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This study was designed to gauge teacher perspectives on student learning outcomes for three common science, technology, engineering and math (STEM) programs. Lego Robotics, website development and model bridge building were compared in an effort to understand the impact of different components of STEM programs on student learning outcomes. Key variables that were studied were student motivation, engagement, collaboration and independent learning. In addition, the value of a program to teach skills that were likely to lead to future STEM success was discussed. Results indicated that Lego Robotics programs were significantly better at providing positive educational outcomes for a variety of measures when compared to other STEM programs.

Headings:

Education, Teaching

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Teaching Pre K-8

STEM EDUCATION IN THE K-8 CLASSROOM: COMPARING ROBOTICS TO WEBSITE DEVELOPMENT AND MODEL BRIDGE BUILDING

by
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Introduction

Science, Technology, Engineering and Math (STEM) programs have been gaining momentum in the world of education. Many people believe that STEM skills are necessary in order to remain competitive in the 21st century global workforce. However, there is surprisingly little research about STEM education. What's more, there doesn't seem to be a standard definition about what STEM programs look like or what a program needs in order to be considered a STEM program.

When thinking about my own experiences teaching science and STEM programs, there seems to be a common thread with the lessons or projects that really stand out in the STEM field. These are the projects where there is heavy interaction between two or more of the STEM disciplines. Using technology in an authentic way when learning science makes technology a tool for engaging in scientific inquiry. Students who build a scale model of a cell use math as a tool for scientific inquiry. These types of learning experiences integrate multiple STEM disciplines so completely that the experience would be incomplete if one of the disciplines were absent.

In the absence of a standard definition of STEM programs, I decided to create my own definition. STEM can be defined as a program that creates learning experiences by integrating two or more of the following disciplines: science, technology, engineering and math. In addition, the integration happens in an authentic way so that each integrated discipline is essential to the success of the program as a whole.

If we examine the ‘T’ in STEM, there is interesting literature about best practices surrounding technology use in the classroom. There are two major ways technology can be used in the classroom: high-level use and low-level use (Inan et al 2010). While there are many low-level uses of technology, some examples might include teachers using PowerPoint presentations to deliver instruction, viewing Internet resources, viewing simulations. Student low-level uses of technology might include typing an assignment, searching for web resources or checking assignments online. Although low-level technology use of this type is not very student-centered, nor what is considered by experts to be best practice, it is the most common way technology is used in schools (Ertmer and Ottenbreit-Leftwich 2010, Kopcha 2010, Inan et al 2010).

High-level, student-centered technology use in classrooms might include data gathering, creative representations of knowledge, real world problem-solving and open-ended problems (Kopcha 2010, Inan et al 2010).

I would argue that similar, high-level instruction in the other STEM fields is just as important as it is in technology instruction. This high-level, inquiry-based instruction in technology is consistent with much of the mainstream educational research. The emphasis should not be on low-level rote learning, but on high-level, process-based learning.

This paper seeks to examine teacher perspectives on Lego Robotics programs as a high-level STEM program. At a minimum, Lego Robotics incorporates high-level technology use and engineering as students construct and program robots. At its best, Lego Robotics incorporates all four STEM disciplines.

For the purposes of this study, Lego Robotics will be compared to two common STEM programs: website development and model bridge building. Each of these programs has different levels of technology integration and hands-on manipulatives. Lego Robotics programs have a high level of technology integration and a high level of hands-on manipulatives. Website development has a high level of technology integration and a low level of hands-on manipulatives. Model bridge building has a low level of technology integration and a high level of hands-on manipulatives. I hypothesize that STEM programs that include high levels of both technology integration and hands-on manipulatives lead to better educational outcomes than STEM programs that do not include high levels of both technology integration and hands-on manipulatives.

Literature Review

Much of the current literature on STEM programs or STEM-related education seems to be geared toward high school and college environments. There seems to be a distinct lack of significant research on elementary and middle school STEM programs. Just as it's important to begin teaching reading, writing and arithmetic early in the primary years, instruction in STEM skills should begin early as well.

Elementary and Middle School STEM

In their article, Bautista and Peters (2010) discussed an inquiry-based STEM project that was conducted in a first grade classroom. Through several hands-on activities, students used skills in science, math and engineering to design and create model houses meant to withstand common environmental concerns. The article describes the process the teacher used in her classroom to teach this particular unit. The project began with a knowledge activation technique where students talk about what they know and what they would like to learn about a particular subject. In this case, the subject was houses. Students spent time examining current houses and recording information that they observed about materials and structure. When it was time to build their model houses, students were given money to 'purchase' supplies from the classroom supplies. They were required to use math and planning skills to stay within their price range. Students used materials to build their model houses. After the houses were constructed, they were subjected to three stress tests: wind, rain and earthquake. At the end of the experience, the students and teacher reflected on the experience and talked about what worked best and what didn't work. The article discussed the positive results of inquiry-based STEM projects but the difficulties teachers have integrating them into a curriculum that emphasizes math and language arts. This article is a very good resource for teachers who are looking to incorporate project-based, integrated work into their classrooms.

Gerlach (2010) discussed a STEM teaching lesson that involved an inquiry-based model plane building activity. In this activity, students were able to think critically and design model airplanes that they would test. The author described the design process that was used as a design, building, test, record data and analyze results cycle. After completing one cycle of this experience, students had the opportunity to go through the cycle again and design and build a new flying craft. According to the author, this type of double experience allows students the valuable experience of learning from mistakes of making improvements to maximize success. The author notes that this type of repetition deepens a student's understanding of the topic and introduces them to real-world science. This article offers a good resource for teachers who are interested in design-based, open-ended activities.

In an article by Miller, Chang and Hoyt (2010), the authors explore a possible tool that can be used by teachers to conduct virtual STEM lessons in forensics. The article describes a traveling museum and an online software package that is based on the CSI television series. The software package can be used by students, teachers and families to explore virtual crime scenes, collect evidence and conduct forensics tests. The authors note that some of the scenarios are more advanced than others and that teachers can enhance the software experience by teaching concepts that students might encounter in the software. This article just explored the software and did not offer any true evaluation.

However, there was a call for additional research on the impact of games on learning. Serious games have been in the news recently as a tool for business and government, but this article offers a nice perspective on how gaming can be used in the school setting within tight budgets.

Perrin (2004) discusses four activities that can be used as tools to introduce engineering to elementary students. The author notes that many elementary science lessons revolve around life and earth science, but neglect some basic physical science topics despite their inclusion in National Science Education Standards. The four activities in this article focus on sound, light, temperature and objects in motion. Each of the activities uses physical experimentation in combination with computer software and USB based sensors. The author offers several positive outcomes of the discussed activities including the acquisition of foundational science concepts, implementation of current technology and the understanding of how everyday things work. This article presents STEM education as something that needs a foundation in the early grades. It's a very good article that supports teaching some of the basic physical sciences that are often neglected in the curriculum in younger grades.

Robotics and its Impact on Science and Math Achievement

Barak and Zadok (2009) experimented with three different versions of robotics instruction. Each version exposed some interesting information about instructional delivery methods.

The first version of the course was taught in the "traditional teacher-instructed" method where content about how the robotics components worked was taught to students.

While the article does not discuss the science outcomes for this type of instruction, it does mention that student motivation was low.

The second version of the course did not include any discrete science instruction, rather students were given tasks to complete with robotics in a project-based format. Students, in this version of the course, were unable to explain various scientific concepts.

In its third iteration, the course was revised to include small workshops that taught some science concepts via a constructivist approach. In this final version students began using scientific terms as they worked on their robotics tasks.

Barak and Zadok (2009) conclude that project-based work alone or teacher-instructed work alone does not result in the best learning outcomes for students. They suggest that instruction should take place within the context of a project-based framework.

Sullivan (2008) takes on the idea of science literacy through robotics as a skill set that students acquire. She describes several skill sets gained through robotics that are considered to be skills sets of those who are scientifically literate. For example, skills in "computation, estimation, manipulation, and observation." She also describes components of scientific literacy gained through robotics such as design, programming and learning about systems.

Cejka, Rogers and Portsmore (2006) did research that was primarily concerned with teacher perspectives on scientific lessons that could be taught with robotics. They show that teachers are able to teach specific topics (some of which had been previously neglected) using robotics programs. While not the focus of the article, student outcomes were discussed briefly. The student learning outcomes appeared to be positive.

Matson et al (2004) discussed a STEM program that was meant to increase student interest in math and science. The focus of the article was in rural and underserved elementary school populations. In this program traveling program, classes are initially prepared for a robotics visit through a workbook that is mailed out in advance of the program. The visit day consists of an hour-long event per class that includes demonstrations and usage of pre-built robots and other tools such as video. The article discusses several of the robotics demonstrations. After the robots visit, there is a follow-up and then a program improvement process. The authors discuss the positive impact that their program has on increasing student interest in STEM education and offer future directions for their program. This article does a great job highlighting the need for equal access to STEM programs despite a lack of resources.

There are several other articles that discuss various aspects of robotics programs and some of the potential benefits gained by participants. Caron (2010) discusses how robotics competitions encourage high school students to think "outside the box." Ewers (2010) discusses how robotics can be used outside of the traditional classroom to encourage participants to think about careers in scientific fields.

Robotics and its Impact on Student Motivation and Engagement

Rogers and Portsmore (2004) offered an extensive survey of the types of activities and educational benefits of using LEGO robotics to bring engineering to the elementary classroom. The authors described the basic tools and learning techniques that LEGO robotics affords as well as an elementary sequence of topics that can be used to guide implementation from kindergarten through fifth grade. In this article, STEM subject such as engineering, math and science were explored with technology being the programming that makes it all work. In addition, the authors explored the integration of reading and writing into the robotics program. In addition to the successes of such programs, the authors discussed challenges to implementation such as the need to teacher training and how gender differences impact the program. In addition, other positive aspects of the program were discussed such as student engagement and motivation. Because engagement and motivation are so important for success in the classroom, this article presents some good evidence for use of programs like Lego Robotics that tend to have a high level of engagement.

Petre and Price (2004) argue that robotics programs are a particularly motivating technology. Part of what the authors attribute as a draw to robotics is the "fascination" people seem to have with them. In a problem-based robotics scenario, the authors describe what might best be described as a means-to-an-end system of learning whereby students seem to be motivated to learn new skills in an attempt to get closer to their end goal. In addition, the authors note that students learned about "social contexts" inherent in this type of group work.

Likewise, Brand, Collver and Kasarda (2008) claim that student motivation in robotics programs might be rooted in the real world applications that the discipline holds. In their article, the authors describe a program aimed at older high school students who work with high school teachers and graduate students who act as mentors. They conclude that the program, called MCVTRC, helps increase student "comfort level with…science, technology, engineering, and mathematics…."

Robotics and its Impact on Student Collaboration

Piotrowski and Kressly (2009) discuss a form of robotics program that stresses both collaboration and real-world problem solving. In their article, the authors describe a classroom challenge where students are set to the task of creating robots designed for bomb disposal. The students worked in pairs, with each pair set to solve the same task. What is unique about this program, other than the strong real-world connection, is that each pair was not meant to compete with classmates, but cooperate and collaborate with them. The authors note that the perceived collective purpose of the students' work increased a desire to perform well.

Lego Robotics and Younger Students

There are several articles that discuss specific ways teachers have implemented robotics programs in schools. Many of those articles speak to high school or college level programs. However, there are several instances of robotics being used in the K-8 classroom. Most of these articles seem to describe Lego Robotics as the specific type of program of choice.

Murray and Bartelmay (2005) describe a project-based approach to teaching robotics for a second grade class at Duke School in Durham, North Carolina. Their integrated approach to using Lego Robotics not only had students building robots during their "Project Workshop" time, but also had students connecting their experiences to the experiences of real-life inventors during "Reading Workshops." In addition, the second grade students would participate in a "circle time" at the end of each project session that were, essentially, knowledge and experience sharing sessions. This type of sharing further highlights to significant amount of social interaction and collaboration that contributes to learning in robotics programs.

Bayley and Mackey (2008) discuss the implementation of a Lego Robotics program where elementary students have specific differentiated roles. In their small groups, students would rotate through the roles of "engineer, programmer, troubleshooter, tester and recorder" daily. By assuming specific roles, the students were essentially experts for a day in their role, but were also able to explore all the roles or robot development.

Matthew and Wilson (2006), discussed teachers approaches "to educate students about engineering." Elementary and middle school students took on the role of engineers. Using Lego Robotics, they designed and built robots to be used in a competition.

Bers (2008), in her book Block to Robots, offers several vignettes about teachers experiences using Lego Robotics in the early childhood classroom. There is also a wealth of information for teachers who are seeking methodological information about robotics integration into their curricula. Also, helpful rubrics for writing a robotics curriculum and teaching standards that are accomplished through such programs are presented.

Author's Thoughts

There is abundant literature about how robotics programs are used in the classroom. I've read vignettes about strictly project-based implementation and accounts of instruction-based implementation. Some articles discussed increasing student motivation and interest in the classroom, while others often sidelined skills such as collaboration and problem-solving.

It's clear that there is some excitement surrounding robotics in the classroom. But as with all technology use in schools, it seems best practice for its implementation still needs to be examined and refined. What should a robotics program look like to achieve high motivation, strong learning outcomes and maximized interpersonal and analytical skills? As a STEM tool, are robotics programs better at teaching the necessary skills for a 21st century education?

Methodology

My hypothesis is that STEM programs that include high levels of both technology integration and hands-on manipulatives lead to better educational outcomes than STEM programs that do not include high levels of both technology integration and hands-on manipulatives. To support this hypothesis, K-8 teacher perspectives were used. Participants were limited to K-8 teachers who implement one or more STEM programs in robotics, website development or model bridge building. In order to solicit a large participation pool, a web-based survey instrument was developed and deployed. This survey was designed to measure basic teacher and demographic characteristics and opinions about effectiveness of specific STEM programs. The survey instrument contained questions leading to both quantitative and qualitative data.

Sampling and Participants

In order to reach as many participants as possible, an email solicitation was sent to several teacher mailings lists. These mailing lists were a combination of free teacher lists, lists in paid teaching membership organizations and a list through a company that distributes STEM products. Each list was used because it was likely to contain a significant number of K through 8 teachers. However, the likelihood that those teachers use the three STEM programs targeted by this research was not known.

In addition to first-level solicitations by the researcher, a form of snowball sampling was employed. Participants and recipients of the solicitation email were asked to forward the solicitation to other potential participants in an effort to increase the sampling pool. Participants who received the solicitation email as a forward are considered second-level participants. There was no measure to determine the difference between first-level and second-level participants.

The subscriber details for each mailing list are unknown. In addition, the extent to which email solicitations were forwarded is unknown. While the response rate and demographic distribution appear to be encouraging, it's impossible to know if the sample is representative of the K-8 teacher population being studied.

The survey period was from December 1, 2010 until February 28, 2011.

Survey Instrument

Qualtrics survey software was used to construct the survey instrument. The survey was designed to capture demographic information and opinions about the targeted STEM programs. The majority of the questions were close-ended and a few were open-ended questions that allowed textual responses.

While the solicitation email clearly described the type of participant desired for the research, the survey included two test questions to determine if participants matched the sample profile. If respondents to the survey were not K-8 teachers or if they did not teach one of the three targeted STEM programs (Questions #1 and #6 in Appendix A), they were redirected to the end of the survey and their initial responses were excluded from evaluation. These test questions were placed early in the survey so that respondents who did not meet the research profile had a minimal amount of time wasted.

The demographic sections of the survey were meant to capture basic profiles of the survey respondents. Some questions about demographics were asked near the beginning of the survey and some were asked toward the end. The initial demographic questions solicited information about respondents teaching roles. These questions included grade or grades taught, school type and philosophy, type of classroom environment and a general location based on the first three digits of the zip code. The demographic data toward the end of the survey was designed to gather information about each respondent's personal profile. This included information about gender, age, educational attainment and years of teaching experience. These questions can be found in Appendix A.

When respondents met the research profile, they were presented with questions about the specific STEM programs that they had indicated were included in their 'normal teaching schedule.' The content of the questions for each STEM program were essentially the same with the one exception being for respondents who indicated use of robotics programs were asked an additional yes or no question about the type of robotics program. The other two STEM programs had no such yes or no question.

The questions about the STEM programs consisted of basic programmatic structure questions, Likert-style opinion questions and open-ended questions. The programmatic structure questions were meant to gauge the scope and style of the STEM programs that were taught. These included questions that measured how much time was spent in a particular STEM program during the school year and whether students worked individually, in pairs or small groups or in a combination of individual and small group situations. These are questions #7 through #13 in Appendix A.

The initial block of Likert-style questions were designed to measure teacher opinions about the effectiveness of their implemented STEM programs in four areas of educational outcomes. These areas were motivation, engagement, collaboration and independent learning. In addition, there was one question included that was meant to measure the degree to which such programs facilitate interdisciplinary learning.

Table 1 shows the questions that were asked for each STEM program implemented along with the targeted educational outcome. The exact wording of these questions can be found in Appendix A, questions #14 through #19. These questions were asked using a five-point Likert-style scale with the headings of strongly disagree, disagree, neither agree nor disagree, agree and strongly agree. These potential responses were assigned the potential values of 1 through 5, respectively.

Table 1

Question:	Educational Outcome Variable:
Work at learning new things	Motivation
Generally pay attention and focus on what I am teaching	Engagement
Generally do class-related tasks and assignments willingly	Motivation
Are genuinely interested in what they are asked to learn	Engagement
Share ideas with each other	Collaboration
Consider each others' ideas	Collaboration
Listen to each other	Collaboration
Design their own creations	Independent Learning
Design their own experiments	Independent Learning
Have become more independent learners	Independent Learning
Have gained a deeper understanding of other academic subjects	Interdisciplinary Learning

In addition to the questions above that ask respondents to provide opinions of STEM programs alone, the survey instrument included a second block of questions that were designed to measure opinions of STEM programs implemented by the respondents as compared to other STEM programs. Before answering these questions, respondents were provided with the broad definition of STEM education found in the survey language in Appendix A just before questions #20 through #22.

For respondents that indicated implementation of only one of the three targeted STEM programs, they were asked a yes or no question to determine if they were familiar with other STEM programs. If they indicated that they were not familiar with other STEM programs, they were not provided the opportunity to answer these particular questions. If respondents indicated implementation of more than one of the targeted STEM programs, it was assumed that they were familiar with more than one STEM program and they were taken directly to these questions. The questions were designed to measure engagement, collaboration, motivation, general opinion of educational outcomes and acquisition of skills needed for future STEM endeavors. Table 2 shows the questions that were asked of respondents along with the educational outcome as compared to other STEM programs. The exact wording of these questions can be found in Appendix A, questions #23 through #25. These questions were asked using a five-point Likert-style scale with the headings of strongly disagree, disagree, neither agree nor disagree, agree and strongly agree. These potential responses were assigned the potential values of 1 through 5, respectively.

Table 2

Question:	Educational Outcome Variable:
Are better at engaging students in STEM work	Engagement
Are better at teaching students how to collaborate	Collaboration
Provide better educational outcomes for students	General Educational Outcomes
Are better at motivating children to do well in the classroom	Motivation
Are better at providing skills to children that they need to be prepared for future STEM endeavors	STEM Skills Acquisition and future STEM preparation

Survey questions #30 through #38 listed in Appendix A were open-ended responses based on the type of STEM program that respondents indicated were implemented in their classrooms. The purpose of these open-ended questions was to allow for anecdotal or quotable responses from participants. Because of the limitations of the survey and Likert-style responses, there may be educational outcomes or trends in

STEM programs that were not included in the survey instrument. The open-ended questions offer an opportunity to gain some information on such outcomes or trends.

Data Analysis

Data were analyzed using a combination of JMP software and the Qualtrics survey software. The Qualtrics platform provided tools for evaluating basic descriptive statistics and for graphing those data.

JMP software was used for more complex statistical analyses such as t-tests.

When analyzing the data specific to educational outcomes, two types of data groups were created. First, participants were differentiated based on number of STEM programs they taught. If teachers only taught a single STEM program that was studied, they were placed in one group. This group was compared using t-tests. Teachers who reported implementing two or more of the programs studied were analyzed as a separate group. This group was compared using matched pair t-tests.

When looking for larger trends in the data, the entire dataset was analyzed together. These types of analyses were designed to find demographic trends in STEM implementation. Fisher's exact tests were used for these analyses.

Ethical Concerns

The Institutional Review Board (IRB) of the University of North Carolina at Chapel Hill reviewed and approved the procedures and instruments of this study. The IRB considers the safety of human subjects a top priority. As such, great care was taken to assure that participants were informed of their rights and were exposed to no more than minimal risk.

Before participating in the survey for this study, potential participants were informed of the purpose and scope of their involvement. If they chose to participate in the survey, they were made aware that they could skip any question for any reason and could quit taking the survey at any time.

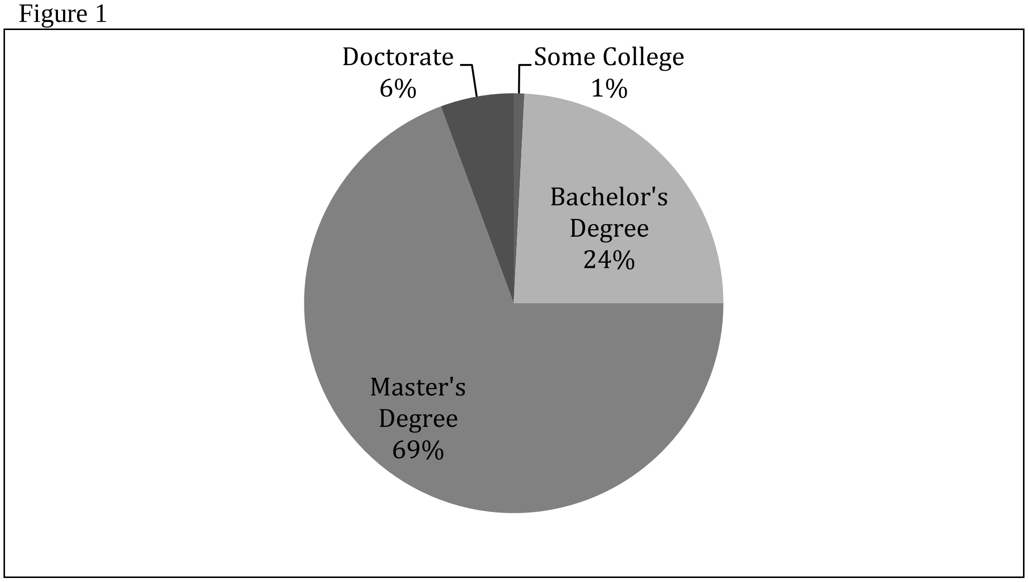
Efforts were made to protect participants' identities, however IP addresses were automatically collected as respondents participated in the survey. When the data were exported to the statistical software, IP addresses were stripped from the results. No participant identifying information was linked to responses.

Results

During the survey period from December 1, 2010 through February 28, 2011, 390 participants clicked on the survey link. Of those, 248 were respondents that fell within the desired parameters. Survey responses that were excluded from evaluation included 42 incomplete responses, 26 that indicated a grade level teaching responsibility outside the desired range and 74 respondents that did not teach the desired STEM topics. In addition, 9 respondents who indicated use of a robotics program other than Lego Robotics but also use of model bridge building and/or website development had their data regarding robotics programs excluded.

The participants of this study were 60% female and 40% male. Over 75% of the participants reported an educational attainment level of masters degree or higher. Figure 1 shows the percentage of respondents at each educational level.

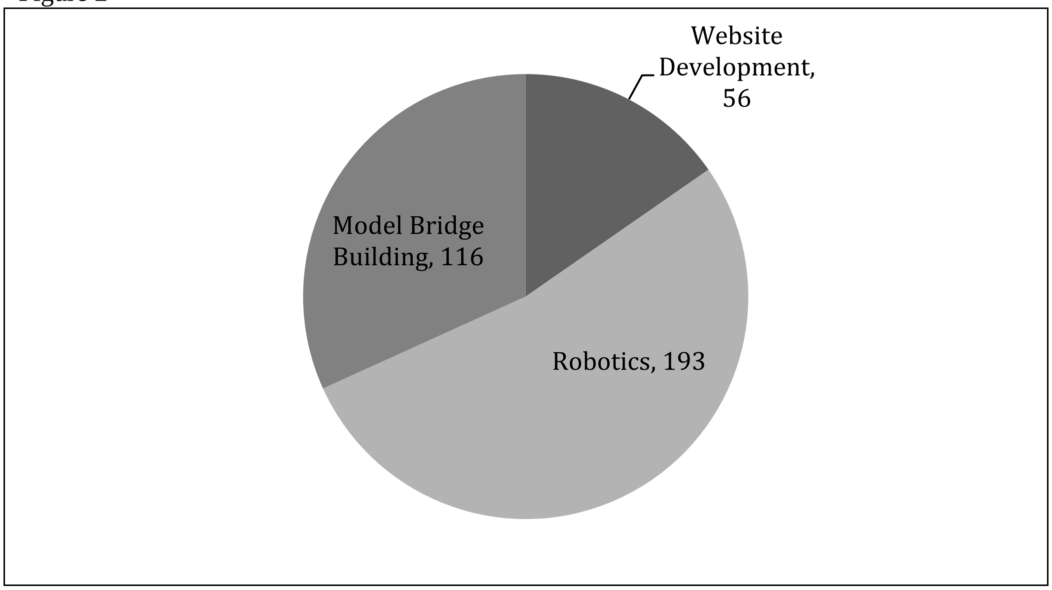
Figure 1



Respondent Educational Attainment Levels

Figure 2 shows the number of respondents who indicated that they implemented each of the three targeted STEM programs. Respondents may have indicated implementation of more than one program.

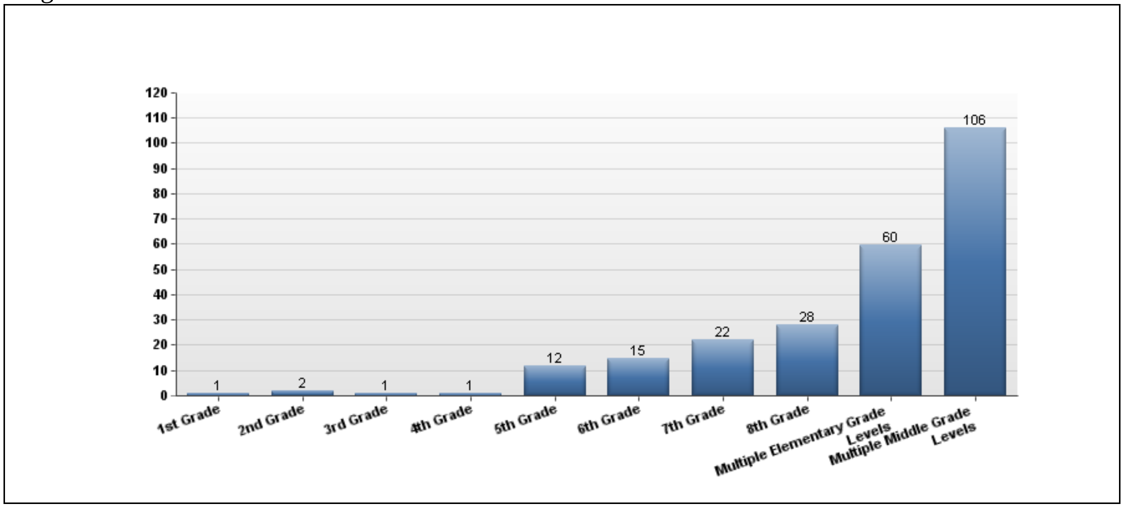
Figure 2



STEM Programs Implemented by Respondents

Participants in this study had a broad range of teaching responsibilities. While the terms "elementary" and "middle" grades vary in schools, the data indicate that most respondents had teaching responsibilities in the middle grades. The Kindergarten grade level had no teacher respondents and grades one through four had relatively few. However, 60 respondents indicated teaching responsibilities for multiple elementary grades. Assuming that most schools consider K-5 as elementary school and grades 6-8 as middle school, the participants can be assigned as elementary school teachers or middle school teachers. Under this assumption, 77 (31%) respondents were elementary school teachers (K-5) and 171 (69%) were middle school teachers (6-8). Figure 3 shows the breakdown of the teaching responsibilities as indicated by the respondents.

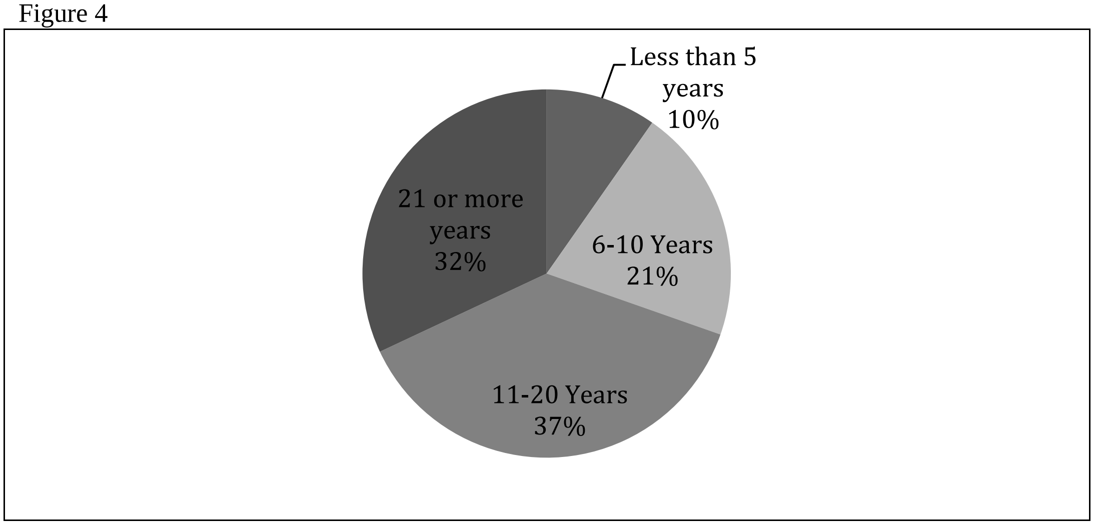
Figure 3



Respondents by Grade Level Teaching Responsibility

In addition to variations of grade level teaching responsibilities and type of STEM program implemented, respondents to the survey had a broad range of teaching experience and educational attainment. Figure 4 shows how many years of teaching experience the participants reported. Nearly 70% of the respondents had been teaching for eleven years or more.

Figure 4



Years of Respondent Teaching Experience

Data from respondents who only indicated teaching one of the three STEM programs were analyzed separately from respondents who implemented two or more of the STEM programs. Of the 248 respondents, 100 only indicated implementing a Lego Robotics program, 40 indicated only implementing a model bridge building program and 9 indicated only implementing a website development program.

Table 3 compares measures of teacher perspectives student motivation (2 measures), engagement (2 measures), collaboration (3 measures) and independent learning (2 measures) in Lego Robotics programs to model bridge building programs. In addition, t-tests were performed to determine if there were significant differences ($p<0.05$) between each of the measures. The means for teacher perspectives on student performance in Lego Robotics programs were greater for all measures compared to model bridge building programs. However, significant differences were only obtained for one measure of student motivation, one measure of student engagement, two measures of student collaboration and one measure of student independent learning.

Table 3
Comparison of teacher perspectives of those who only implement one STEM program studied

Groups	Lego Robotics (n=100)		Model Bridge Building (n=40)			
Variable	M	SD	M	SD	T-Ratio	p<0.05
Work at learning new things (motivation)	4.40	0.63	4.10	0.81	2.10	yes
Pay attention and focus (engagement)	4.23	0.66	4.10	0.67	1.04	no
Do tasks and assignments willingly (motivation)	4.39	0.63	4.23	0.89	1.07	no
Interested in what they are learning (engagement)	4.45	0.59	4.05	0.93	2.52	yes
Share ideas with each other (collaboration)	4.49	0.61	4.07	0.83	2.87	yes
Consider each others' ideas (collaboration)	4.19	0.61	3.82	0.84	2.48	yes
Listen to each other (collaboration)	4.06 n=99	0.67	3.83	0.81	1.63	no
Design their own creations (independent learning)	4.33	0.82	4.23	0.12	0.72	no
Design their own experiments (independent learning)	3.86 n=99	1.07	3.46 n=39	0.91	2.18	yes

Table 4 compares measures of teacher perspectives student motivation (2 measures), engagement (2 measures), collaboration (3 measures) and independent learning (2 measures) in Lego Robotics programs to website development programs. In addition, t-tests were performed to determine if there were significant differences ($p<0.05$) between each of the measures. The means for teacher perspectives on student performance in Lego Robotics programs were greater for all measures compared to website development programs. However, significant differences were only obtained for one measure of student motivation, both measures of student engagement, one measures of student collaboration and one measure of student independent learning.

Table 4
Comparison of teacher perspectives of those who only implement one STEM program studied

Groups	Lego Robotics (n=100)		Website Development (n=9)			
Variable	M	SD	M	SD	T-Ratio	p<0.05
Work at learning new things (motivation)	4.40	0.63	4.22	0.44	1.11	No
Pay attention and focus (engagement)	4.23	0.66	3.89	0.33	2.63	Yes
Do tasks and assignments willingly (motivation)	4.39	0.63	4.00	0.50	2.19	Yes
Interested in what they are learning (engagement)	4.45	0.59	4.00	0.50	2.54	Yes
Share ideas with each other (collaboration)	4.49	0.61	4.22	0.67	1.16	No
Consider each others' ideas (collaboration)	4.19	0.61	3.78	0.44	2.59	Yes
Listen to each other (collaboration)	4.06 n=99	0.67	3.78	0.44	1.75	No
Design their own creations (independent learning)	4.33	0.82	4.11	0.60	1.01	No
Design their own experiments (independent learning)	3.86 n=99	1.07	2.78	1.09	2.85	Yes

Of the 149 respondents that indicated implementing only one of the targeted STEM programs, 116 indicated being familiar with other STEM programs. These participants were asked additional questions about how the STEM program that they implemented compares in to other STEM programs. These questions included single measures of student engagement, collaboration, educational outcomes, motivation and a measure about skills acquisition and preparation for future STEM endeavors.

Table 5 compares these measures of teacher perspectives of student performance in Lego Robotics programs and model bridge building programs. While Lego Robotics had higher means in all measures, only one measure was significantly different. The measure of skills acquisition and preparation for future STEM endeavors was significantly different at $p<0.05$.

Table 5
Comparison of teacher perspectives of those who only implement one of the STEM programs studied, but who are familiar with other STEM programs

Groups	Lego Robotics (n=71)		Model Bridge Building (n=40)			
Variable	M	SD	M	SD	T-Ratio	p<0.05
Better at engaging students	3.72	0.65	3.50	0.85	1.41	no
Better at teaching how to collaborate	3.87	0.83	3.60	0.84	1.65	no
Better educational outcomes	3.62	0.72	3.50	0.91	0.72	no
Better at motivating children	3.90 n=70	0.78	3.70	0.85	1.22	no
Better at providing skills to children that they need to be prepared for future STEM endeavors	3.94	0.79	3.58	0.81	2.32	yes

Table 6 compares these measures of teacher perspectives of student performance in Lego Robotics programs and website development programs. Lego Robotics programs showed significant differences ($p<0.05$) in all but one of the measures of student performance. There were significant differences ($p<0.05$) in measures of student engagement, educational outcomes, motivation and skills acquisition and preparation for future STEM endeavors. There was no significant difference in measures of teacher perspectives on student collaboration.

Table 6
Comparison of teacher perspectives of those who only implement one of the STEM programs studied, but who are familiar with other STEM programs

Groups	Lego Robotics (n=71)		Website Development (n=5)			
Variable	M	SD	M	SD	T-Ratio	p<0.05
Better at engaging students	3.72	0.65	2.80	0.84	2.40	Yes
Better at teaching how to collaborate	3.87	0.83	3.40	0.89	1.15	No
Better educational outcomes	3.62	0.72	2.80	0.84	2.14	Yes
Better at motivating children	3.90 n=70	0.78	2.80	0.84	2.85	Yes
Better at providing skills to children that they need to be prepared for future STEM endeavors	3.94	0.79	2.80	0.84	2.96	Yes

Data from respondents who indicated implementing two or more of the targeted STEM programs were compared using paired t-tests. 67 participants indicated that they had implemented both Lego Robotics and Model Bridge Building programs. Very few respondents indicated implementation of all three programs. Teacher perspectives on student motivation (two measures), engagement (two measures), collaboration (three measures) and independent learning (two measures) were measured.

Table 7
Comparison of teacher perspectives of those who implement two or more STEM programs studied

Groups	Lego Robotics	Model Bridge Building				
Variable	M	M	N	M Difference	T-Ratio	p<0.05
Work at learning new things (motivation)	4.46	4.34	67	0.12	1.82	Yes
Pay attention and focus (engagement)	4.30	4.25	67	0.04	0.69	No
Do tasks and assignments willingly (motivation)	4.54	4.38	67	0.15	1.74	Yes
Interested in what they are learning (engagement)	4.52	4.34	67	0.18	2.44	Yes
Share ideas with each other (collaboration)	4.51	4.35	67	0.15	2.31	Yes
Consider each others' ideas (collaboration)	4.19	4.20	67	-0.01	-0.22	No
Listen to each other (collaboration)	4.12	4.10	67	0.01	0.26	No
Design their own creations (independent learning)	4.32	4.39	67	-0.06	-0.57	No
Design their own experiments (independent learning)	3.78	3.82	67	-0.04	-0.39	No

Table 7 shows the means comparisons of teacher perspectives on student performance for Lego Robotics Programs and model bridge building programs. There were significant differences ($p<0.05$) in both measures of motivation, one measure of engagement and one measure of collaboration.

Thirty eight respondents indicated that they had implemented both Lego Robotics and website development programs. The same teacher perspectives were measured for this pair of STEM programs. Table 8 shows the results of the paired t-tests. There were significant differences ($p<0.05$) for both measures of motivation, one measure of collaboration, and one measure of independent learning.

Table 8
Comparison of teacher perspectives of those who implement two or more STEM programs studied

Groups	Lego Robotics	Website Development				
Variable	M	M	N	M Difference	T-Ratio	p<0.05
Work at learning new things (motivation)	4.58	4.34	38	0.23	2.48	Yes
Pay attention and focus (engagement)	4.37	4.28	38	0.08	0.77	No
Do tasks and assignments willingly (motivation)	4.71	4.42	38	0.29	2.73	Yes
Interested in what they are learning (engagement)	4.74	4.53	38	0.21	1.95	No
Share ideas with each other (collaboration)	4.68	4.61	38	.08	0.83	No
Consider each others' ideas (collaboration)	4.58	4.34	38	0.24	2.69	Yes
Listen to each other (collaboration)	4.37	4.18	38	0.18	1.56	No
Design their own creations (independent learning)	4.63	4.50	38	0.13	1.15	No
Design their own experiments (independent learning)	4.42	3.71	38	0.71	4.72	Yes

Paired t-tests were also performed for respondent perspectives on the three STEM programs and how they compared to other STEM programs in general. Table 9 shows differences in responses for those who implemented Lego Robotics programs and model bridge building programs. There were significant differences ($p<0.05$) in three of the five measures. Differences were found in measures of collaboration, motivation and skills acquisition and preparation for future STEM endeavors.

Table 9
Comparison of teacher perspectives of those who implement two or more STEM programs studied

Groups	Lego Robotics	Model Bridge Building				
Variable	M	M	N	M Difference	T-Ratio	p<0.05
Better at engaging students	4.14	4.05	64	0.09	1.14	No
Better at teaching how to collaborate	4.14	3.95	64	0.19	2.35	Yes
Better educational outcomes	3.95	3.92	64	0.03	0.42	No
Better at motivating children	4.22	3.95	64	0.27	3.41	Yes
Better at providing skills to children that they need to be prepared for future STEM endeavors	4.09	3.95	64	0.14	2.12	Yes

Table 10 shows differences in responses for those who implemented Lego Robotics programs and website development programs. There were significant differences ($p<0.05$) in all five measures. These measures included measures of engagement, collaboration, educational outcomes, motivation and skills acquisition and preparation for future STEM endeavors.

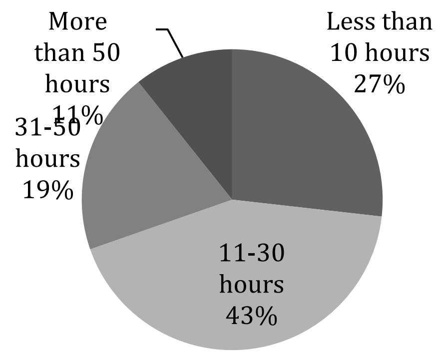
Table 10
Comparison of teacher perspectives of those who implement two or more STEM programs studied

Groups	Lego Robotics	Website Development				
Variable	M	M	N	M Difference	T-Ratio	p<0.05
Better at engaging students	4.26	3.66	38	0.61	4.07	Yes
Better at teaching how to collaborate	4.26	3.66	38	0.61	3.73	Yes
Better educational outcomes	4.16	3.71	38	0.45	3.81	Yes
Better at motivating children	4.34	3.95	38	0.39	3.22	Yes
Better at providing skills to children that they need to be prepared for future STEM endeavors	4.26	3.95	38	0.32	2.51	Yes

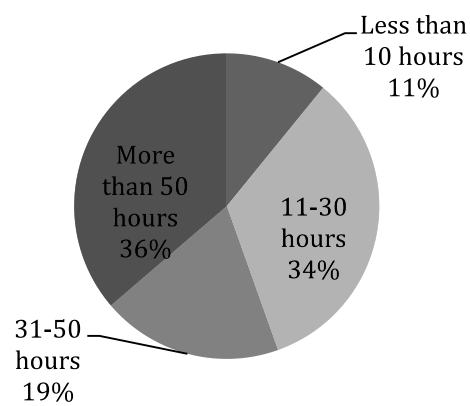
Participants in this study were asked to report how much time their students would spend doing a given STEM program in their current school year. Figure 5 compares the time spent per STEM program. T-tests were performed on these data and time invested in robotics programs was significantly different ($p<0.05$) that time invested in either website development or model bridge building.

Figure 5

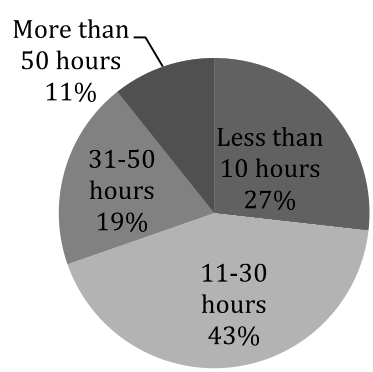
Website Development



Robotics



Model Bridge Building



Hours Spent Engaged in STEM Programs

Respondent data were also analyzed based on the grade level that participants listed as their primary responsibility. Using Fisher's Exact Test, the likelihood that elementary school teachers implemented a Lego Robotics program was greater than for middle school teachers ($p<0.01$, $n=248$). Fisher's Exact Test also indicated that the likelihood that middle school teachers implemented a model bridge building program was greater than for elementary school teachers ($p<0.01$, $n=248$). There was no significant difference based on grade for implementation of website development programs.

Discussion

This study was designed to gain a better understanding of the effectiveness of Lego Robotics programs compared to two other STEM education programs. The primary gauge used to understand these programs was the perspective of teachers on such programs. Before discussing the results of the study, it's important to understand the validity of teacher perspectives on educational outcomes.

Many current studies in education have used teacher perspectives and teacher rankings of student performance as a basis for their analyses. Hoge and Coladarci (1989), in their literature review, examined several studies that worked to understand the validity of teacher perspectives on student performance. They concluded that, while not the best measure of student performance, teacher perspectives were generally on par with student performance. They go on to suggest that researchers should consider teacher perspectives just as they would other measurement tools.

Overall, the group of respondents to this study represents a highly educated and highly experienced group of K-8 teachers. The teachers seem to have a broad range of STEM experiences. Some teachers were unfamiliar with STEM programs other than the one that they implemented. Others were aware of other STEM programs or even implemented multiple STEM programs. The respondents seemed to represent a diverse group of educators.

Lego Robotics, model bridge building and website development are all STEM programs that teachers seem to view favorably as educational tools. On average, teachers who implemented Lego Robotics and/or model bridge building had responses that were better than neutral on the Likert scale responses for educational outcomes. For those teachers who implemented website development programs, average Likert scale responses were somewhat mixed. Website development programs seemed to offer good educational outcomes in some areas, but not in others. Each program, however, seemed to have educational merit and a justified place in the classroom.

When teachers and schools decide on how to invest their funds when budgeting for STEM programs, they may have to prioritize which programs will be funded. As an educational tool, Lego Robotics programs seem to offer several advantages when compared to website development and model bridge building. Lego Robotics outperformed the other two programs in several measures with statistical significance. At the same time, the other two STEM programs did not outperform Lego Robotics on any of the measures with any statistical significance.

Robotics vs. Website Development

For the purposes of this study, website development was defined as having a high level of technology integration and a low level of hands-on manipulatives. Lego Robotics programs was defined as having a high level of technology integration and a high level of hands-on manipulatives.

When comparing teacher perspectives of various educational outcomes for each of these programs, the mean Likert responses for robotics programs appeared to be better than those of website development for all measures. While these results are encouraging for the support of robotics programs, not all measures were significantly different.

When looking at the responses of teachers who only implemented robotics as compared to teachers who only implemented website development, there is an interesting result. Teachers who implemented robotics programs indicated significantly higher engagement levels in their students than teachers who implemented website development programs. Engagement is a very important component to positive educational outcomes. Skinner and Belmont (1993) report that engagement and motivation is valued “for its long-term contribution to children’s learning and self-esteem.”

Responses by teachers who indicated teaching both robotics and website development programs were compared. This allowed for a direct comparison between responses for each program by teachers who implemented both programs. When comparing these responses, student motivation levels for robotics programs were significantly higher. Similar to engagement, student motivation is an important component to effective learning.

Teacher perspectives on the effectiveness of website development programs were not significantly higher in any measure than robotics programs. Groups of teachers indicated that robotics programs were significantly better on several measures of educational outcomes. Both programs include a significant technology component, but robotics incorporates physical manipulation of artifacts into the learning. The combination of technology and physical manipulation of artifacts may serve to make robotics programs more engaging and motivating to students than simply using technology alone.

Robotics vs. Model Bridge Building

For the purposes of this study, model bridge building was defined as having a high level of hands-on manipulatives and a low level of technology integration. Lego Robotics programs was defined as having a high level of technology integration and a high level of hands-on manipulatives.

When comparing teacher perspectives on student educational outcomes for these two programs, robotics programs significantly outperformed model bridge building on several measures. However, model bridge building compared more favorably to robotics than website development.

When looking at the perspective of teachers who only implemented one STEM program, robotics programs outperform model bridge building on five of the nine measures. However, robotics does not seem to significantly outperform model bridge building consistently in variables of motivation, engagement, collaboration or independent learning. While robotics programs may slightly outperform model bridge building programs in general, it's difficult to identify any key differences in educational outcomes or impact on learning.

However, when we compare responses for robotics programs and model bridge building programs for teachers who implemented both, robotics significantly outperformed model bridge building for both measures motivation. Teachers who see these two programs implemented together appear to notice a difference in student motivation.

Model bridge building did not outperform robotics programs on any of the measures of student performance. While many of the results were not significantly different, robotics programs do seem to offer slightly better results on several key measures.

Model bridge building includes a significant amount of hands-on work with physical artifacts, much in the same style as robotics programs. However, model bridge building lacks the strong technology component that is included in robotics programs. The results seem to indicate that working with a physical artifact has a greater impact on student learning than working with technology. STEM programs that implement a high level of the ‘E’ (engineering), might be better teaching tools than programs that concentrate on other areas.

Time Investment per STEM Program

Teachers devoted a significantly greater amount of classroom time to robotics programs than they did for either model bridge building or website development. This increase in time could be due to several factors. Depending on the curriculum, the programs themselves may serve to limit or demand time. Website development programs might be used more as presentation tools in conjunction with another project. Some model bridge building programs might be in the form of a challenge that lasts for only a few class periods. Because robotics programs include both construction and programming, they may necessarily require more instructional time.

Despite the reasons for robotics programs being given more time, teachers seem willing and eager to devote the increased time to robotics programs. With limited time for implementing a full curriculum, this time commitment is a testament to the value teachers place of robotics programs and their benefits.

<u>Robotics and Skills Acquisition</u>

When participants who implemented a particular STEM program were asked to compare it against other STEM programs, some interesting data resulted. It's important to note that the Likert responses were given after some key characteristics of STEM programs were described. Respondents didn't necessarily implement other STEM programs, but were, at the very least, familiar with other STEM programs.

Lego Robotics programs were statistically different from model bridge building and website development on a key measure. This was the measure that asked whether a program provided skills that children need to be prepared for future STEM endeavors. Lego Robotics programs were ranked significantly better in this measure by all data subgroups for all programs.

Gaining STEM skills that will be valuable in future STEM endeavors is a very important educational outcome. As student progress through school, they use prior knowledge as a basis for future learning. When teachers begin teaching new topics, many of them start with an exercise that is meant to activate prior knowledge. The teachers in this study have indicated that they value the skills that Lego Robotics can provide to students. These skills are not limited to the Lego Robotics platform, but are transferable to other STEM endeavors.

While these skills were not defined in this research, participants in this study offered their thoughts on the benefits that Lego Robotics provides to students. Responses to these open-ended questions on the survey contained several high-level skills that respondents claimed were achieved through Lego Robotics programs. The skills that were mentioned most frequently included problem solving, teamwork, collaboration, creativity and logical thinking.

Elementary School vs. Middle School

When participants were grouped according to the grade level they taught, some interesting trends appeared. Participants who implemented Lego Robotics programs were significantly more likely to be elementary school teachers. And, participants who implemented model bridge building programs were significantly more likely to be middle school teachers. There was no difference for participants who implemented website development programs.

Not only does Lego Robotics appear to be better in several measures of educational outcomes, but it appears to be more developmentally appropriate for children in the elementary school setting. There are several reasons why this may be the case.

Lego Robotics programs allow students to test ideas and modify those ideas in a relatively short amount of time. Because of this, students aren't bound by a single decision through the course of their project. Younger students, who may still be acquiring scientific skills such as predicting, are able to try different design and programming ideas while gaining immediate feedback about functionality. This immediate feedback during a trial and error method allows for many smaller successes throughout the project implementation. In addition, troubleshooting behaviors might be limited to a problem on a micro scale rather than the whole project on a macro scale.

Many children are familiar with Lego building blocks. The construction component of Lego Robotics programs have similar building supplies while offering additional pieces. Familiarity with a product's function may be appealing to children.

The method of construction may already be intuitive. Children just need to assimilate the purpose and function of the additional pieces into their knowledge.

The programming language of Lego Robotics programs is flexible enough to appeal to many experience levels. Functional robots can be controlled using very simple programming. For more advanced students, the programming can become more complex using conditional statements, loops and other programming techniques. In addition, most programming is done with an intuitive graphical user interface.

Lego Robotics programs are very open-ended and facilitate inquiry-based learning. Although other STEM programs are frequently inquiry-based and allow for freedom of design, Lego Robotics programs allow for a wide range of final products. Where model bridges tend to have a single function, Lego Robots might navigate an obstacle course, sound an alarm when a temperature is reached, respond to movement, or many other possible functions. This versatility allows students and teachers to create products to solve a wide range of problems.

Model bridge building appears to be more developmentally appropriate for children in the middle school setting. There are several reasons why this may be the case.

Model bridge building programs require students to think about abstract concepts. Because students in middle school are developing and refining their abstract thinking skills, model bridge building seems to be an appropriate STEM program for this age group.

Unlike Lego Robotics, it’s more difficult to test individual components of a bridge and determine how they will function in the final design. Students who participate in model bridge building may have to make a series of predictions that won't be tested until after the bridge has been fully constructed.

There is significant flexibility in construction materials for model bridge building. The pieces don't simply snap together in certain ways. Model bridges may require cutting materials, shaping material, gluing and other processes. These types of actions might be too challenging for elementary school students but appropriately challenging for middle school students.

Limitations

This study is meant to be an initial look into the perspectives of teachers on educational outcomes of three STEM education programs. As such, this study has several limitations that should be considered as future research is conducted.

This study would be stronger if the data were more quantitative in nature. If I were to have access to standardized test scores of individual classes, a more uniform evaluation of actual student performance could have been conducted.

This survey instrument for this study was distributed using snowball sampling techniques. This is a type of convenience sampling that is not random. A study with a true random sample may have yielded different results and may have been more representative of the population.

Due to the nature of the survey, the definitions of the STEM programs were not given to the participants. Participants were required to decide on their own if their implemented programs could be considered one of the three STEM programs. The data don't tell us if a website development STEM program used HTML programming skills, Google Sites, Dreamweaver or other programs to do the actual website development.

Each of these types of programs may have a different impact on teacher perspectives and student learning outcomes. The same is true for model bridge building programs. The survey didn't determine if participants implemented bridge building programs using popsicle sticks, metal construction kits, spaghetti or other types of bridge building programs. These differences may also impact teacher perspectives and student learning outcomes.

For all three programs, there are several other variables that were not considered. The culture of learning in a classroom may have an impact on how each of these programs may be implemented. Open-ended tasks that might be assigned during each of these STEM programs may illicit different student responses depending on how the classroom culture normally operates. Teachers may also compare the final products to other examples in the world. Since student websites may appear rudimentary compared to professional sites on the web, teachers my not value the result as much robots and model bridges that don't have a ubiquitous real-world counterpart.

Since much of the survey data relies on the judgment of teachers, it may not be the best, true measure of the outcome variables despite the literature that supports such conclusions. Not only do the data's accuracy rely on the truthfulness of the reporter, but it also assumes that the teacher has a strong grasp of the educational outcomes of his or her students. Teacher attitudes may have impacted the study results. Because robotics programs tend to be more costly than the other two STEM programs, there may be a higher perceived value for the robotics program.

Because this survey was distributed electronically, some potential participants were necessarily excluded. It's possible that some teachers may be implementing technology education, including robotics programs, but might not have full access to the Internet.

There were several respondents who indicated implementing a Lego Robotics program or a model bridge building program. However, the number of respondents who indicated implementing a website development program was somewhat low. A greater number of respondents who implemented a website development program would have been desirable and would have made the results for that program more reliable.

There may be data, outside the scope of the survey, that impact the outcome variables. School budget and available tangible and non-tangible resources for teachers (including professional development opportunities), might have an impact.

While there were data that supported the hypothesis, it is not possible to attribute causation to the variables being examined. The use of high-level technology integration practices such as those used in robotics programs may very well occur with other best practice teaching methods and tools. In short, using various best practice teaching methods may have a greater impact on student learning than any single variable that is also considered best practice.

For this study, three STEM programs were chosen based on how students interact with each of them. Some of these programs may not have equal applicability across the K-8 spectrum. Teachers may be more likely to implement robotics programs over several grades whereas website development or model bridge building might be more age appropriate for middle school students.

Future Research

Several opportunities exist to expand on this initial research. STEM programs have become popular topics in the education community. However, it seems that much of the research is targeted on high school or college students and programs. STEM programs of various types are suitable for K-8 classrooms. These programs have the potential to have a significant impact of student learning. As schools plan to increase their STEM offerings, it's important for them to have research to help guide their decisions.

Lego Robotics seems to be a strong STEM program that can be used in K-8 classrooms. Future research might aim to determine how strong Lego Robotics is as a STEM program. For a study of this sort, a quantitative research model using random samples might help provide more conclusive evidence to support the use of Lego Robotics in K-8 classrooms.

This study is limited to three STEM programs. There are certainly other STEM programs that are suitable to K-8 classrooms. While robotics appears to be a strong program for this grade range, research on other STEM programs should be done so that schools and teachers can gain a broad understanding of the positive impacts of STEM programs.

Professional Recommendations

The data from this study lead to several conclusions or recommendations that can be made when educators choose to implement STEM programs in the K-8 classroom.

Robotics Programs

Overall, teachers rated Lego Robotics programs significantly better in multiple measures. It seems that teachers believe that Lego Robotics programs are more engaging, motivational and collaborative. Students who participate in Lego Robotics programs are reported to engage in increased independent learning. Lego Robotics was reported to be significantly better at providing children with the skills they need to be prepared for future STEM endeavors.

In addition, Lego Robotics programs are more likely to be implemented in the elementary classroom than other STEM programs. This indicates that robotics programs are suitable for younger students. But since Lego Robotics was also implemented in middle school, it can also be taught at a more sophisticated level. Lego Robotics has a wide range for potential implementation.

Because Lego Robotics appears to teach students necessary foundational STEM skills and because it can be implemented in younger classrooms, it seems to be an ideal tool to have in the 21st century elementary classroom.

Lego Robotics does require a significant initial investment. Of the three STEM programs, it is the most expensive. However, when looking at the educational outcomes and the reusability of Lego Robotics, the initial investment will result in ongoing educational benefits. In addition, multiple teachers and classrooms can share resources throughout the year.

The data suggest that elementary teachers should implement STEM programs like Lego Robotics in order to give students a foundation in STEM skills and prepare them for future STEM endeavors.

Model Bridge Building Programs

While model bridge building programs did not outperform Lego Robotics, there does seem to be merit in its implementation in the classroom. According to the data, model bridge building has good educational outcomes. It does seem to be a program that is best used with middle school students. In addition, model bridge building does not appear to be a foundational STEM program. Students who participate in model bridge building will most likely need to have some STEM skills already in place. And because model bridge building often requires cutting, shaping and gluing of materials, better fine motor skills are required. Model bridge building doesn't appear to be a good program for younger elementary school students.

In many cases, materials for model bridge building programs are inexpensive. Programs may use materials such as glue and popsicle sticks. While the initial investment is rather low, materials will need to be replenished each year. Over time, the cost of a model bridge building program adds up.

Model bridge building appears to be a strong program that provides good educational outcomes in STEM learning. It does, however, have a limited age group for which it can be implemented. The data suggest that model bridge building programs should be implemented in middle school classrooms in order to build on students' existing STEM skills.

Website Development

Of the three STEM programs in this study, website development programs appear to offer the lowest level of educational outcomes. Not only were the number of teachers who implemented website development low, but the means for the educational outcomes were somewhat low as well.

Website development can take many forms. It can be pure HTML coding, application supported design such as Dreamweaver or web-based design such as Google Sites. Depending on the type and scope of a website development program, students may engage in high-level technology use or low-level technology use. Implementation of website development program may be more successful with older students. Coding in HTML isn't something that younger elementary students will be able to do. Younger students might find some success in using website development applications, but it will most likely be in a low-level format.

It's clear that using Web 2.0 tools such as Google Sites is important. It's also important for students to have an understanding of how websites function. Website development programs appear to work best as components of a larger program. They might work best as a tool to present information from another class. As a STEM program, however, website development is somewhat weak.

Conclusion

STEM education is a buzzword that has been gaining popularity. But there seems to be little research about best practices for STEM implementation and educational outcomes for students in grades K through 8. Of the three STEM programs included in this study, robotics programs seemed to outperform website development and model bridge building on several key measures of student success. Robotics programs also seemed to be better at preparing students with the skills they need as they engage in additional STEM endeavors. Of the three programs, Lego Robotics seemed to be the most age-appropriate for younger students. Also, Lego Robotics seems to offer the high-level technology integration that is important to authentic learning. While there was some evidence to support my hypothesis, more research needs to be done to determine which STEM factors have the most impact on student learning outcomes.

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Appendix A

1. Which of the choices below best describes your primary teaching responsibility?

- Kindergarten
- 1st Grade
- 2nd Grade
- 3rd Grade
- 4th Grade
- 5th Grade
- 6th Grade
- 7th Grade
- 8th Grade
- Multiple Elementary Grade Levels
- Multiple Middle Grade Levels
- Other

2. Which of the following best describes the type of school where you teach?

- Public
- Independent
- Parochial
- Charter
- Other

3. Which of the following best describes the educational philosophy of the school where you teach?

- Traditional
- Progressive/Project Based
- Montessori
- Other

4. Would you consider your classroom self-contained (do you teach the same group of children for the majority of the school day)?

- Yes
- No

5. What are the first three digits of the zip code for the school where you teach?

zip code (first three digits)

6. During the school year, which of the following do you teach during your normal teaching schedule (check all that apply)?

- ❑ Website Development
- ❑ Robotics
- ❑ Model Bridge Building
- ❑ None of these

7. For this school year, how many hours do you plan for your students to spend doing website development?

- ❍ Less than 10
- ❍ 11 to 30
- ❍ 31 to 50
- ❍ More than 50

8. For this school year, how many hours do you plan for your students to spend doing robotics?

- ❍ Less than 10
- ❍ 11 to 30
- ❍ 31 to 50
- ❍ More than 50

9. For your robotics program, do you use Lego robotics?

- ❍ Yes
- ❍ No

10. For this school year, how many hours do you plan for your students to spend doing model bridge building?

- ❍ Less than 10
- ❍ 11 to 30
- ❍ 31 to 50
- ❍ More than 50

11. When students are working on website development, do they normally work individually or in pairs/small groups?

- ❍ Individually
- ❍ Pairs/small groups
- ❍ A mixture of individual work and pair/small group work

12. When students are working on robotics, do they normally work individually or in pairs/small groups?

- Individually
- Pairs/small groups
- A mixture of individual work and pair/small group work

13. When students are working on model bridge building, do they normally work individually or in pairs/small groups?

- Individually
- Pairs/small groups
- A mixture of individual work and pair/small group work

14. Most students in my website development class...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
work at learning new things	❍	❍	❍	❍	❍
generally pay attention and focus on what I am teaching	❍	❍	❍	❍	❍
generally do class-related tasks and assignments willingly	❍	❍	❍	❍	❍
are genuinely interested in what they are asked to learn	❍	❍	❍	❍	❍
share ideas with each other	❍	❍	❍	❍	❍
consider each others' ideas	❍	❍	❍	❍	❍
listen to each other	❍	❍	❍	❍	❍
design their own creations	❍	❍	❍	❍	❍
design their own experiments	❍	❍	❍	❍	❍

15. Most students in my robotics class...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
work at learning new things	❍	❍	❍	❍	❍
generally pay attention and focus on what I am teaching	❍	❍	❍	❍	❍
generally do class-related tasks and assignments willingly	❍	❍	❍	❍	❍
are genuinely interested in what they are asked to learn	❍	❍	❍	❍	❍
share ideas with each other	❍	❍	❍	❍	❍
consider each others' ideas	❍	❍	❍	❍	❍
listen to each other	❍	❍	❍	❍	❍
design their own creations	❍	❍	❍	❍	❍
design their own experiments	❍	❍	❍	❍	❍

16. Most students in my model bridge building class...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
work at learning new things	❍	❍	❍	❍	❍
generally pay attention and focus on what I am teaching	❍	❍	❍	❍	❍
generally do class-related tasks and assignments willingly	❍	❍	❍	❍	❍
are genuinely interested in what they are asked to learn	❍	❍	❍	❍	❍
share ideas with each other	❍	❍	❍	❍	❍
consider each others' ideas	❍	❍	❍	❍	❍
listen to each other	❍	❍	❍	❍	❍
design their own creations	❍	❍	❍	❍	❍
design their own experiments	❍	❍	❍	❍	❍

17. Because of their experience with website development, most students in my class...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
have become more independent learners	❍	❍	❍	❍	❍
have gained a deeper understanding of other academic subjects	❍	❍	❍	❍	❍

18. Because of their experience with robotics, most students in my class...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
have become more independent learners	❍	❍	❍	❍	❍
have gained a deeper understanding of other academic subjects	❍	❍	❍	❍	❍

19. Because of their experience with model bridge building, most students in my class...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
have become more independent learners	❍	❍	❍	❍	❍
have gained a deeper understanding of other academic subjects	❍	❍	❍	❍	❍

Science, Technology, Engineering and Math (STEM) education has been a hot topic in recent years. While there is no distinct definition of STEM education, it generally includes the following components: focus on student learning in one or more areas of Science, technology, engineering or math student problem-solving the potential for real-world application Please think about your experiences with STEM Education as you answer the following questions.

20. Are you familiar with STEM programs other than website development?

❍ Yes
❍ No

21. Are you familiar with STEM programs other than robotics?

❍ Yes
❍ No

22. Are you familiar with STEM programs other than model bridge building?

❍ Yes
❍ No

23. Compared to other STEM programs, I believe that website development programs...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
are better at engaging students in STEM work.	❍	❍	❍	❍	❍
are better at teaching students how to collaborate.	❍	❍	❍	❍	❍
provide better educational outcomes for students.	❍	❍	❍	❍	❍
are better at motivating children to do well in the classroom.	❍	❍	❍	❍	❍
are better at providing skills to children that they need to be prepared for future STEM endeavors.	❍	❍	❍	❍	❍

24. Compared to other STEM programs, I believe that robotics programs...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
are better at engaging students in STEM work.	❍	❍	❍	❍	❍
are better at teaching students how to collaborate.	❍	❍	❍	❍	❍
provide better educational outcomes for students.	❍	❍	❍	❍	❍
are better at motivating children to do well in the classroom.	❍	❍	❍	❍	❍
are better at providing skills to children that they need to be prepared for future STEM endeavors.	❍	❍	❍	❍	❍

25. Compared to other STEM programs, I believe that model bridge building programs...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
are better at engaging students in STEM work.	❍	❍	❍	❍	❍
are better at teaching students how to collaborate.	❍	❍	❍	❍	❍
provide better educational outcomes for students.	❍	❍	❍	❍	❍
are better at motivating children to do well in the classroom.	❍	❍	❍	❍	❍
are better at providing skills to children that they need to be prepared for future STEM endeavors.	❍	❍	❍	❍	❍

26. What is your gender?

- ❍ Male
- ❍ Female

27. What is your age?

- ❍ 21 to 30
- ❍ 31 to 40
- ❍ 41 to 50
- ❍ 51 to 60
- ❍ 61 or older

28. What is your highest level of education?

- ❍ High School Diploma
- ❍ Some College
- ❍ Associate's Degree
- ❍ Bachelor's Degree
- ❍ Master's Degree
- ❍ Doctorate

29. How many years have you been a teacher?

- ❍ Less than 5
- ❍ 6 to 10
- ❍ 11 to 20
- ❍ 21 or more

30. What do students learn most from website development programs?

31. What are the most important skills students gain from website development programs?

32. If another teacher were deciding on implementing a new program in his or her classroom, what argument would you make on behalf of a website development program?

33. What do students learn most from robotics programs?

34. What are the most important skills students gain from robotics programs?

35. If another teacher were deciding on implementing a new program in his or her classroom, what argument would you make on behalf of a robotics program?

36. What do students learn most from model bridge building programs?

37. What are the most important skills students gain from model bridge building programs?

38. If another teacher were deciding on implementing a new program in his or her classroom, what argument would you make on behalf of a model bridge building program?