Robotic Cooperative Learning Promotes Student STEM Interest

Pauline Mosley, Pace University, USA
Gerald Ardito, Pace University, USA
Lauren Scollins, Pierre Van Cortlandt Middle School, USA

ABSTRACT

The principal purpose of this investigation is to study the effect of robotic cooperative learning methodologies on middle school students' critical thinking, and STEM interest. The semi-experimental inquiry consisted of ninety four six-grade students (forty nine students in the experimental group, forty five students in the control group), chosen by their principals. A critical thinking test was administered to evaluate the cognitive skills and STEM interest of the students. Instruction was implemented in two formats: cooperative learning and problem-based learning. The experimental group utilized robotic cooperative learning while the control group utilized problem-based learning. After four sessions of both instruction types with both groups the findings reveal that critical thinking of students is enhanced significantly by robotic cooperative learning (P<0.01).

Keywords: Cognitive Skills; Cooperative Robotic Learning; Critical Thinking; LEGO Robotics; STEM; STEM Interest

CONTEXT AND BACKGROUND

There exist a phenomena among high school students' where they perceive that STEM subjects are hard and difficult and that they will fail if they pursue STEM courses, before even trying, so they never really know if they are interested or not. NSF data revealed that in 2010 only 7.5% of engineering or computer science technicians were African American or Hispanic. This percentage is considerably lower than the 12.2% national population of African Americans and Hispanics (NSF et .al., 2013). Experts in the field attribute this lack of STEM+C interest to students' perceptions that computing is "too hard", "expensive", and inadequate preparation and encouragement along educational transition points. Additional STEM research portray that students, in particularly minority students, are not interested in STEM at all. Multiple studies have been conducted trying to understand why the STEM decline exists? (University of the Sciences [USciences], 2012). Is it false perception (STEM is hard), lack of interest, poor pre-STEM preparation, lack of STEM minority-teachers, lack of awareness, poor self-efficacy, or some other reason? (PCAST, 2010, p. vi). For example, 18% of students in a recent Harris Poll cited a lack of knowledge about health science careers as the reason for low interest (USciences, 2012).

What we do know is that students from K-6 are very interested in the STEM subjects, however, as they begin junior high school and then high school this interest declines sharply. We also know that a major percentage of girls do not pursue the STEM subjects beyond eighth grade. Thereby impacting the STEM workforce and creating a gross disparity among gender and ethnicity within the STEM field. This is a very serious issue and everyone needs to encourage women and underrepresented minorities to stay with STEM.

(National Science Foundation, National Center for Science and Engineering Statistics, 2013). The STEM pipeline begins to get progressively weaker as students transition from elementary school to junior high to high school and college. Researchers are scrambling trying to correlate the decline to a specific reason. Numerous studies center around the student and the type of student and what the student is or isn't doing that may or may not that contributes to the decline. Very few studies have been done that focus on how the instruction and the instructional environment affect a student's ability to learn or be interested in learning.

This study introduces an innovative framework for addressing STEM decline. We propose that using robotics (a mechanical platform) cooperative learning pedagogy to instruct STEM education creates a nurturing instructional environment which cultivates a positive attitudinal student mindset towards STEM. Furthermore, the hands-on activities help to promote self-efficacy which will sustain their interest and provide the springboard for further pursuits in the STEM fields. Cooperative learning is being seriously considered as teaching tool to encourage students to think critically and problem-solve (Gillies 2014).

The presentation of STEM we believe is critical and pivotal as to whether or not a student will be engage or disengaged in learning STEM. The delivery of STEM and its overall presentation has a direct correlation of the cognitive aspects and student's perception as to ascertain if the knowledge unit is hard or simple. In a study investigating "the relationship between university students' perceptions of their academic environment, their approaches to study, and academic outcomes" (Lizzio et al. 2002) found that "students' perceptions of their current learning environment were a stronger predictor of learning outcomes at university than prior achievement at school". The core ideology within this framework is that students learn difficult concepts when they can play. In other words, the robotic cooperative learning curriculum is 90% hands-on laboratory classroom style. Whereas, the problem-based learning curriculum uses the traditional lecture-style classroom. In the hands-on laboratory classroom, the learning environment is very active and students perform hands-on experiments and have the opportunity to relate a kinesthetic activity to a concept. This visualization coupled with the kinesthetic helps to generate interest and is conducive to learning and not memorizing. In the problem-based learning environment, students are encouraged to mentally think through a solution as oppose to physically doing the solution. A student's confidence or self-efficacy shapes their attitude towards learning.

We believe that the robotic-cooperative learning environment promotes self-efficacy whereby stimulating a positive attitude towards STEM. According to motivational theories, self-efficacy is the belief in an individual's ability to execute the recommended courses of action successfully (Rogers 1975). A key to furnishing and sustaining this pipeline is to provide an educational experience that is not only exciting, relatable, but interweaves self-efficacy throughout the learning process. It has been proven that students who are confident in their STEM abilities typically perform better and persist longer in STEM disciplines than their counterparts (Britner & Pajares, 2006; Pajares, 2005). Academic achievement and future achievements can be traced back to one's self-efficacy in their ability (e.g., Bandura, 1997). This idea is further supported by the report "College Board AP Program Summary Report, 2013" published by NCWIT. It suggests that active engagement and innovative programs for young students can play a major role in stimulating interests in the STEM occupations.

Cooperative Robotics Learning

Service-Learning + Cooperative Robotics Learning = CIS 102Q Problem Solving Using LEGO Robotics. This service-learning offered at Pace University has no pre-requisites and is offered to freshman, sophomores, juniors, and seniors. Students enrolled in this course learn how to solve problems using robotic technology by working in groups. They perform demonstrations and assist local elementary schools in Westchester County in establishing a robotic club to inspire girls, in particularly, to learn programming. There is a lecture portion and a cooperative robotic laboratory component. The lecture portion of the course met one hour per week. Lecture topics included basic robotic principles, creative thinking, problem solving, and elementary programming concepts. A typical class session is 30-40 minutes which consists of a mini-lecture and a hands-on activity supporting the lecture. This learning style which implements a hands-on approach is dynamic because it enables the student to immediately apply what they have learn. The learning experience elucidates the relevancy of the course content. Hence, combining a robotics program with cooperative learning complements classroom learning and when implemented correctly, we believe that it can increase the critical thinking skills for girls. Almost all of the assignments and activities in the course, both in Pace classrooms and outside of the classroom (middle-school interaction) are team-based. Cooperative learning occurs first with the Pace University students at Pace. Mid-semester, that reiterate this learning with middle school students at the middle school and they take on the role of "instructor". Students realize in this learning environment that they need each other in order to learn and succeed. Consequently, the notion of a "being a team" and the characteristics of team activities become quite apparent when students learn very quickly that everyone in the team is learning and no one knows everything. As a team they can lean and learn from each other and everyone has a strength is very empowering.

For the first seven weeks of the semester, the Pace students are placed into teams consisting of three or four members. As a team they are given a robotic challenge each week which they must solve as a team. In addition, they are prepped for working with a younger student population and special instruction is given to all students who will be working with young girls. All students are encouraged to state positive comments to all girls that they will be working with. For example, "*Sally you are smart and we expect you to work on this robot*". Each team determines how the roles of: builder, parts specialist, programmer, and tester will be handled. Each section of Problem Solving Using LEGO Robotics partners with a middle school. The teacher of the middle school class places his or her class into teams of three or four members as well. In the last 4-5 weeks of the course, the Pace students travel to the middle school or agency and will work very closely with the middle school-teams in engaging them to learn about robotics. Prior to us visiting the classroom, students at the middle school will be in teams consisting of three or four students. The Pace student teams work with the middle school teams. This peer-to-peer group mentoring has proven to be extremely effective.

Cooperative Robotic Learning Labs

In 102Q Problem Solving Using LEGO Robotics there are four lab exercises designed to be fun while yet challenging the students to think as a team and develop solutions. Table 1 depicts all of the cooperative learning labs covered in this course. The Pace students will visit the school or agency the last four sessions of the course. During these visits they will engage the middle-school students into cooperative learning about the mechanics and programming of the robot. In addition, they will give additional attention to the girls in their group as instructed prior to the visit. Each of these labs is designed to be completed within 20 minutes since we usually only have about 45 minutes in total to work with the students. The objective of all of the labs is to motivate all of the students, but in particularly the girls to think critically and to develop problem-solving strategies when encountering the unknown.

The middle school students are placed into a four-team member group. The group has the task of building and programming the robot. The group can determine how they wish to divide these tasks as long as all members of the group have an opportunity to learn each phase of robotic construction and assembly. This cooperative learning environment provides students with hands-on experience with building and programming robots. The Pace students oversee these two-member teams and guide and coach them thru the lab.

Table 1. Lab Exercises for Six Grade Classes

Lab	Title	Objectives
1	Introduction	• To become familiarized with gears and gear ratios. • To understand the relationship between gears and motors in regards to acceleration.
2	Car Racing	• To construct a chassis using plates, beams, and connectors. • To understand how a motor works. • To learn basic programming concepts.
3	Sensors	• To become acquainted with the light and touch sensors. • To develop a solution using all the skill sets covered in class. • To learn untaught skills and troubleshoot issues as they arise
4	The Big Race	• To develop a solution using all the skill sets covered in class. • To learn untaught skills and troubleshoot issues as they arise

METHOD

Statistical Population

Statistical population of this research is composed of all six grade middle school students of Westchester County 2011-2012 educational year.

Sampling

Initially, two middle schools were chosen randomly and then two classes in six grade, one in empirical field (control group) and the other in cooperative robotics program (experimental group) were selected by their principals at each respective school. Ninety-four students (forty-five pupils from control group and forty nine from experimental group) participated in this study. The implementation of this experiment was pseudo-experimental by forming two sets that were dissimilar to pre and posttest. Table 1 reveals male (n = 48) and female students (n = 46) were approximately equally represented in the sample. The Pace University student break down in Table 2 clearly reveals that there is a shortage of young women exposing themselves to LEGO robotics on the college level. Only 23 women enrolled in this course as oppose to the 63 men who did.

Table 2. Six Grade Sampling Profile (Control Group)

Six Grade Classes	Student Gender Breakdown				Instructor
	Fall 2011		Spring2012		
Pierre Van Cortlandt	15 girls	11 boys	12 girls	11 boys	Lauren Scollins
	Spring 2012		Fall 2012		
Ward Elementary	11 girls	12 boys	8 girls	14 boys	Rob Nodoff
Totals	**26 girls**	**23 boys**	**20 girls**	**25 boys**	

Table 3. Pace University Student Profile (Experimental Group)

Class Sections	Student Gender Breakdown				Professor
	Fall 2011		Spring 2012		
CIS 102Q	7 girls	16 boys	6 girls	14 boys	Pauline Mosley
	Spring 2012		Fall 2012		
CIS 102Q	4 girls	18 boys	7 girls	15 boys	Pauline Mosley
Totals	**11 girls**	**34 boys**	**13 girls**	**29 boys**	

Assessment

The STEM engagement pretest and posttest was designed for the purpose of measuring young adults' engagement and self-efficacy using robotic cooperative learning methodologies. The constructs that were identified as being central to this endeavor included: STEM engagement, perceived risk of failing, self-efficacy for problem solving, self-efficacy for robotic concepts, and the intention to pursue STEM education. The scale is currently under revision as more input is being gathered from professionals and researchers. The table of specifications and estimates of reliability using Cronbach's alpha based on two administrations with approximately 46 participants is provided herein.

The posttest was a paper-and-pencil test consisting of 15 "drill-and-practice" items and 15 "critical-thinking" items. How does one assess "drill-and-practice"? The classifications of Bloom's Taxonomy such as: "knowledge," "comprehension," and "application" were categorized as "drill-and-practice" items. Any hands-on activity that pertained to beams, connectors, sensors, wiring, and building the robot. The items that belonged to "synthesis," "analysis," and "evaluation" classifications of Bloom's Taxonomy were categorized as "critical-thinking" items. These items required students to clarify information, combine the component parts into a coherent whole, and then using the NXT-G programming platform create an algorithm using the skill sets covered in class to solve a problem. The pretest consisted of 12 items, two items belonging to each classification of Bloom's Taxonomy.

RESULTS

The results of this study are presented and discussed in details in this section. At the beginning of this study, all eighty-six students indicated that they had no formal knowledge or experience with LEGO Mindstorms. Eight students stated that they had played with LEGO's as a child, but did not have any experience with LEGO Mindstorms. The pretest and posttest were slightly different and one should note that the was a difference between the pretest and posttest score, but it was not meaningful.

It became quite obvious that the that pretest variances among the groups were not significant. Analysis of the posttest scores were done to determine which learning environment using the t-test group's implementation is appropriate for this innovative framework. Furthermore, a covariance procedure was used to reduce the error variance by an amount proportional to the correlation between the pre and posttests. The correlation between the pretest and the posttest was significant ($r=0.21$, $p<0.05$). In this approach, the pretest was used as a single covariate in a simple ANCOVA analysis.

We conducted a t-test to further determine if the change in student's attitude was related to PBL or RCL. The outcome showed that the posttest scores for the participants in the RCL (12.56) was slightly higher than the PBL group (10.89). It is also interesting to note that the mean of the posttest scores for the participants in the RCL group (11.21) was higher than the PBL group (7.63). The data supports the claim that RCL warrants further investigation and that it does contribute to a student's attitude and how the student thinks critically. To what extend needs to be explored further. However, it did not show a significant difference between the two groups. The result is given in Table 4. An analysis of covariance procedure yielded a F-value that was not statistically significant ($F=1.91$, $p>0.05$). These conclusions are valid with confidence level of 95%. This result is presented in Table 4. An analysis of covariance yielded a F-value that was significant at the same significance level ($F=3.69$, $p<0.001$).

Table 4. Results of t-Test

Item	Method of teaching	N	Mean	SD	t	p
Drill-and-Practice	PBL	45	10.89	2.52	1.63	.08
	RCL	49	12.56	1.98		
Critical-thinking	PBL	45	7.63	3.01	3.23	.001***
	RCL	49	11.21	2.32		

The results of the test scores indicated that girls who participated in RCL had performed significantly better on the critical-thinking test than students who studied PBL. We are unsure as to what role the girl's self-efficacy contributed to this, but we do know that the repeated drill-and-practice certainly confirm what they knew which translated into a positive attitude. It was noted that both groups did equally well on the drill-and-practice test.

Pierre Van Cortlandt Mathematics Exam Scores

At the end of the year of the study, students were required to take the 2012 6th Grade New York State Mathematics Exam. Several data points were collected for each students (e.g., total score, performance level, etc.) which included what the New York State Education Department (NYSED) refers to as standard Performance Indices (SPIs): Number Sense and Operations; Algebra; Geometry; Measurement; and Statistics/Probability. Figure 1 shows these SPIs and their definitions.

Figure 1. NYSED Standard Performance Indices for the 2012 6th Grade Mathematics Exam

Standard Performance Index (SPI) Strand	SPI Description
SPI1: Number Sense and Operations	Students will: • understand numbers, multiple ways of representing numbers, relationships among numbers, and systems; • understand meanings of operations and procedures, and how they relate to one another; • compute accurately and make reasonable estimates.
SPI2: Algebra	Students will: • represent and analyze algebraically a wide variety of problem solving situations; • preform algebraic procedures accurately; • recognize, use, and represent algebraically patterns, relations, and functions.
SPI3: Geometry	Students will: • use visualization and spatial reasoning to analyze characteristics an properties of geometric shapes; • identify and justify geometric relationships, formally and informally; • apply transformations and symmetry to analyze problem solving solutions; • apply coordinate geometry to analyze problem solving situations.
SPI4: Measurements	Students will: • determine what can be measured and how, using appropriate methods and formulas; • use units to give meaning to measurements; • understand that all measurement contains error and be able to determine significance; • develop strategies for estimating measurements.
SPI5: Statistics and Probability	Students will: • collect, organize, display, and analyze data; • make predictions that are based upon data analysis; • understand and apply concepts of probability.

The performance on these SPIs for Lauren's students was analyzed, as were any gender differences within and between them. Throughout the robotics program, Lauren indicated on several occasions that her students' mathematical understandings of area, circumference, and measurement had improved as a result of their participation in the robotics program. She also observed that the students had a greater ability, as a whole, to problem-solve and collaborate effectively. Lauren's students had a higher percentage of students who were above and within the NYSED benchmarks for each SPI than the students of her colleagues. Table 5 illustrates the numbers and percentages of students who were above (A), within (W), and below (B) the NYSED benchmarks for each SPI are indicated. Lauren had higher numbers and percentages of students in were either above or within the NYSED benchmarks for each SPI than her colleagues, whose students did not have the same intensive robots program that Lauren's students participated in.

Table 5. Comparison of NYSED SPI Difference data on 2012 sixth grade math exam by teacher

Teacher	SPI Strand									
	SPI1		SPI2		SPI3		SPI4		SPI5	
Lauren	#A/W*	%A/W	#A/W	%A/W	#A/W	%A/W	#A/W	%A/W	#A/W	%A/W
	44	90%	45	92%	44	90%	45	92%	45	92%
	#B**	%B	#B	%B	#B	%B	#B	%B	#B	%B
	5	10%	4	8%	5	10%	4	8%	4	8%
Other Teachers	#A/W	%A/W	#A/W	%A/W	#A/W	%A/W	#A/W	%A/W	#A/W	%A/W
	82	85%	85	88%	85	88%	85	88%	80	82%
	#B	%B	#B	%B	#B	%B	#B	%B	#B	%B
	15	15%	12	12%	12	12%	12	12%	17	18%

* Above/within
**Below

In addition, Lauren's students had the highest numbers and percentages of students overall in the three SPI areas which correlate to the areas of improvement indicated: Algebra, Geometry, and Measurement (SPIs 2,3, and 4, respectively). These data were then broken down across gender lines. Table 6 illustrates the numbers and percentages of Lauren's students who were above (A) or within (W) the NYSED benchmarks for each of the Standard Performance Indices.

Table 6. Student performance compared to NYSED benchmarks for each Standard Performance Index (SPI) on the 2012 6th Grade Mathematics

Panel A: Girls (27 total)

	SPI1		SPI2		SPI3		SPI4		SPI5	
	Amt A/W	% A/W	Amt A/W	% A/W	Amt A/W	% A/W	Amt A/W	% A/W	Amt A/W	% A/W
Above	24	89%	25	93%	24	89%	24	89%	24	89%
Within	1	4%	1	4%	1	4%	1	4%	1	4%
Total	3	93%	26	97%	25	93%	25	93%	25	93%

Panel B: Boys (22 total)

	SPI1		SPI2		SPI3		SPI4		SPI5	
	Amt A/W	% A/W	Amt A/W	% A/W	Amt A/W	% A/W	Amt A/W	% A/W	Amt A/W	% A/W
Above	18	82%	17	77%	16	73%	19	86%	19	86%
Within	4	18%	3	14%	4	18%	3	14%	3	14%
Below	22	100%	20	91%	20	91%	22	100%	22	100%

There were a higher percentage of girls compared to the boys in the "Above" category for each of the SPIs. The biggest differences between girls and boys were in SP2 (Algebra) and SP3 (Geometry), which correlated with the gains reported by Lauren. Lauren had observed that her students showed the biggest improvements in the areas of problem-solving (Algebra) and area and circumference (Geometry) as a result of the students' participation in the robotics problem. These gains were particularly notable for the girls.

Cooperative Blog Responses

Throughout the robotics program, Lauren asked her students to reflect on certain aspects of their experiences by writing on a class blog. This student's writing took the form of responses to prompts by Lauren. Figure 2 shows these blog writing prompts.

Figure 2. Blog writing prompts used through the robotics project

Blog Post Number	Prompt Title	Prompt Description
1	Robot Report!	Write about: "The challenged your group has faced. The things you like or love about using LEGO's. Something you were proud of works too! What you have you learned about science using LEGO's? What you have learned about yourself during our robotics time?"
2	Pace Mentors Day 1	Write about: "What were you feeling as you looked around room 103 and 20 college students were standing there? Explain the initial introduction of your groups? What are 1-2 things that the PACE students helped you learn/better understand? How did your team and the PACE group interact? Please include anything else you learned/felt/saw/experienced during your time with your mentors."
3	Pace Mentors Day 2	Write about: "What were you feeling as you looked around room 103 and 20 college students were standing there! Explain the initial introduction of your groups? What are the 1-2 things that the PACE students helped you learn/better understand? How did your team and the PACE group interact? Please include anything else you learned/felt/saw/experienced during your time with your mentors!"
4	LEGO Race Reflection	Write about: " – How did your team do? How long did it take you to complete the challenge? – What was the hardest part of the challenge? – Now that the first part of the LEGO's is over and we have working computers, what do you think has been the hardest about this unit? – What will you do differently in your groups for next time? – What do you love or like about this unit and challenge? What are you looking forward to for the next challenge the robot dance-off?"
5	Looking back at LEGOs	Write about: " – What has been the hardest part of LEGO's? – If you have never built a robot or used LEGO's before - how have these challenges changed your point of view on LEGO's robotics? – If you had to grade yourself on our progress thus far on LEGO's (including your knowledge of the program, you ability to build and program, use of sensors, etc.), are you below expectations, meeting or exceeding them? – Are LEGO's important to keep in the 6th grade? – What has been the best part of LEGO's? – How do you feel you have grown as a student and team member (or friend) during this process? – In the spring we will be competing one more challenge – would you rather compete in an obstacle course or design a robot that is graded on how many challenges it can complete? Why?

The student blog responses were analyzed using some of the tools of textual analysis, namely relative frequencies and word densities (Sinclair & Rockwell, 2009). These word densities and relative frequencies were then used to investigate how students wrote about their collaborative work as a whole, and then how the girls and boys wrote differently about their participation in the robotics project. In two of the blog writing prompts, the students were asked to talk about their experiences working with their undergraduate mentors from Pace University. Analyses of relative frequencies were performed on their writing as a whole, as well as their writing examined along gender lines. For all sets of this writing, the peak activity in relative frequencies of the relevant terms takes place for the two prompts in which Lauren asked her students to write about their work with their Pace mentors. What is most interesting is that the girls wrote with more relative frequencies about the mentors than did the boys. Of course, it is difficult to know why this would be the case, but observations from Lauren suggest that the girls connected more easily with the Pace mentors.

If this were the case, the increased relative frequencies make sense. Lauren had also observed that the boys in each group were less open to help and support. This, too, could be reflected in the relative frequencies of the term "mentor" in their writing. The textual analysis of this blog writing data also demonstrated gender differences in the terms "group" and "team," which were considered essential to the one of the goals of this project which was to determine if the use of robots could foster effective collaboration within groups of students. This relative frequency analysis data demonstrates a consistent pattern. There was a higher relative frequency of the term "group" as compared with "team," until the fourth blog writing prompt, where the relative frequencies of the two terms got closer to one another. Here, too, there was in interesting difference in the writings of the girls and boys. For the girls, the relative frequencies of "group" and "team" get close, but "group" has a consistently high relative frequency. For the boys, however, the relative frequency of "team" surpasses that of "group." This seems to reflect the boys' understanding of collaboration as compared with that of the girls. It also matches Lauren's observations that what was important for the girls as a whole was their relatedness to one another, where the association of boys was more goal oriented.

DISCUSSION

This pedagogic methodology enabled us to connect three critical spheres of needed for STEM learning: critical thinking, STEM interests, and self-efficacy. The cooperative learning environment was further strengthening by usage of the connected age to service-learning thereby making, creating and producing a powerful path to deeper learning and understanding. Students in this connected learning framework were asked to experiment, to be hands-on, and to be active and entrepreneurial in their learning.

These environments are non-competitive and nurturing enables students. All students, both the boys and the girls, had a higher STEM interest after interacting with the robotics. It is difficult to determine whether it is the robotics or the robotics coupled with the cooperative learning that promoted this interest. What is very clear is that the usage of robotics is very captivating and it is immediately gratifying to the students as it engages them in a very exciting way. In the cooperative learning classroom, a stereotype-free learning environment was established. Hence, the cooperative learning environment promotes self-efficacy. This classroom when contrasted to the heterogeneous mix of students revealed that this all-girl environment not only encouraged girls to take risks but they were more willing to experiment and ask questions without feeling intimidated since it was an all-girl classroom. Additional metrics and methodologies need to be explored to fully conclude if Lauren's students had better performance because of the cooperative robotic learning experiences. Gender and teaching pedagogy are factors that were overlooked in this study. These findings are premature and require further analysis of the metrics, scales, and assessments.

We also learned that there is a linkage between robotic cooperative learning and students' cognition. This is supported by the results of the sixth grade mathematics examination. We can firmly state that connecting robotic cooperative learning with academic course material does indeed enhance the development of cognitive skills. The results strongly indicate that integration of RCL has multiple benefits and we should rethink our current curriculums with teaching core content as well as promoting STEM interest. RCL is not just a STEM pedagogical tool but it can be utilized to strengthen students' cognitive development.

Girls want their work to have clear social purpose (Eccles 2006). This strategy not only promotes STEM interest for boys as well as girls, but robotics is used to solve social problems and this resonates with the girls. In a study conducted by Gibbons, it revealed that STEM careers often do not appeal to women (or men) who want to make a social contribution (Gibbons 2009). This is an interesting thought to think that STEM careers have a gender connotation attached to them. This false gender connotation certainly effects a students perception and attitude, especially girls, and is another reason why a STEM decline exists.

Middle school students who participated in this program scored higher on these exams than students who did not participate. Students who participate in service- learning courses exhibit higher Standard Performance Indices (SPIs), the rationale for this is not entirely clear. Could it be that robotic service-learning courses tend to stimulate students to think critically? While it may seem far-fetched to argue that in a four-week robotic program students' math scores will significantly improve, because they participated used robotics in a connective-learning environment and consequently improve their math? Another explanation, of course, is that participating in robotic service-learning program helps to get students more engaged in the overall academic experience, thereby enhancing their overall academic performance. Clearly, these alternative interpretations need to be tested in further research.

The analyses conducted on the student blog responses in this study further indicate how students participating in a robotic service-learning can benefit from this experience. The results demonstrated clearly that the young women connected more with the Pace students than the boys. This could be attributed to the "special attention" that was given to them. The girls also felt safe in a group environment that was positive, non-threatening and continuously encouraged them to take a risk. It could also be that since girls enjoy journaling they were able to express themselves better than the boys and these results may be skewed. Further tests need to be developed and implemented in this area. Further studies need to be performed so we can better apply robotic cooperative learning methodologies within the STEM disciplines. Lastly, not all students learn the same way which implies additional investigation research needs to be explored as to how various types of learners, gender, and race affect student's attitudes and perceptions of learning STEM.

AUTHOR BIOGRAPHIES

Dr. Pauline Mosley holds a Bachelor of Science in Math and a Bachelor of Science in Computer Science from Mercy College; a Master of Science in Information Systems and a Doctorate of Professional Studies from Pace University. She is a board member of the YWCA where she is actively involved with the GEMS program and STEM related activities that encourage minorities and young women to pursue careers in the STEM fields. E-mail: pmosley@pace.edu (Contact Author)

Dr. Gerald Ardito has worked with students at all levels, and his work has focused on the development of learning environments that foster, promote and support independent learning. His is currently on the faculty of Pace University's School of Education, and is an Assistant Professor in STEM-D Education. Email: gardito@pace.edu

Lauren Scollins is a professionally certified elementary teacher with a Master's degree in Curriculum and Teaching from Columbia University, Teachers College. With 8 years of experience, she currently teaches 6th grade Math and Science. Lauren is interested in collaborative learning and STEM education at the elementary and middle school levels. E-mail: lauren.habib@chufsd.org

REFERENCES

Abrami, P. C., Bernard, R. M., Borokhovski, E., Wade, A., Surkes, M. A., Tamim, R., & Zhang, D. (2008). Instructional interventions affecting critical thinking skills and dispositions: A stage 1 meta-analysis. *Review of Educational Research, 78*(4), 1102-1134.

Anderson, V., Kinsley, C., Negroni, P., & Price, C. (1991, June). Community service learning and school improvement in Springfield, Massachusetts. *Phi Delta Kappa,* 76, 1–64.

Bailey, R., & Mentz, E. (2015). IT teachers' experience of teaching–learning strategies to promote critical thinking. *Issues in Informing Science and Information Technology, 12,* 141-152

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. P*sychological Review*, 84, 191-215.

Berliner, D. (1983, September). The executive functions of teaching. *Instructor Magazine,* 29–39.

Belkin, D. (2015. January). "Test Finds College Graduates Lack Skills for White-Collar Jobs," *The Wall Street Journal*, January 16, 2015.

Bland, J.M.; Altman, D.G. (1997). "Statistics notes: Cronbach's alpha". BMJ. 314 (7080): 572.

Bloom, Benjamin S. & David R. Krathwohl. (1956). Taxonomy of educational objectives: The classification of educational goals, by a committee of college and university examiners. Handbook 1: Cognitive domain. New York , Longmans.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. Journal of Research in Science Teaching, 43, 485–499.

Cama, J., (1998). *Service-learning associates program faculty handbook. Richmond, Virginia:* Virginia Commonwealth University, Office of Community Programs.

Chen, C.-H., & Howard, B. (2010). Effect of Live Simulation on Middle School Students' Attitudes and Learning toward Science. *Educational Technology & Society*, *13* (1), 133–139.

Crabtree, R.D. (1998, May). Mutual empowerment in cross-cultural participatory development and service learning: Lesson in communication and social justice from projects in El Salvador and Nicaragua. *Journal of Applied Communication Research*, 182-209.

Cronbach LJ (1951). "Coefficient alpha and the internal structure of tests". Psychometrika. 16 (3): 297–334.

Department of Education, National Center for Education Statistics.

Higher Education Research Institute. (2007). *Survey of the American freshman: Special tabulations* . Los Angeles: Higher Education Research Institute.

Dinkes. 2009. *Condition of Education 2009* (NCES 2009-081). Washington, DC: U.S.

Druin, A., Hendler, J., (2000). *Robots for kids: Exploring new technologies for learning*. San Diego, CA: Academic Press.

Eccles, J. S. (2006). Where are all the women? Gender differences in participation in physical science and engineering. In *Why aren't more women in science? Top researchers debate the evidence*, ed. S. J. Ceci and W. M. Williams, 199–210. Washington, DC: American Psychological Association.

Fisher, M. (2003) "Youth Courts as Service Learning." *Service-Learning NETWORK*, 9.3.

Gibbons, M. T. (2009). Engineering by the numbers. In *Profiles of engineering and engineering technology colleges*. Washington, DC: American Society for Engineering Education.

Gillies, R. (2014). Cooperative learning: Developments in research. *International Journal of Educational Psychology, 3*(2), 125–140.

Godfrey, P.C. (1999, December). Service-learning and management education: A call to action. *Journal of Management Inquiry,* 363-378.

Hill, C., C. Corbett, and A. St. Rose. (2010). *Why so few? Women in science, technology, engineering, and mathematics*. Washington, DC: AAUW.

Higher Education Research Institute at UCLA. (2010, January). *Degrees of success: Bachelor's degree completion rates among initial STEM majors.* Retrieved from http://www.heri.ucla. edu/nih/downloads/2010%20-%20Hurtado,%20 Eagan,%20Chang%20-%20Degrees%20of%20 Success.pdf

Institute for Women's Policy Research. (2010). *The gender wage gap: 2009*. Washington, DC: Institute for Women's Policy Research.

Korn, M. (2014, October). "Bosses Seek 'Critical Thinking,' But What Is That?" *The Wall Street Journal*.

Jonassen, D.H., (2000). *Computers as Mindtools for schools: Engaging critical things* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. United States Department of Commerce,
(2011). *Stem: Good jobs now and for the future*. Retrieved from Economics and Statistics
Administration website: http://www.esa.doc.gov/Reports/stem-good-jobs-now-and-future

Lowell, L. B., Salzman, H., Bernstein, H., & Henderson, E. (2009). *Steady as she goes?: Three generations of students through the science and engineering pipeline.* Paper presented at the Annual Meeting of the Association for Public Policy Analysis and Management, Washington, DC, November 5-7. Retrieved from http://policy.rutgers.edu/faculty/ salzman/SteadyAsSheGoes.pdf

Lizzio, A., Wilson, K., & Simons, R. (2002). University students' perceptions of the learning environment and academic outcomes: Implications for theory and practice. *Studies in Higher Education, 27*(1), 27-53.

Melchior, A., & Bailis, L. (2002). Institutionalizing Service-Learning: Preliminary Findings from a Study of Learn and Serve America. Presentation at the Second Annual International Service-Learning Research Conference, October, Nashville, TN.

National and Community Service Roles for Higher Education: A Resource Guide. (1994). Washington, *D.C.:* The Corporation for National and Community Service.

National Association of Colleges and Employers. (2009). Salary survey.

National Research Council. (2011). *National science education standards.* Washington, DC: National Academy Press. National Research Council on Information Technology Literacy (1999) Being fluent with information technology. National Academy Press, Washington, DC

National Science Foundation, National Center for Science and Engineering Statistics. (2013). *Women, minorities, and persons with disabilities in science and engineering: 2013.* Special Report NSF 13-304. Arlington, VA. Retrieved from http:// www.nsf.gov/statistics/wmpd/

NCWIT, *By the Numbers 2009*.

Paul, R., & Elder, L. (2013a). Study of 38 public universities and 28 private universities to determine faculty emphasis on critical thinking in instruction.

President's Council of Advisors on Science and Technology (PCAST). (2010). *Prepare and inspire: K-12 education in science, technology, engineering and math (STEM) for America's future.* Retrieved from http://www.whitehouse. gov/sites/default/files/microsites/ostp/ pcaststemed-report.pdf

Planty, M., W. Hussar, T. Snyder, G. Kena, A. KewalRamani, J. Kemp, K. Bianco, and R. Sinclair, S., & Rockwell, G. (2009). Voyeur Tools (Home Page).

Price, M. (2012, July 06). Pushing Students Toward STEM. *Science Career Magazine*, Retrieved from http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2012_07_06/caredit.a1200076

Rogers R. W. 1975. "A protection motivation theory of fear appeals and attitude change," *J. Psychol.*, vol. 91, pp. 93–114.

Rogers R. (1983). "Cognitive and physiological processes in fear appeals and attitude change: a revised theory of protected motivation," in *In Social Psychophysiology: A Sourcebook*, W., Cacioppo J. T., and Petty R. (eds.) New York: The Guilford Press, pp. 153–176.

Tavakol M, Mohagheghi MA, Dennick R. (2008). Assessing the skills of surgical residents using simulation. J. Surg Educ., pp.77-83.

University of the Sciences (USciences). (2012, April). A survey of high school students' attitudes towards careers in healthcare and science. *Survey conducted by Harris Interactive.* April 2012. Retrieved from http://www.usciences.edu/newsEvents/newsDetails.aspx?Channel=%2FChannels%2FAdmissions%2FAdmissions+Conte nt&WorkflowItemID=61a1f646-130e-4372-afe0- a60e61b9a359

Willis JA. (2009). Inspiring middle school minds: Gifted, creative, & challenging. Scottsdale, AZ: Great Potential Press.