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Robotics as Means to Increase Achievement Scores in an Informal Learning Environment

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Abstract

This paper reports on a pilot study that examined the use of a science and technology curriculum based on robotics to increase the achievement scores of youth ages 9-11 in an after school program. The study examined and compared the pretest and posttest scores of youth in the robotics intervention with youth in a control group. The results revealed that youth in the robotics intervention had a significant increase in mean scores on the posttest and that the control group had no significant change in scores from the pretest to the posttest. In addition, the results of the study indicated that the evaluation instrument used to measure achievement was valid and reliable for this study. (Keywords: robotics, 4-H, informal learning, science achievement, experiential learning.)

INTRODUCTION

Robots have left assembly lines and research labs and arrived on the doorstep of education. Some educators have claimed that through hands-on experimentation, robots help youth transform abstract science, engineering and technology (SET) concepts into concrete real-world understanding. Recent improvements in cost and simplicity make it possible for students to engage in this kind of hands-on experimentation with robots. Nebraska 4-H has begun investigating this potential robotics holds for improving SET education. Nebraska 4-H implemented a new robotics curriculum in an after school program and evaluated it using a new testing instrument based on the stated learning objectives in the curriculum.

REVIEW OF RELATED LITERATURE

Robotics in the Classroom

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

One new approach to improving SET education that is gaining popularity is the use of robots to teach the content. Advances in technology have brought down the cost of robots and made it easier to bring them into classrooms with tight budgets. Seymour Papert (1980) laid much of the groundwork for using robots in the classroom in the 1970s. Breaking with traditional computer aided instruction models where computers essentially programmed children, Papert attempted to create an environment where children programmed computers and robots. In doing so, the children could gain a sense of power over technology. He believed that children could identify with the robots because they are concrete, physical manifestations of the computer and the computer's programs. Other researchers have also identified the concrete nature of robots as being one of their important advantages. By testing scientific and mechanical principles with the robots, students can understand abstract concepts and gain a more functional level of understanding (Nourbakhsh, Crowley, Bhave, Hamner, Hsium, Perez-Bergquist, Richards, & Wilkinson, 2005). Students can also learn that in the real world there is not necessarily only one correct answer to every question (Beer, Chiel, & Drushel, 1999). Beer et al. (1999) felt that it was more important for their students to come up with creative solutions to problems than it was to recite answers they learned in class by rote.

Another argument for teaching children with robots is that they see the robots as toys (Mauch, 2001). In fact, one widely used kit of robotic equipment is made by Lego, a well-known manufacturer of children's building block toys. Children using this kit can build and program robots out of the same materials they have in their toy chests at home. This makes anything they learn with the kits seem entertaining as well.

Research also suggests that robots tie into a variety of disciplines. A robot is made of component parts of motors, sensors and programs. Each of these parts depends on different fields of knowledge such as engineering, electronics, and computer science. This interdisciplinary nature of robots means that when students learn to engineer robots they will inevitably learn about the many other disciplines that robotics utilize (Papert, 1980; Rogers & Portsmore, 2004). In the same way, teaching students how to build robots teaches them how all the parts of a complex system interact and depend upon each other (Beer et al., 1999). This is an important lesson for computer scientists, biologists, doctors or anyone who will ultimately need to understand complex systems.

Early adopters of robotics in the classroom have reported many accolades; however, there is a clear lack of quantitative research on how robotics can increase STEM achievement in students. Most research involving robotics in the classroom was conducted with high school and college age students with results dependent on teacher or student perceptions rather than rigorous research designs based on student achievement data.

The case studies which exist in the literature positively document the use of robotics to teach a variety of subjects to a wide array of age groups. They illustrate the potential effectiveness of robotics to positively impact both learning and motivation (Fagin & Merkle, 2003). Studies show that robotics generates a high degree of student interest and engagement and promotes interest in math and science careers (Barnes, 1999; Robinson, 2005; Rogers & Portsmore 2004). The robotics platform also promotes learning of scientific and mathematic principles through experimentation (Rogers & Portsmore, 2004), encourages problem solving (Barnes, 1999, Mauch, 2001; Nourbakhsh et al., 2005; Robinson, 2005; Rogers & Portsmore, 2004) and promotes cooperative learning (Beer et al., 1999; Nourbakhsh et al., 2005). Despite the positive instructional and motivational benefits these studies suggest, rigorous quantitative research is missing from the literature.

In the classroom, some educators have used robots as a tool to assist in the teaching of actual programming languages (Barnes, 2002; Fagin & Merkle, 2003). For example, Fagin and Merkle (2003) and Barnes (2002) used robots to help teach the programming languages of ADA and Java, respectively. The main emphasis for their courses was on teaching the programming languages and basic programming structures over the engineering and mechanical aspects of robots. Other courses that use robots have focused on the construction and programming of the robots themselves (Beer et al., 1999; Nourbakhsh et al., 2005).

Moore (1999) used robots to teach her fourth-grade students several different topics under the umbrella of examining robots. She used the topic as a "hook" to capture her students' attention; then she weaved other disciplines into this central theme and asked her students to think critically about robots. According to Moore (1999) students will build and program robots, understand geometry concepts, write and share stories with peers and compare and contrast technology systems with human body systems. The study does not provide a quantitative evaluation of the robotics program. Rogers and Portsmore (2004) also taught young students using robots. They designed a curriculum using LEGO robots that teaches kindergarten though fifth-grade students about engineering.

Most of the literature describing the use of robots to teach science and technology reports positive impacts on what their students learned about SET. Several researchers reported that learning with robots is more interesting and improves students' attitudes about SET subjects (Fagin & Merkle, 2003; Mauch, 2001; Robinson, 2005). Some researchers noted that female students in particular are more likely to appreciate learning with robots than traditional SET teaching techniques (Nourbakhsh et al., 2005; Rogers & Portsmore, 2004).

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

Not all the reported results of using robotics are positive, however. In one of the very few quantitative studies that examined the use of robots' effectiveness in the classroom with test scores, Fagin and Merkle (2003) found that robots did not help introductory computer science students learn to program. The students taught using robots did significantly worse than students not taught with robots. Fagin and Merkle reported that there were limitations to the way they were implemented that might have counteracted the helpfulness of the robots, but it is clear that while robots have positive potential, they are no panacea.

THE 4-H ROBOTICS PROGRAM: AN OVERVIEW

In the winter of 2005 Nebraska State 4-H teamed with an elementary school in a small rural town in central Nebraska to pilot test educational robotics in an after school program. The intervention used in this program is composed of a newly developed National 4-H Cooperative Curriculum System (CCS) robotics curriculum and a kit of robotic components from LEGO, called LEGO Mindstorms. The LEGO Mindstorms kit is comprised of 828 parts including axles, gears, motors and sensors. The kit includes a programmable microcomputer with three output and three input ports for controlling sensors and motors. In addition, the robots are programmed using a specialized programming language called ROBOLAB. The 4-H robotics curriculum contains 28 lessons designed around the Mindstorms kit. It begins with simple building and programming challenges and culminates in advanced robotic programming and engineering topics.

Nebraska 4-H began the robotics intervention by training some of the after school personnel with the robotics and curriculum. The training focused on the fundamentals of the program. When the training was complete, the participants knew the primary components of the robotics kit, had built their first robot, and had learned how to write simple programs for the robot with the ROBOLAB programming environment. After the initial training, the adult leaders were allowed to take home the robotics kit and curriculum and work through the rest of the materials on their own over the course of a few weeks. When the after school program began, the teacher and two or three adult assistants were able to lead small groups of children through the activities.

THEORETICAL FRAMEWORK

4-H's robotics curriculum was designed around the experiential learning model, which is built on Kolb's (1984) experiential learning theory. The model has five phases: 1) experience—do the activity, 2) share—reactions and observations in a social context, 3) process —analyze and reflect upon what happened, 4) generalize—discover what was learned and connect to life, and 5) apply—what was learned to a similar or different situation (Woffinden & Packham, 2001).

Experiential learning distinguishes 4-H youth development education from many formal education methods. Youth are first provided an opportunity to learn before being told or shown how and then share what they did, consider what was important about what they did, generalize the experience to their own lives and finally apply what they learned to a new situation. Each activity of the curriculum begins with a brief overview of the topics covered in the activity followed by a challenge for the youth to complete. After the youth have completed the challenge they are prompted to answer questions that cause them to reflect and generalize on their experiences.

Experiential learning is based on a constructivist theory that purports that learning is an active process in which much of what an individual learns and understands is constructed by integrating new knowledge with existing knowledge. It is similar in principle to problem-based learning in that students learn concepts and principles through authentic experiences and problems; learning occurs in small groups; and teachers act as facilitators (Barrows, l996). While procedural knowledge is provided, students are encouraged to transfer such knowledge to similar and different situations. Students who learn in this manner are responsible for their own learning, seek out new knowledge and are better prepared to generalize knowledge (Pressley, Hogan, Wharton-McDonald, Misretta, & Ettenberger, 1996). This approach results in better long-term content retention than traditional instruction (Norman & Schmidt, l992), higher motivation (Albanese & Mitchell, l993), and the development of problem-solving skills (Hmelo, Gotterer, & Bransford, 1997). Research also indicates that experiential education enhances social and academic development among children by encouraging social interaction and cooperative learning (Deen, Bailey, & Parker, 2001; Slavin, 2000).

Papert (1980) found that robots were an excellent way to put constructivist theory into practice. The children learning with robots were able to imagine themselves in the place of the robot and understand how a computer's programming worked. The children were able to transfer their understanding of the real world into comprehension of logic and mathematical principles. Papert believed that what makes many concepts difficult for children to understand is a lack of real-world materials that demonstrate the concept. He believed that programmable robots were flexible and powerful enough to be able to demonstrate ideas that previously had no easy real-world analogy.

PURPOSE AND RESEARCH QUESTIONS

The theoretical framework that guides this research is founded in the 4-H experiential learning model based on Kolb's (1984) theory of experiential learning. This study looked for quantitative data that describes how an experiential, robotics-based curriculum affected youths' understanding of SET topics.

The main purpose of this study was to determine the effects of an informal 4-H experiential science intervention based on robotics in an after school environment on levels of achievement in science, engineering, and technology (SET) for youth ages nine to eleven. In addition, the research intended to validate a 24-item multiple-choice assessment instrument to measure general SET domain knowledge and specific domain knowledge based on the stated learning objectives in the curriculum. This study compares the achievement of youth who participated in the robotic intervention with those that did not participate in the intervention. Specifically, the following research questions were addressed:

1. What is the validity and reliability of the assessment instrument developed for this study?

2. What is the impact of the robotics instruction in promoting student learning in science, engineering, and technology (SET) for youth ages nine to eleven at an after school program?

METHOD

To determine the effectiveness of the intervention a pretest/posttest quasi-experimental study with a control group was designed. The control group did not participate in the after school robotics program and did not have access to the robotic kits or computers. The experimental group participated in the robotics program twice a week for one hour over six weeks. The pretest was administered to each group prior to the beginning of the intervention. After six weeks the posttest was administered to both groups. The evaluation instrument was a paper-and-pencil based, 24-item assessment instrument with one right answer and three distracters per question created by the researchers. Each assessment question was derived from activities within the 4-H robotics curriculum.

Participants

The participants for the study were all from the same Nebraska rural elementary school. The overall sample (including both the experimental and a comparison groups) contained 32 students, with an age range of 9-11 years (median age was 9.00). A group of 14 students (65% male, 35% female) represented the experimental group and were selected to participate in the robotics intervention based on their participation in the after school program. To help provide some similarity in a comparison group, 18 additional students (63% male, 38% female) were randomly selected by the lead educator from the remaining students in the school, who were not participating in the robotics intervention.

Procedure

A national writing team comprised of youth development specialists from 4-H and content experts from Carnegie Mellon University's Robotics Academy developed the 4-H Robotics curriculum. The curriculum features two activity manuals with 12 lessons per manual and a leaders' guide. For the intervention, the after school youth were broken into groups of 4 to 5; each group had an adult volunteer or after school teacher to lead the activities.

Students were introduced to robotics by building a basic "tankbot," a LEGO robot that has two motors attached to two tank-like treads. Next, the youth learned to program the "tankbot" using the ROBOLAB software and advanced through increasingly complex programming tasks. For example, once students learn to turn their robots, they are introduced to the concept of "calibration," where they determine how long it takes the robot to turn 90 degrees. Another activity had the students program their robots to navigate a maze with several left and right 90-degree turns. Students learned to loop sections of their programming code by having their robot race around a 36" by 36" square racetrack three times. Finally, students fitted their robots with touch and light sensors and programmed the robots to react to changes registered by the sensors.

Instrument Validation

Prior to administration of the evaluation instrument, two experts from Carnegie Mellon University's Robotics Academy reviewed the relevance and validity of each item. The expert reviewers were selected based on their knowledge of robotic engineering and their success in developing curriculum based on robotics to teach SET topics. Together, these experts have published more than 12 curricular programs and led the effort to develop the 4-H robotics curriculum used in this intervention. Modifications to the instrument were done based on the expert reviews.

To determine the internal consistency estimates of reliability a Cronbach's alpha reliability coefficient was calculated for the posttest. The alpha coefficient for the posttest was 0.86 on 24 items. Because the assessment instrument covered topics specific to the ROBOLAB program that youth in the control group would not have been exposed to, the ROBOLAB specific questions were separated. A Cronbach's alpha was calculated for SET concepts (alpha = .764) and the ROBOLAB concepts (alpha = .750). A Kuder-Richardson (KR20) reliability measure was calculated to determine the stability of the scores on the posttest. Said another way, the KR20 score indicates if the youth would score the same if they took the test again. An acceptable KR20 measure is 0.7 or greater. The KR20 score for the posttest was 0.87, indicating an 87% probability of achieving the same score if the student took the test again.

The information in Table 1 displays an overview of the perceived value of each posttest question based on P-values, point biserial correlations, and an analysis of distractors chosen by the students. Experimental and comparison group scores are combined. Questions 12, 13, 19, and 21 had low P-values (.00 to .16) indicating the questions were extremely difficult. Moreover, questions 19, 21 and 22 had negative point biseral values indicating that higher performing students missed the questions more often than lower performing students. In addition, a proportion value (P-value) was established for each question on the posttest. The P-value represents the proportion of students answering the question correctly. Items that are shaded in dark gray have a low P-value under 0.25 and may be questions that are extremely difficult (see Table 1, page 236).

Moreover, a Point Biserial value was calculated for each item to determine item discrimination between high-scoring and low-scoring examinees. The Point Biserial calculation is used to determine the relative quality of the assessment questions. The Point Biserial score should range from 0.3 to 0.7. A negative Point Biserial score indicates that high-scoring examinees missed that question (see Table 1). Point Biserial values from 0.3 are shaded in light gray and negative Point Biserial scores have a black background. These values indicate questions where higher performing students scored lower than lower performing students. Finally, the table displays the distractors for each question and the percentage of students that selected the distractor; correct answers are in bold (see Table 1).

RESULTS

The data were analyzed using SPSS for Windows v.13. Two sets of data from the experimental group were excluded because the posttest was incomplete. An

Table 1: Posttest—Proportion of Correct Answers (p-values) and Point Biserial Scores by Question Number Groups Combined

	1	2	3	4	5	6	7	8	9	10	11	12
p-value	0.88	0.50	0.63	0.63	0.78	0.59	0.56	0.41	0.75	0.31	0.59	0.00
rpb	0.44	0.58	0.72	0.71	0.63	0.78	0.81	0.57	0.52	0.27	0.79	0.00
A's	87.50	9.38	62.50	62.50	78.13	9.38	56.25	40.63	75.00	31.25	59.38	0.00
B's	6.25	12.50	9.38	6.25	6.25	3.13	3.13	12.50	9.38	6.25	3.13	28.13
C's	3.13	28.13	9.38	18.75	9.38	59.38	40.63	12.50	6.25	25.00	15.63	59.38
D's	3.13	50.00	18.75	12.50	6.25	25.00	0.00	34.38	9.38	37.50	21.88	12.50
	13	14	15	16	17	18	19	20	21	22	23	24
p-value	0.16	0.63	0.63	0.56	0.50	0.63	0.09	0.59	0.13	0.38	0.38	0.34
rpb	0.01	0.62	0.60	0.57	0.81	0.49	-0.22	0.57	-0.17	-0.02	0.42	0.37
A's	46.88	25.00	62.50	21.88	34.38	15.63	9.38	59.38	62.50	37.50	37.50	34.38
B's	15.63	9.38	12.50	56.25	3.13	15.63	21.88	21.88	12.50	25.00	31.25	12.50
C's	21.88	62.50	6.25	6.25	50.00	62.50	59.38	12.50	12.50	18.75	12.50	25.00
D's	15.63	3.13	18.75	15.63	12.50	3.13	9.38	3.13	12.50	18.75	18.75	28.13

independent t-test was conducted on each exam question to compare the means scores between the control and experimental group (see Table 2, pp. 238–239). The posttest questions are broken down by SET concepts and the ROBOLAB computer programming interface.

To examine the group performance on each question, Pearson's correlation coefficient was calculated to indicate the relative effect size. A Pearson's correlation coefficient as a measure of effect can lie between 0 (no effect) to 1 (a perfect effect) (Field, 2001). In addition, the difference of mean scores between groups on the posttest was calculated as was the percent change score (see Table 3, page 240).

To determine the effectiveness of the intervention overall, pretest and posttest scores were compared between the control and the experimental group using an independent t-test. A Levene's test for the homogeneity of variance F(30) = 1.52, $p = .227$ on the pretest indicated that the variances between mean scores were equal. However, a significant difference was detected on the posttest mean scores F(30) = 10.84, $p < .003$ indicating that the variance of the posttest means were not equal between the control and experimental group and therefore equal variances were not assumed. The results of the pretest mean scores between the control group ($M = 7.50$, $SD = 2.58$) and the experimental group ($M = 7.93$, $SD = 3.71$) were not significant $t(30) = 11.60$, $p = .702$. To determine if there was a significant difference between the posttest scores for the control group and experimental group an additional independent-samples t-test was conducted. The results of the posttest mean score between the control group ($M = 7.44$, $SD = 2.98$) and the experimental group ($M = 17.00$, $SD = .88$) was significant $t(22.17) = 12.93$, $p < .000$. A Pearson's correlation coefficient r_s was calculated to determine the effect size of the intervention. The results indicate a large effect $r_s = .943$ where $t(20.67) = 12.93$. Boxplots showing the pretest and posttest mean scores by group are shown in Figure 1 (page 241).

DISCUSSION

The purpose of this study was to investigate the effectiveness of an informal 4-H science curriculum to teach SET concepts. The results of the study based on the increase of mean scores from the pretest to the posttest for the experimental group indicate the robotics was effective at teaching youth about SET concepts like computer programming, robotics, mathematics, and engineering. The overall effect size for the intervention was calculated at .943, which indicates a large effect from the robotics program. The overall percent change from the control group ($M = 7.44$, $SD = 2.98$) to the 4-H robotics group ($M = 17.00$, $SD = .88$) was 128%. Moreover, there was no significant difference between the control groups pretest and posttest scores, while the robotics group had a significant increase from the pretest ($M = 7.93$, $SD = 3.71$) to the posttest ($M = 17.00$, $SD = .88$) $t(14) = 8.95$, $p < .000$. The mean difference was 9.07 between the pretest and the posttest for the robotics group.

The second purpose of the study was to validate an assessment instrument to document the degree to which students can recognize SET concepts taught in the 4-H Robotics curriculum. The results of the Cronbach's alpha (.86) indicate that the instrument is reliable. In addition, the KR20 score .87 indicates a similar high

Table 2: Mean Scores and Standard Deviations by Question by Group for the Pretest and Posttest with T-Scores and Significance

	Pretest						Posttest					
	Group						Group					
	Control		Experimental				Control		Experimental			
Knowledge Domain: SET a												
	M	SD	M	SD	t b	P c	M	SD	M	SD	t b	p c
1	.78	.428	.93	.267	1.220	.232	.78	.428	1.00	.000	2.204	.042 *
2	.28	.461	.21	.426	-.404	.689	.22	.428	.86	.363	4.537	.000 *
4	.50	.514	.71	.469	1.229	.229	.33	.485	1.00	.000	5.831	.000 *
6	.22	.428	.07	.267	-1.220	.232	.28	.461	1.00	.000	6.648	.000 *
9	.50	.514	.71	.469	1.229	.229	.56	.511	1.00	.000	3.688	.002 *
10	.28	.461	.14	.363	-.926	.362	.28	.461	.36	.497	.462	.079
11	.22	.428	.21	.426	-.052	.959	.28	.461	1.00	.000	6.648	.000 *
13	.39	.502	.29	.469	-.599	.554	.17	.383	.14	.363	-.180	.859
14	.22	.428	.29	.469	.395	.696	.39	.502	.93	.267	3.907	.001 *
15	.11	.323	.21	.426	.753	.426	.33	.485	1.00	.000	5.831	.000 *
16	.22	.428	.36	.497	.809	.416	.33	.485	.86	.363	3.493	.002 *
17	.17	.383	.21	.514	.328	.746	.11	.323	1.00	.000	11.662	.000 *
18	.33	.485	.57	.516	1.333	.194	.39	.502	.93	.267	3.907	.001 *
19	.39	.502	.07	.502	-2.298	.030 *	.17	.383	.00	.000	-1.844	.083
20	.33	.485	.36	.497	.136	.893	.33	.485	.93	.267	4.41 5	.000 *

Table 2, Con't

21	.06	.236	.14	.363	.781	.444	.17	.383	.07	.267	-.827	.415
22	.33	.485	.21	.426	-.738	.466	.44	.511	.29	.469	-.913	.369
23	.33	.485	.21	.426	-.738	.466	.22	.428	.57	.514	2.050	.051
24	.17	.383	.07	.267	-.827	.415	.28	.461	.43	.514	.861	.397
Knowledge Domain: ROBOLAB [a]												
	M	SD	M	SD	t b	p c	M	SD	M	SD	t b	p c
3	.22	.428	.14	.363	9.567	.575	.33	.485	1.00	.000	5.831	.000 *
5	.67	.485	.71	.469	.281	.781	.61	.502	1.00	.000	3.289	.004 *
7	.22	.428	.14	.363	-.567	.575	.22	.428	1.00	.000	7.714	.000 *
8	.28	.461	.57	.514	1.678	.105	.22	.428	.64	.497	2.522	.018 *
12	.28	.461	.36	.497	.462	.648	.00	.000	.00	.000	.	.

Note: a. Cronbach's Alpha was calculated at .764 for the SET concepts and .750 for the ROBOLAB concepts, the overall Alpha was .86.
b. Equal variances not assumed.
c. Significance for a 2-tailed test.
** Significant difference between mean scores $p < .05$.*

Table 3: Posttest Questions with T-Scores, Effect Size, Mean Difference, and Percent Change in Mean Scores

Posttest Question	t	Effect Size 1	M Diff	% Δ
A robot must be _____ in order to move	2.204	.47	.22	28
A programming loop does which of the following	4.537	.64	.64	291
The following is a(n) in ROBOLAB (Image of Icon) 	5.831	.82	.67	203
What enables a robot to interact with its environment?	5.831	.82	.67	203
What icons are needed in every ROBOLAB program?	3.289	.62	.64	64
What is a computer program?	6.648	.85	.72	257
How does the RCX communicate with your computer?	7.714	.88	.78	355
If you did not know what an icon did within ROBOLAB how would you find out?	2.522	.45	.42	191
What does a robot have that a machine does not?	3.688	.67	.44	79
What is a ratio?	0.462	.09	.08	29
If a plate is 1/3 as think as a brick how many plates would you need to equal one brick?	6.648	.85	.72	257
What does firmware on the RCX do?		0	0	0
Collecting information about how far your robot will travel in a given amount of time and using the information to estimate how long it will take the robot to go a given distance is called ________ .	-0.18	.03	-.03	-18
What is pseudocode?	3.907	.60	.54	138
When programming your robot a fork is used to ______ .	5.831	.82	.67	20.
What does the math symbol < mean?	3.493	.54	.53	161
If you had a light sensor reading of 30 for dark and 50 for light what should the threshold value be?	11.662	.94	.89	809
Which would be an example of multi-tasking?	3.907	.60	.54	138
The rotation sensor works like what on a car?	-1.844	-.41	-.17	-100
What is the primary purpose of gears?	4.415	.64	.60	182
Which gear ratio will permit your robot to cover 3 feet the fastest?	-0.827	-.15	-.10	-59
Which gear ratio has the most torque?	-0.913	-.17	-.15	-34
In computer programming what is a variable or container icon used for?	2.05	.38	.35	159
A programming subroutine is used when ________ .	0.861	.17	.15	54

Note: 1 The effect size of change can be interpreted by the follow numbers.
r = .10 (small effect)
r = .30 (medium effect)
r = .50 (large effect)

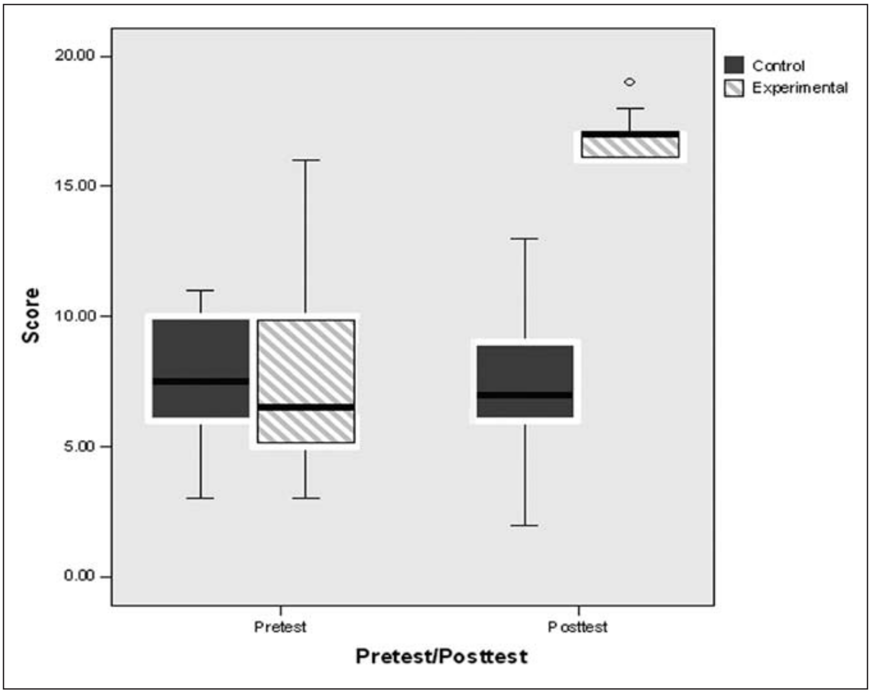

Figure 1. Boxplots of student scores on the pretest and posttest by group

reliability. Two robotics experts were called on to validate the questions used in the instrument.

While there was a vast improvement on the posttest for the robotics group there were a few questions where the control group outscored the robotics group. Three questions, 19, 21, and 22 had negative Point Biserial values indicating the lower performing students outperformed higher-level students on these questions. One explanation for the lower scores on those particular items is related to the limitation that the robotics group did not get completely through the full curriculum, and thus those particular concept questions were not supported with instruction. This explanation is plausible since the lead educator mentioned that the Robotics group, due to time restraints, did not complete the entire curriculum as originally planned. In addition, it may be that the control group's more generalized classroom instruction did have at least some partial contribution to their scores on those same items. For example, a portion of the comparison group might have had limited classroom instruction on ratios and gears explaining their higher scores on questions 19, 21 and 22.

While the assessment instrument was deemed valid and reliable it may not be useful outside of the scope of this study due to the specificity of the questions. Some questions were general in scope and could be used in other assessment instruments. However, many questions were very specific and tied to the stated learning objectives of the 4-H robotics intervention and thereby limited the usefulness of the assessment instrument. Conversely, the assessment instrument did provide a means to quantitatively measure the achievement of students.

CONCLUSION

Overall, the findings of this study support the use of 4-H robotics to teach SET concepts in an after school program and that the evaluation instrument developed to test the SET concepts is reliable and valid. More research is needed to determine the effectiveness of the robotics program with different populations. In addition, research is needed to determine if the mean scores will increase on questions 19, 21, and 22 when the youth complete the entire curriculum. Another question to look at is the effectiveness of using robotics in an informal environment like traditional 4-H clubs led by adult volunteers and extension personnel in non-school environments (at home or extension office) that meet on evenings and weekends. An additional research area is the effectiveness of the 4-H Robotics program with individual youth working with a parent in the home. Moreover, research is needed to examine whether the program helps fosters positive attitudes towards SET in school and as a career.

Contributors

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