THE SHORT-TERM BENEFITS OF EDUCATIONAL ROBOTICS WHEN PAIRED WITH GEOSPATIAL TECHNOLOGIES IN INFORMAL LEARNING ENVIRONMENTS

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Abstract: Educational robotics, when paired with geospatial technologies and taught in an informal educational environment, can be an innovative strategy to teach youth about science, technology, engineering, and mathematic (STEM) concepts. However, little is known about the true effects on conceptual knowledge and associated attitudes. Therefore, this study was conducted to examine the short-term effects of a series of five-day summer robotics/geospatial camps held in Nebraska. The study was conducted at six diverse locations and consisted of a five-day 4-H camp experience. The study examined the experiences of 147 youth between the ages of 10 and 15. A pretest-posttest quasi-experimental design was used in the study. Instrumentation consisted of a 37-question multiple-choice assessment targeting various STEM topics, and a 38-question attitude questionnaire assessing STEM interests and attitudes. Results suggest that the 4-H robotics and geospatial summer camp program is a promising approach for supporting STEM-related learning and enhancing attitudes towards STEM.

1 INTRODUCTION

The Nebraska 4-H, with grant funding from the National Science Foundation, is developing a program to increase science, technology, engineering and mathematics (STEM) achievement and interest using robotics and geospatial technologies. The widespread availability of robotic kits such as the LEGO NXT Mindstrom kit, handheld Global Positioning System (GPS) devices, and geographical information systems (GIS) like GoogleEarth and ArcMap make it possible for youth (ages 10 to 15) to explore the integration of these technologies. The curriculum was developed by Nebraska 4-H and faculty from University of Nebraska's Biological Systems Engineering Department, in cooperation with Carnegie Mellon University's Robotics Academy, and involves 40 hours of instruction. The 40-hour summer camp activities include the building and programming of robots, working with handheld GPS receivers to explore and collect information, and the development and customization of GIS maps. The camp activities were led by project staff and in some cases faculty from the University of Nebraska. The content and context for the activities were delivered in a short introductory lecture format followed by hands-on activities. Two formal STEM-related assessments were also administered, one related to conceptual learning and one related to attitudes. The participating youth also shared their general perceptions of the activities.

Research in the use of educational robotics in an informal learning environment implies that robotics can increase academic achievement in specific STEM concept areas closely aligned with formal education topics and coursework (Nourbakhsh et al. 2005**;** Barker & Ansorge, 2007; Barker, Nugent, Grandgenett, & Hampton, 2008). Similarly, past research has indicated that GIS can be used to teach project-based science, environmental education and geography concepts to middle school students (McWilliams & Rooney, 1997). Research also sug-

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Table 1: Camp Participant Demographics.

Location	Demographics of Camp Participants					
	N total	Male	Female	Age (Mean)	% Minority	Overnight
1. Omaha North	18	9	9	11.39	100	No
2. Omaha South	16	9	7	11.12	56	No
3. Lincoln	67	55	12	12.52	12	Yes
4. Ord	10	9	1	12.40	0	No
5. Chadron	16	13	3	12.69	0	Yes
6. Grand Island	20	17	3	12.80	5	No

gests that the use of GIS helps in the development of analytical skills and problem solving (Wanner & Kerski, 1999). Moreover, there is growing interest in examining students' attitudes towards learning, with recognition that affect surrounds cognition and can moderate learners' conceptual change (Alsop & Watts, 2003; Koballa & Glynn, 2007). Measuring a student's attitude is not a trivial matter; and much of the robotics literature looking at attitudes relies heavily on subjective secondary observation. For example, Rogers and Portsmore (2004) reported that using robotics as an outreach activity in elementary schools increased confidence and interest in mathematics and science. This conclusion was based on teacher perceptions; the researchers did not directly gather any data from individual youth participants.

There are several instruments that have been developed to assess youth attitudes within science-related contexts. The most widely used is arguably the Scientific Attitude Inventory (SAI) developed by Moore and Sutman (1970). The SAI (I) consisted of a 60 item, four-point Likert-type scale with a series of 12 statements of attitude called "position statements." These twelve position statements assess six scientific attitudes – three based on intellectual attitudes and three based on emotional attitudes. The six attitudes include: 1) laws of science, 2) scientific explanation, 3) manner of scientific observation, 4) value of scientific activities, 5) usefulness of science to society and 6) student career aspirations. Each scientific attitude has a positive and a negative scale to create the 12 position statements used as potentially measurable constructs. According to Moore and Sutman (1970) the reliability of the SAI was measured through the use of the Winer test-retest method using the pre and posttest scores of the control group resulting in a test-retest reliability coefficient of .934. Based on the lack of significance using the SAI and other instruments when piloting the project, we elected to develop our own instrument based on specific constructs that originate from our 4-H robotics and GPS/GIS program. Our instrument measures eight scales including: task values in science, mathematics, robotics, and GPS/GIS, problem solving/critical thinking, cooperative learning/teamwork, self efficacy in robotics, and self efficacy in GIS/GPS.

2 PURPOSE AND METHODOLOGY

The purpose of this study was to investigate the short-term impacts of informal summer programs centered on robotics and geospatial technologies in a) promoting STEM learning for youth ages 10-15 and b) positively impacting their attitudes towards STEM. A total of 147 participants in six different 4-H facilitated camps participated in the summer program. Overall, 112 males and 35 females attended the camps. In addition, 75% of participants were identified as Caucasian, 12% were African American, 12% were Hispanic and 1% Asian. The overall mean age for the camps was 12.28 years with a median age of 12.00 years. Demographics are displayed by location in table one.

2.1 Instrumentation

The instrumentation used for the study consisted of two parts. To measure STEM learning, the project staff developed a 37-item, paper-and-pencil, multiple-choice assessment, covering a variety of topics including computer programming, mathematics, geospatial concepts and engineering/ robotics. The assessment was based on a previous 24-item robotics assessment instrument that demonstrated a Cronbach's alpha reliability

Table 2: Content questionnaire paired samples test.

	Paired Differences						
Location	Pre Mean	Post Mean	Mean	Std. Deviation	t	df	Sig. (2-tailed)
Omaha North	10.80	10.53	.267	3.22	.32	14	.753
Omaha South	11.58	15.50	-3.92	3.55	-3.82	11	.003
Lincoln	16.87	20.87	-4.00	3.01	-10.90	66	.001
Ord	17.60	23.80	-6.20	4.21	-4.66	9	.001
Chadron	16.53	23.20	-6.67	2.90	-8.93	14	.001
Grand Island	15.89	23.78	-7.89	3.18	-10.53	17	.001

coefficient of 0.86 (Barker & Ansorge, 2007). Two experts from Carnegie Mellon University's Robotics Academy and two engineers from the University of Nebraska-Lincoln Department of Biological Systems Engineering reviewed and validated the assessment instrument's content. The overall Cronbach's alpha reliability coefficient of 0.80 was reported for this instrument.

The attitude instrument was also developed by the project staff and was modeled after the Motivated Strategies for Learning Questionnaire (Pintrich, et al., 1991). The questionnaire focuses on the following eight constructs: task value for science, mathematics, robotics and GPS/GIS, problem solving/critical thinking, cooperative learning/teamwork, self-efficacy in robotics and self-efficacy in GPS/GIS. All the statements on the attitude instrument used positively worded items due to the relatively young age of the participants. The task value for science included questions like "It is important to me to learn how to conduct a scientific investigation." The mathematics task value construct included questions like "It is important for me to learn how to make accurate measurements to help solve mathematical problems." The robotics construct asked questions like "It is important for me to learn about robotics." The GPS/GIS construct included questions like "It is important for me to learn about GIS." In addition, problem solving skills (i.e." I try new methods to solve a problem when one does not work") and teamwork constructs (i.e. "I like being part of a team that is trying to solve a problem") were also explored. Finally the instrument examined self-efficacy in robotics (i.e. "I am confident that I can program a LEGO robot to follow a black line using a light sensor") and GPS/GIS concepts (i.e. "I am certain that I can log locations of a series of waypoints within a GPS unit"). The overall Cronbach's alpha reliability coefficient of 0.94 was reported for this administration of the post attitudinal instrument.

2.2 Data Collection

The pretest was administered by the researchers on the first day of the camp prior to the start of program activities. The posttest was administered in the morning of the last day of camp. Administration of the pretest-posttest assessment was conducted in the same manner for each camp.

2.3 Data Analysis Procedures

The study used a pretest-posttest quasi-experimental design, with the same assessment acting as both a pretest and posttest in each summer campsite. The learning assessment used a total score for the number of items correct. The primary analysis was a repeated measures t-test for the combined groups by location. The attitudinal instrument used a five-point Likert-type scale with five equaling "strongly agree" and one equaling "strongly disagree". A total score was calculated by summing all 38 items and comparing them using a repeated measures t-test for the entire group and by location.

Table 3: Attitudinal paired samples test.

Location	Paired Differences						
	Pre Mean	Post Mean	Mean	Std. Deviation	t	df	Sig. (2-tailed)
Omaha North	152.93	152.87	.067	22.72	.011	14	.991
Omaha South	148.09	153.45	-5.36	9.39	-1.89	10	.088
Lincoln	149.39	156.13	-6.75	14.95	-3.69	66	.001
Ord	148.11	161.67	-13.56	26.81	-1.52	8	.168
Chadron	138.13	151.06	-12.94	22.98	-2.25	15	.040
Grand Island	143.31	161.13	-17.81	23.89	-2.98	15	.009

3 RESULTS

3.1 Learning

Overall there was a significant increase from the pretest (M = 15.63, SD = 4.52) to the posttest scores (M = 20.12, SD = 5.60, t (136) = -13.71), p < .001) for the combined groups. These results suggest that the 4-H robotics and the geospatial summer camp program is a promising approach for supporting STEM-related learning. Results suggest that, overall, youth had significant increases in scores. Each location except for Omaha North had a significant mean increase (p < .001) from pre to posttest. See Table 2.

To get a better understanding of how individual sites scored on the test; the mean scores are separated by location. See Figure 1. The sites are listed in chronological order with the Omaha North camp first and ending with the Grand Island camp six weeks later.

3.2 Attitude

Similar to the knowledge instrument participants scored significantly higher on the posttest (M=155.91, SD = 20.20) than on the pretest (M=147.52, SD = 22.03, t (133) = -5.09), p < .001) indicating the 4-H robotics and GPS/GIS summer camps have a positive short-term effect on attitudes towards STEM topics. While all sites excluding the Omaha North had pre-post increases in attitudinal means, the t-results were not as significant as those from the content test. In addition, three sites did not have significant increase in scores. See table 3.

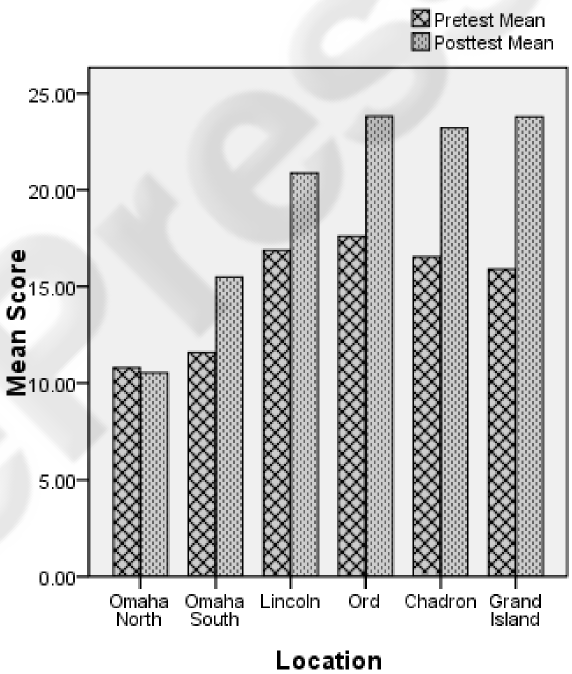

Figure 1: Pre and posttest mean scores by location for the content test.

4 DISCUSSIONS AND CONCLUSIONS

The significant increase in student scores on the learning assessment provides evidence for the use of robotics and GIS/GPS technologies as a means to promote STEM learning. With one exception, all the sites produced short-term gains from pre to posttest.

The Omaha North site did not show significant improvement from pre to posttest scores. One plausible explanation for the lack of improvement at that site is that chronologically it was the first camp run by the project staff. Therefore, activities and presentation methods were still relatively new, and were still evaluated and refined. This can be supported by the apparent increase of the mean paired difference between post and pretest that occurred later in the program. Another difference with the Omaha North site is that it had a lower mean score on the pretest (M=10.80, SD = 3.22) compared to other sites. The lower pretest score may indicate that this particular group of youth did not have as much initial experience and therefore, prior knowledge of robotics and geospatial concepts as other groups, perhaps suggesting that at least a minimal level of initial understanding of these topics is needed for students to be fully successful with this level of activities.

Documenting the positive impacts of robotics and GPS/GIS activities on student's attitudes has been a struggle in past research (Nugent, Barker, & Grandgenett (2008). Prior to this study the project team piloted two other existing attitude instruments (Scientific Attitude Inventory, Moore & Foy. 1997; Pell & Jarvis, 2001) with nonsignificant pre to post comparisons. Past results suggest that youth have a difficult time in making the connection between STEM concepts and Robotics and GPS/GIS activities. When robotics and GPS/GIS are embedded into a natural experiential learning environment, as opposed to the more traditional direct instruction, students may become excited about robotic and GPS/GIS, but not recognize that STEM learning is actually being integrated into the activities. Results have led to curricular revisions, including specific instruction on how robotics activities relate to science, engineering, math and technology and the creation of a new measurement tool.

The results of this study indicate that our attitudinal measurement instrument can detect short-term attitudinal changes towards STEM. More research is needed to examine each of the eight constructs and to assess various trends and the potential interactions of these constructs with participant demographics.

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