6-2008

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Recommended Citation

Barker, Bradley S.; Nugent, Gwen; and Grandgenett, Neal, "Examining 4-H Robotics and Geospatial Technologies in the Learning of Science, Technology, Engineering, and Mathematics Topics" (2008). *Teacher Education Faculty Publications*. 37.
https://digitalcommons.unomaha.edu/tedfacpub/37

June 2008 // Volume 46 // Number 3 // Research in Brief // 3RIB7

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Abstract
The study reported here investigated the use of educational robotics, paired with GPS and GIS geospatial technologies, as a context for learning selected concepts in science, technology, engineering, and mathematics within a 4-H camp setting. The study involved 38 students between the ages of 11 to 15. A pretest-posttest quasi-experimental design was used in the study, with a 29-question multiple-choice instrument targeting various academic topics. The results of the study suggest that the 4-H robotics and geospatial summer camp program is a promising approach for supporting STEM-related learning, as represented by a significant increase of means from pretest to posttest.

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Introduction

The Nebraska 4-H is developing a program to increase Science, Technology, Engineering, and Mathematics (STEM) achievement and interest using robotics and geospatial technologies as they relate to precision agriculture. The widespread availability of robotic kits like the LEGO NXT Mindstrom kit and handheld global positioning system (GPS) devices make it possible for youth to explore how the integration of these technologies work together to improve agriculture.

Precision agriculture is an emerging management strategy aimed at increasing profitability in food and other biomaterials production while maintaining environmental quality and improving the sociologic status of rural communities. Precision agriculture involves site-specific crop management, automated and robotic processes, soil sampling, mapping, analysis, food traceability, and wireless data communication (Watson, Segarra, Lascano, Bronson, & Schubert, 2005). Because precision agriculture encompasses many divergent hands-on technologies, it is ideally suited for exploration by youth in a non-formal learning environment such as 4H camps and after-school programs.

The 4-H Robotics and Geospatial Project is a statewide program offered through the state 4-H office and is open to youth ages 11 to 15. During the initial development phase of the program pilot, youth participated in a summer camp setting. The activities involved the building and programming of robots, working with handheld GPS devices to explore and collect information, and the development of geographic information systems (GIS) maps.

The culminating activity combined the three technologies through the taking of an aerial photograph of the camp that had three GPS coordinates marked. These coordinates were then referenced on a GIS map. Finally, youth programmed their robots to travel around the photographed areas enabled with a GPS receiver. The GPS tracks were transmitted to a nearby laptop computer, thereby recording the movement of the robot. This enabled youth to see, in real-time, the tracking of the movements of the robot on a GIS map.

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 suggests that the use of GIS helps in the development of analytical skills and problem-solving skills (Wanner & Kerski, 1999). Similarly, research in the use of educational robotics in a non-formal learning environment suggests 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). The study reported here examined the potential of using robotics and geospatial technologies in two Nebraska 4-H summer camps to teach STEM concepts.

Purpose and Methodology

The study investigated the impact of non-formal summer programs centered on robotics and geospatial technologies in promoting learning in science, technology, engineering, and mathematics (STEM) for youth ages 11-15.

A total of 38 students in two different 4-H facilitated camps participated in the summer program. The first camp was held at a 4-H camping center in eastern Nebraska over 6 days and 5 nights. Twelve youth (eight males and four females, median age of 12.50 years) from across Nebraska attended the camp. The second camp was held in central Nebraska at a public middle school. Twenty-six youth (18 males and eight females, median age of 12.00 years) participated and the camp was held over 5 days with no overnight stays.

Instrumentation

The instrument used for the study was a 29-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 coefficient of 0.86 (Barker & Ansorge, 2007). Six questions on the original assessment were modified to reflect changes in the LEGO programming language, and five GPS/GIS questions were added. An overall Cronbach's alpha reliability coefficient of 0.72 was demonstrated for the study. 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.

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 on the morning of the last day of camp. Administration of the pretest-posttest assessment was conducted in the same manner for each camp.

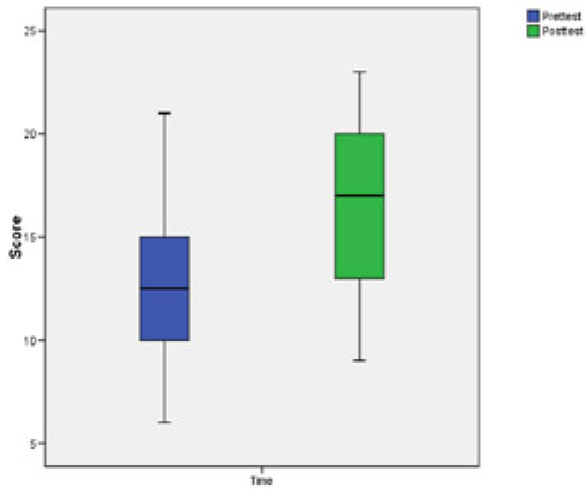
Data Analysis Procedures

The study used a pretest-posttest quasi-experimental design for the investigation, with the same assessment acting as both a pretest and posttest in each summer camp site. The assessment used a total score for the number of items correct. The primary analysis was a repeated measures t-test for the combined group and by site. Results were also analyzed by specific STEM concepts to identify which STEM concepts appeared to be learned within the context of the camp.

Results

The results of the study suggest that the 4-H robotics and geospatial summer camp program is a promising approach for supporting STEM-related learning. Overall there was a significant increase from the pretest (M = 12.63, SD = 3.67) to the posttest scores (M = 16.50, SD = 4.10, $t(37) = -7.38$), $p < .000$) for the combined groups (Figure 1).

Figure 1.
Boxplots for Pre- and Posttest Scores for Summer Camps



The camp in eastern Nebraska (Gretna) had a higher pretest score (*M* = 14.50, *SD* = 4.42) as compared to the central Nebraska camp (*M* = 11.77, *SD* = 2.99). In addition, the eastern Nebraska camp had a higher posttest (*M* = 17.50, *SD* = 4.89) than the camp in central Nebraska (*M* = 16.04, *SD* = 3.68). However, both camps made significant progress in STEM learning as represented by the assessment results. See Table 1 for descriptive statistics and repeated measure t-test results.

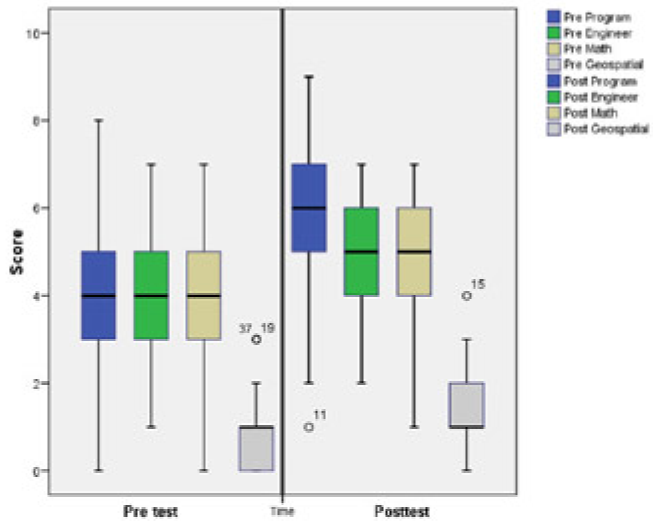
Table 1.
Repeated Measures t-tests

Group	**Test**	**Mean**	**SD**	**t-score**	**p**	**Effect size r^2**
Gretna (N=12)	Pre	14.50	4.42			
	Post	17.50	4.89	4.18	.002 *	.78
Central (N=26)	Pre	11.77	2.99			
	Post	16.04	3.68	6.23	.000 *	.78
Total (N=38)	Pre	12.63	3.67			
	Post	16.50	4.10	7.38	.000 *	.77

* Indicates a significant difference in mean scores from pretest to posttest at the .05 level.

A breakdown was also conducted of student responses related to particular STEM concepts broken down into four categories; mathematics (9 questions), geospatial (5 questions), programming (8 questions), and engineering (7 questions) were also conducted. See Figure 2.

Figure 2.
Boxplots for Pre- and Posttest by Category Scores for Summer Camps



Results suggest that, overall, youth had significant increases in scores in mathematics (including fractions and ratios), programming concepts (such as looping and multi-tasking), and engineering concepts (such as gears, and sensors). In the area of geospatial concepts (coordinate estimation based on location), there was an increase from pre to post, but the difference was not significant. The results are shown in Table 2.

Table 2.
Descriptive Statistics of Assessment Broken Down into STEM Components Area

Concept	N(DF)	Mean	SD	t	p	Effect size r^2	Cronbach's Alpha
Math Pre	38(37)	4.24	1.63				
Math Post	38(37)	4.89	1.43	2.39	.022*	0.37	.30
Geospatial Pre	38(37)	1.03	.85				
Geospatial Post	38(37)	1.21	.99	.827	.413	0.14	.12
Programming Pre	38(37)	4.13	1.83				
Programming Post	38(37)	5.68	1.84	5.42	.000*	0.67	.58
Engineering	38(37)	4.11	1.56				

Pre							
Engineering Post	38(37)	4.71	1.38	2.59	.014*	0.39	.49

* Indicates a significant difference in mean scores from pretest to posttest at the .05 level.

Discussions and Conclusions

In reflection upon the two 4-H camp interventions, the lack of significant improvement observed for the geospatial concepts would appear to be explainable given various informal observations of the camp interventions. Some of the geospatial activities relied on rather difficult concepts for the middle school aged children, such as the use of trigonometric ratios and coordinate distance formulas, while in contrast, the robotics activities involved concepts that were more traditionally aligned with a middle school curriculum, such as fractions, ratios, and degrees. However, it is also important to note that the students did appear to be very interested in the geospatial technologies, and given more time, the related geospatial concepts may well have been learned by these students. The participating students also appeared to be quite unafraid of these more advanced concepts. Future camp interventions with the GPS and GIS technologies will more carefully align the related geospatial activities and concepts to middle school curriculum.

The results of this pilot study do provide support for the use of educational robotics integrated with geospatial technologies to engage 4-H youth in activities that directly support their learning of STEM concepts in a summer camp program structure. Through hands-on, creative, self-directed learning, integrated STEM concepts are introduced naturally within the activity, rather than artificially, as students build, test, and refine their skills. The results of the study support the conclusion that youth were able to increase test scores across four content areas including, mathematics, geospatial concepts (limited but not significant improvement), computer programming, and engineering/robotics. The largest increases were in the computer programming area, which is to be expected since youth had little previous experience with the programming concepts covered in the camp as reflected on the pretest ($M = 4.13$). What is especially encouraging, however, is the increase in the mathematics scores, showing that the summer camp can reinforce in-school learning related to that discipline.

The concepts identified within the mathematics-related questions of the pretest and posttest were topics that are still traditionally difficult for students to learn within their formal education coursework, such as fractions, proportions, distance-related formulas, and geometry topics associated with degrees and circles. This potential for informal educational activities to directly support the learning of various challenging topics within the formal educational setting is especially encouraging.

While the results are promising, this study did have a relatively small number of participants (n=38) and results may not generalize well to the entire population of 4-H youth in Nebraska. Moreover, when dividing the assessment into four individual components, the associated

Cronbach's alpha reliability coefficients are low. The low reliabilities are a function of the smaller number of questions per topic and may not adequately represent the concept areas as anticipated. The study will be replicated in the summer of 2008 with a larger number of youth at three separate sites.

As stated earlier, the study does appear to imply that educational robotics combined with GPS and GIS technologies may be an encouraging context for informal educational programs, as represented in the two camp settings of this study, to support the learning of some relatively challenging STEM topics. Educational robotics (as well as GPS and GIS technologies), with a context of natural student engagement and dynamic interaction, appears to be a worthy platform to consider when informal educational settings desire to be more directly supportive to formal education. The Nebraska 4-H is finding that such camps can indeed be popular with both parents and students who recognize this academic potential, and see GPS, GIS, and educational robotics as a fun way to connect to both the agricultural technologies of today, and the STEM needs of students within their formal education classrooms.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. ESI-0624591.

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