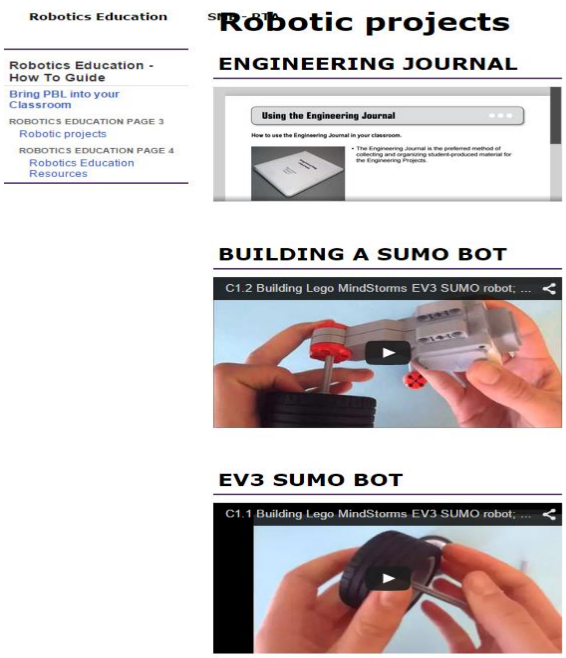


Figure 4.2

Sample Robotic project on the Web page (May, 2015)

This site interface is a great tool for schools who are looking into building a powerful web site for their high tech needs on the web. This site allows one to add video, pictures, large amounts of written data, and ability to create a variety of folders/lockers that can hold a large amount of files that some sites give limit storage capabilities. This site allows a variety of page templates, page setups and themes for the site. Not only does this site have the capability to hold a large amount of files for your every need, but the use of school loop gives you the capability to link external videos and images.

Chapter 5: Discussion and Conclusion

When working on the robotic project, I had fun keeping the students engaged, but one must remember that the lesson needs to be meaningful, not just to build a robot and make it run. When working through the lesson, "the really difficult part of teaching is not organizing and presenting the content, but rather doing something that inspires students to focus on that content to become engage" (Leamson, 2000, pg. 37).

Robotics give the students plenty of opportunity to use engineering and technology to help boost science instruction for both the teacher and the student. "The integration of robotics into the science curriculum capitalizes on the embedded science concepts", (Kimmel, Carpinelli, Burr-Alexander, Hirsch, & Rockland, 2008, pg. 54). When students work on the design concept of a robot it helps them stay engaged on the task at hand in order to fulfill obstacles they will encounter while programming the robot.

The obstacle and the real life world situations that the students must encounter before building the robot will be given to them in a scenario format. Students must build a robot and program it to grab a Lego block and move it into another position in the room while avoiding obstacles. This will be closely related to the problems that NASA-JPL had when they were maneuvering the Mars Rover. The students will work in groups of four and use measuring devices such as yard sticks and compasses to help them come up with an appropriate program in order for their robot to complete the task. When developing the program, designing the robot, and working as a team, the group will need to problem solve in order to successfully finish the obstacle given. When students use active learning they are likely to trouble shoot and problem solve through an obstacle as opposed to giving up on the first few tries. While applying sight, sound, and touch to a lesson this allows the students to immerse themselves into the hands on activity. According to (Kimmel, Carpinelli, Burr-Alexander, Hirsch, & Rockland, 2013, pg. 57).

> "The Learning Pyramid shows that students learn and retain 90% of new knowledge when they are engaged in purposeful activities with their peers. When they learn something new and then teach their peers they are likely to retain 90% of the information. In difference, only 5% is learned when teachers use lectures, and 10% is retained when students read the information."

As the students get involved through the entire lesson, the design process, and challenges, this research is out to show that by having engaging hands on activities it will have the students retain more of the lesson and stay engaged while learning. Also having the hands-on component of the lesson is truly beneficial to the engagement portion of the lesson but the students will also enjoy the process of solving a real life engineering scenario.

Conclusion

After the completion of this project, I hope to encounter that students have a higher retention rate of knowledge when the lesson is presented in a hands-on, engaging activity using robots to guide the lesson. Also I would like to prove that students found the lessons to be enjoyable and challenging while working with their peers in order to solve the problem they were given, while applying science and technology in their learning process.

I hope to find that students have found that working in groups on a project based lesson will keep them fully engaged while working with robotic lesson. My overall goal is to keep engagement level high and distraction level low, with an understanding of what is being taught throughout the lesson. The use of Lego Education kits which include LEGO Mindstorm NXT®

and LEGO EV3® robotic kits will be the driving force to help keep student engagement high while math, science and technology will be addressed in the P.B.L. lesson.

Once this type of robotics lesson has been completed the goal is to continue using project based lessons in order to help keep students engaged in all core subject areas. My goal is to find new, exciting, and challenging ways to get students participating more in lesson without the drag and drab of being bored to learn the topic being taught. Today, as teachers we are constantly competing with portable technology that keep students engaged in the video game that they are playing. If we can find similar means of engagement that help students learn about technology and have them engaged in school subject we may have a chance to challenge and prepare them for the jobs that are coming in the near future.

Bringing robotics into the 3rd through 5th grade classroom continues to be a challenge. However, the results of the my project helped illuminate issues that will help other after school programs and elementary school teachers interested in attempting systemic adoption of robotics and engineering education in their classroom.

The often quoted phrase 'learning by doing' is never more appropriate than in a PBL environment designed to teach students how to build autonomous robots. Such a learning context is highly student-centered as opposed to teacher-centered. Designing a robot to do even a simple task can place extensive demands on students' individual creativity and problem-solving abilities. At the same time, the learning context allows students to work in a constructionist, collaborative learning environment that promotes the sharing of ideas. Furthermore, (Resnick, 1996) suggest that this type of constructionist learning environment is well suited to *learning in a digital world* because it requires the learner to produce artifacts (in this case, a robot) that can be shared with a larger audience.

The current project only begins to explore the potential of how robotics can be effectively used in a PBL environment. The design of similar instructional projects calls for the development of creative teaching techniques in a student-centered learning context.

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