The Use of Digital Manipulatives in K-12: Robotics, GPS/GIS and Programming

Gwen Nugent, Brad Barker, Neal Grandgenett, and Vaicheslav Adamchuk
University of Nebraska, gnugent@unl.edu, bbarker@unl.edu, ngrandgenett@mail.unomaha.edu, vadamchuk2@unl.edu

Abstract - **Faculty from 4-H Youth Development, Biosystems Engineering, and Education have collaborated to develop and implement an innovative robotics and geospatial technologies program, delivered in an informal learning setting of 4-H clubs and afterschool programs. Aimed at middle school youth, the program uses robotics and global positioning system (GPS) receivers and geographic information system (GIS) software to provide hands-on, self-directed learning experiences that promote personalized comprehension of science, technology, engineering, and math (STEM) concepts through experimentation. The goals of the program are to prepare youth for the 21st Century workplace by providing them opportunities to learn STEM concepts and foster positive attitudes about STEM. Funded by the National Science Foundation, the project has undergone extensive research and evaluation over the three years of the project. Results have focused on the project's impact on: a) youth learning of computer programming, mathematics, geospatial concepts, and engineering/robotics concepts and b) youth attitudes and motivation towards science, technology, engineering, and mathematics. In contrast to the preponderance of research on educational robotics relying on anecdotal and descriptive strategies, this research uses empirical, quantitative methods involving the use of comparison groups and pre-post analyses.**

Index Terms - Robotics, GIS, GPS, STEM attitudes

THE USE OF ROBOTICS IN EDUCATION

Unlike traditional manipulatives found in any elementary school classroom (i.e. pattern blocks, geoboards, LEGOs), digital manipulatives embed computational capabilities, often using a technology-based context [1]. The embedded computational capabilities allow youth to collect and interact with various forms of data. Digital manipulatives can be seen as technology "catalysts" that immerse youth in problem solving approaches using technology as a tool to assist in their thinking. In contrast to traditional technology where youth learn more directly **from** the technology (e.g. drill and practice exercises, a google search, or watching a YouTube video) digital manipulatives allow youth to learn **with** the technology and to be actively involved in the learning process. Fundamentally, the general use of manipulatives is based upon constructivist learning theories where youth actively construct knowledge from their personal experience [2].

Educational robotics and global positioning systems (GPS) receivers embody digital manipulation characteristics, allowing hands-on, minds-on, self-directed learning. Research supports the use of educational robotics to increase academic achievement in specific STEM concept areas closely aligned with formal education topics and coursework [3]-[7]. Robotics also encourages student problem solving [3]-[4], [8]-[10], and promotes cooperative learning [4], [11]. Similarly, past research has shown that geographic information systems (GIS) can be used to teach project-based science, environmental education and geography concepts to middle school students [12]. Research also suggests that the use of GIS helps students to develop analytical and problem solving skills [13].

Beyond the potential to influence youth learning, educational robotics also represents a unique technology platform with the potential to excite youth and to attract them into technological careers. The investigation of students' attitudes has a long history in learning research, with recognition that affect is closely related to student cognition, can moderate learners' conceptual change, and is often associated with behavior that is a precursor to learning and achievement outcomes [14]-[15]. The attitudinal dimension is particularly critical in STEM fields because of the need to attract young people to STEM study and careers [16]. Research has also shown that youth goals for STEM learning, their self-efficacy, and the value they assign to STEM tasks and activities are likely to influence their level of engagement [17]. Studies show that robotics generates a high degree of youth interest and engagement and promotes interest in math and science careers [3, [8], [10] [18-19].

EDUCATION PROGRAM DESCRIPTION

Our robotics and GPS/GIS program is targeted at middle school youth who typically spend 40 hours (one week) in a summer camp then meet weekly as a 4-H club or afterschool program for another eight months during the school year. Youth activities include the building and programming of robots using the LEGO Mindstorms NXT robotics platform. The robotics kits include 431 components including axles, gears, servo motors, and light, sound, ultrasonic, touch, and rotational sensors as well as various directions and diagrams. In addition, each kit has been supplemented with a laptop computer with LabView® (National Instruments, Inc., Austin, Texas) based LEGO® Mindstorms software providing a simplified graphical programming interface. The program also includes activities with handheld GPS receivers and ArcMap (ESRI, Redlands, CA) GIS software. The participants use handheld GPS receivers to collect waypoints and coordinate track records that are downloaded to the computer to construct GIS community mapping projects when combining various data layers.

Specifically, the instructional activities for students include:

- Building and programming a robot using the LEGO Mindstorms NXT kit.
- Learning about the principles of GPS, including travel direction, triangulation and geographic coordinates.
- Operating a handheld GPS receiver to record global positions and for navigation.
- Learning about the use of aerial photography and its application for land resource management.
- Learning about the basics of cartography, GIS, and map symbiology.
- Integrating an NXT robot with a GPS receiver for geo-tracking. For example, uploading to a GIS map realtime latitude and longitude coordinates and paths while the robot is moving.
- Exploring career opportunities in the fields of robotics and GPS/GIS, with an emphasis on precision agriculture and management of natural resources.

The integrative nature of the curriculum was implemented by combining educational robotics and GPS/GIS technology using specially developed software modules. The software relies on the real-time Bluetooth communication between a laptop computer, a GPS receiver and a robot. This allows participants to track and map a robot's path while operating outdoors as well as navigating between points with predefined geographic coordinates. Although limited by the accuracy of miniature GPS receivers and the range of Bluetooth communication, relevant activities can take place on a tennis court and/or school backyard where the size of the area is greater than the positioning accuracy of a receiver selected. In addition, several activities simulate practical applications relevant to crop production that rely on integration of the technologies explored. For example, weed spraying, tree harvesting and field scouting are a few simulated example activities being introduced that today rely on GPS and GIS technology.

Camp activities are led by project staff and are organized by faculty from the University of Nebraska. The content and context for the activities are delivered in a short introductory lecture format followed by hands-on activities supported by structured student worksheets.

BACKGROUND AND PREVIOUS ROBOTICS RESEARCH

Our project team has conducted research on the robotics and GPS/GIS intervention for the past three years. An initial study, using a quasi-experimental design with the same learning assessment acting as both a pretest and posttest, was conducted in 2006 with 121 youth in a robotics afterschool program (representing nine different schools) compared with 36 youth from three separate schools acting as the control group [20]. The results of the study indicated a significant increase in scores on STEM concepts from pretest ($M=9.49$. $SD= 3.66$) to posttest for the robotics group ($M=11.07$, $SD=3.82$, $t(119) = -5.06$, $p < .001$). The control group did not display a significant increase from pre to posttest scores.

Research with youth in a summer camp setting the following year [21] used a paper-and-pencil multiple-choice assessment based on the previously used measure. Results indicated that, in addition to overall learning increases ($t(37) = 5.06$, $p < .001$), youth had significant increases in scores in mathematics ($t(37) = 2.39$, $p < .05$), programming concepts ($t(37) = 5.42$, $p < .0001$) and engineering concepts ($t(37) = 2.59$, $p < .05$). In the area of geospatial concepts there was a slight increase from pre to post, but the difference was not significant.

CURRENT RESEARCH

Although previous robotics research has shown that robotics and GPS/GIS interventions are promising approaches for supporting STEM learning and increasing STEM interest, most of the studies were conducted using a within subjects design, lacking appropriate rigor, statistical sophistication, and experimental control. In order to provide more definitive conclusions, the current study involved the use of a control group of youth. It also extended our earlier research by including a focus on youth STEM attitudes, as well as their STEM learning.

I. Description of Sample.

The robotics treatment group consisted of 147 students participating in our 2008 summer robotics camps. These camps were conducted across six Nebraska locations representing both urban and rural settings, as well as diverse populations in both ethnicity (one location was 100% minority) and socio-economic status.

There were a total of 141 students participating in the comparison group. Comparison group students were recruited through Nebraska's Educational Service Units (ESU), a set of 19 state -funded educational support organizations. The ESUs sent e-mails to schools and curriculum leaders in the Omaha area inviting their participation in the research. For the control group, schools were asked to target a mix of student abilities, interests, gender, and ethnicities, and in general, to reflect the school's general population of students. Students selected for the control group took the pretest and posttest a week apart, without any intervention, and then participated in a 3 hour educational robotics exploration event, facilitated in appreciation for their help. Table 1 shows a comparison of the treatment and control students in terms of key demographics.

TABLE 1
COMPARISON OF ROBOTICS TREATMENT AND CONTROL YOUTH

Condition	N	Male	Female	Age (Mean)	% Minority
Robotics	147	112	35	12.28	25%
Control	141	104	31	11.39	20%

II. Instrumentation

The content learning instrument used for this study was an enhanced version of the earlier instrument, representing a 37-item, paper-and-pencil, multiple-choice assessment, covering topics in computer programming, mathematics (including fractions and ratios), geospatial concepts (coordinate estimation based on location), engineering (such as gears and sensors), and robotics (such as looping and multi-tasking). 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 helped to validate the assessment instrument's content. The same assessment instrument was used as the pre and posttest. A Cronbach's alpha reliability coefficient of .80 was reported for the administration of the posttest.

The attitude instrument, consisting of 33 Likert scale items, was also developed by the project staff and was modeled after the Motivated Strategies for Learning Questionnaire [22]. The questionnaire included two sections focusing on: a) motivation and b) the use of learning strategies. The motivation component included questions measuring youth self-efficacy in robotics and GPS/GIS. Self-efficacy is derived from Bandura's [23] theory of self-efficacy that is based on one's belief in their ability to cope with a task. Self-efficacy has also been shown to be correlated with achievement outcomes [24]. The self-efficacy scales (robotics and GPS/GIS) focused on youths' self-appraisal of their confidence in performing certain robotics and GPS/GIS tasks, such as "I am certain that I can build a LEGO robot by following design instructions." By focusing on performance tasks, these scales complemented our multiple choice content test which assessed general comprehension and knowledge.

The motivation section also included questions on students' perceived value of mathematics and science, GPS/GIS technologies and robotics. These task value scales strive to measure youth's evaluation of the importance, usefulness, and interest of a task. Research has shown that an early interest in STEM topics is a predicator for later learning and/or eventual career interests and choices [25]. Sample items included, "It is important for me to learn how to conduct a scientific investigation," and "I like learning new technologies like GIS."

The learning strategies section of the assessment focused on problem solving and teamwork. The problem solving scale measured the degree to which students use specific problem solving approaches to successfully accomplish the robotics tasks. Our anecdotal observations of the students had shown that they appeared to use a variety of problem-solving approaches, including trial and error, with little pre-planning and problem analysis. Sample survey items included, "I use a step by step process to solve problems" and "I make a plan before I start to solve a problem." The teamwork scale was included because a major goal of the project was to encourage teamwork, getting students to work with their peers to solve problems. Students worked in pairs to complete the robotics tasks, in addition to working in small groups of 3 or 4 students to complete certain robotics challenges. An underlying premise was that working with peers could help youth understand the STEM content and to accomplish tasks they could not accomplish on their own. A sample item included "I like being part of a team that is trying to solve problems."

The attitude instrument was factor analyzed using the two constructs of motivation and learning strategies. A confirmatory factor analysis was conducted because it allows a strong test of the theoretical structure of an instrument and also takes measurement error into account. The motivation construct conformed to the recommended Standardized Root Mean Squared Residual (SRMR), Root Mean Square Error of Estimation (RMSEA) and Comparative Fit Index (CFI) fit criteria. The learning construct was close to meeting acceptable fit criteria for the same indices. In addition, the overall Cronbach alpha reliability was .95, with individual scale alphas running from .64 to .88.

Teachers administered the control group pre-test content and attitudinal instruments in their classrooms. In order to mirror the general operational procedures from the robotics treatment group as closely as possible, the post-tests were then administered one week later.

III. Research Design and Data Analysis

The research study used a quasi-experimental design involving comparisons of a treatment (robotics) versus control group (no robotics). Data were analyzed using an Analysis of Covariance (ANCOVA), with the independent variable being intervention (robotics versus control condition) and the dependent variables being student learning (total score on content assessment) and STEM attitudes (overall mean score on attitude survey). The covariate was the pre-test scores on both the learning and attitudinal instruments. Because of a violation of the homogeneity of slopes assumption for the ANCOVA analysis for the cognitive results, a split plot ANOVA was used instead.

IV. Results

Results for the study are presented in two sections focusing on (1) STEM learning analyses and (2) STEM attitudinal analyses.

A. Learning Results

A preliminary analysis evaluating the homogeneity of slopes assumption indicated that the relationship between the covariate and the dependent variables differed significantly as a function of the independent variable. With this violation, an ANCOVA was not an appropriate statistic. Instead a split plot ANOVA was then conducted with time (pre – post) as the within factor and intervention (robotics treatment versus control) as the between variable. There was a significant time by treatment interaction (Wilk's $\Lambda = .72$, $F(1, 268) = 102.20$, $p < .0001$). A graph of the interaction clearly shows the dramatic increase in scores for the robotics group, while the control group scores remained static.

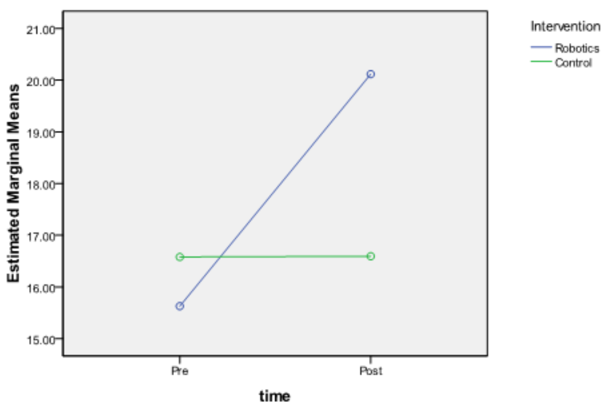

FIGURE 1
GRAPH OF THE TIME BY INTERVENTION INTERACTION FOR CONTENT TEST SCORES

Results also showed that, while males in the robotics group scored significantly higher than females on both the pre and post content assessments, both gender groups had significant pre-post increases (males: $t(105) = 13.92$, $p < .0001$, females: $t(32) = 4.18$, $p < .0001$).

B. Attitudinal Results

A preliminary analysis evaluating the homogeneity-of-slopes assumption for the ANCOVA analysis indicated that the relationship between the covariate (pre scores) and the dependent variable (post scores) did not differ significantly as a function of the independent variable, $F(1,255) = .28$, $p = .60$). The ANCOVA was significant ($F(1, 256) = 10.45$, $MSE = 1.074$, $p < .001$, partial $\eta^2 = .04$). Results indicated that the robotics treatment group scored significantly higher on the post attitudinal assessment than the control group (robotics $M = 4.23$, $s = .53$; control $M = 4.12$, $s = .46$).

To provide more insight into these results, pre-post comparisons from the robotics treatment condition were run for each of the eight attitudinal scales. Results showed significant increases for five of the eight scales. (See Table 2). Nonsignificant results for teamwork and perceived value of GPS/GIS were partially explained by differences between males and females. Girls and boys entered the robotics camps with equivalent attitudes towards GPS/GIS, but the camp positively impacted the girls' attitudes more than the boys on this element. In contrast, the robotics summer camp appeared to decrease females' attitudes towards teamwork, which anecdotally, we believe may have been caused by the interpersonal dynamics that took place between some of the girls in the camp setting. This result underscores how peer relationships within a camp setting can generally influence the experience of a particular youth. The instructional climate can play a distinct role in the learning process.

The positive impact of the instructional program in increasing youths' self-efficacy in performing robotics and GPS/GIS tasks complements study results showing that the robotics program positively impacted youth STEM learning. It is important to note that, while the cognitive results showed differences in male and female scores, the attitudinal research showed no statistically significant gender differences in their relative confidence in performing robotics and GPS/GIS tasks. This is especially encouraging since research has shown that boys tend to have higher self-efficacy in terms of their mathematics skills than girls [26].

TABLE 2
PRE AND POST COMPARISONS FOR ATTITUDINAL SCALES

Measure	M_{pre}	M_{post}	t (df)	p-value (one tail)	α
Motivation					
Science Task Value	4.04	4.20	4.15 (133)	$p < .001$	.75
Mathematics Task Value	4.03	4.14	2.06 (133)	$p < .05$	.83
Robotics Task Value	4.34	4.41	1.65 (133)	$p < .05$	.83
GPS/GIS Task Value	4.11	4.11	.02 (133)	$p = .49$	.86
Self-efficacy					
Robotics	4.10	4.54	7.31 (129)	$p <. 001$	.64
GPS/GIS	4.01	4.39	5.84 (129)	$p < .001$	.72
Learning Strategies					
Problem Approach	3.83	3.96	2.41 (133)	$p < .01$	.80
Teamwork	4.08	4.07	.13 (129)	$p = .448$	.88

DISCUSSION AND FUTURE DIRECTIONS

This research has documented the impact of the robotics and GPS/GIS program in improving youth STEM learning and attitudes by comparison of the intervention to a control group. Educational robotics and GPS/GIS technologies would seem to provide a natural context for youth engagement and dynamic interaction, and the use of these technologies appears to be a promising strategy within an informal educational setting to help directly support overall STEM learning goals and to increase general student interest in STEM. These results extend earlier robotics education research [5], [7], [18], [27] by providing quantitative results that use objective achievement measures instead of selfreport learning assessments and other more qualitative methodologies. In addition, the measurement of youth STEM attitudes has resulted in a project-developed instrument that has undergone careful development and psychometric analysis to assure reliability and validity.

Results extend our earlier research, which has consistently shown that our educational robotics and GPS/GIS program, conducted in both afterschool and summer camp settings, has positively impacted youth learning of computer programming, mathematics, geospatial concepts, and engineering/robotics concepts. The intervention has been effective with youth representing various ethnic, socio-economic, gender, and geographic populations. It is also important to note that these effects have been sustained as the project has increased in size, both in terms of the number of youth served and the number of locations.

As the project continues to expand nationally we are striving to creatively support and expand student participation by use of Internet-based technologies. This year we introduced a virtual robotics competition that was hosted synchronously on-line using Adobe Breeze meeting software. Each site used a web cam to broadcast the live movements of robots through a prescriptive challenge activity. (See Figure 2.)

FIGURE 2
JUDGES WATCHING ROBOTIC TEAMS
RUN THE CHALLENGE COURSE

In this first challenge activity, the robots had to move back and forth across a 4' x 10' sheet of white paper and "spray" areas of discoloration. The challenge illustrated a real life example of the use of robotics in variable rate applications of fertilizes and herbicides based on sensor data. This challenge event allowed youth to showcase their robotics-related talents and to participate in a wider learning community. The virtual competition was intended be a less expensive and more inclusive alternative to other competitions such as the FIRST LEGO League competition. It is a capstone event where youth collaborate on and compete in an integrated STEM challenge using teamwork, applying STEM concepts, practicing public speaking skills, and thinking creatively. Adult leaders for the participating robotics teams were very positive about the event, commenting that "it turned out way better than I thought" and "virtual is pretty neat because it eliminates having to travel." They also commented about the teamwork and troubleshooting skills that the competition event promoted in students and the real-world experience it provided in dealing with a problem within a specified time frame. One leader commented that his team had to learn to look at the big picture and to not get hung up on a single trouble-shooting issue that could consume all the available time. This competition is further undergoing extensive student evaluation, with the intent of documenting its impact on youth regarding workforce preparation and related teamwork skills and providing best practice guidelines for others who may want to replicate such a virtual competition event in their own locales.

Other current research is also now examining the impact of a short-term, 3-hour robotics intervention, intended to briefly introduce youth to robotics through the use of hands-on experimentation. This intervention was the experience provided to the control group in appreciation for taking the pre and post assessments. While we do not expect such a short-term experience to realize the same learning gains as those from the intensive week-long robotics camp, we are hopeful that the program will provide some initial excitement for youth about robotics and perhaps even increase their interest in robotics and GPS/GIS technologies. We are also beginning a focused research agenda on the impact of the educational robotics program on the adult club leaders. Educator implementation of the robotics and GIS/GPS curriculum and their participation in the project's professional development training could potentially result in increased STEM content knowledge and self-efficacy or confidence for these adults in presenting informal STEM instruction, particularly since these leaders are usually volunteers, with relatively limited STEM backgrounds.

In summary, educational robotics combined with geospatial technologies appears to promote hands-on, creative, self-directed learning, while allowing STEM concepts to be introduced naturally within the student robotics activities, rather than artificially, as the participating youth build, test, and refine their robotics/geospatial projects. In addition, the use of intensive summer camps offer a chance for youth to become more deeply involved in STEM activities than what might be possible in more formal educational settings, where the typical time constraints make extended involvement with a particular STEM application more difficult. The results to date in our studies suggest that the benefits to such student involvement may well be increased STEM conceptual knowledge, increased interest in science, engineering and technology subject areas; greater self-efficacy in performing technology-based tasks; and an increased use of effective problem-solving approaches.

ACKNOWLEDGEMENTS

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

REFERENCES

[1]Resnick, Mitchel. 1998. "Technologies for Lifelong Kindergarten." *Educational Technology Research and Development*. Vol. 46(4).

[2]Piaget. Jean. 1972. *The Child's Conception of the World*. Towota, NJ: Littlefield Adams.

[3]Rogers, Chris, and Merredith Portsmore. 2004. "Bringing Engineering to Elementary School. *Journal of STEM Education*. Vol. 5(3/4), pp.17-28.

[4]Nourbakhsh, Illah, Crowley, K., Bhave, A., Hamner, E., Hsium, T., Perez-Bergquist, A., Richards, S., and Wilkinson, K. 2005. "The robotic autonomy mobile robots course: Robot design, curriculum design, and educational assessment. *Autonomous Robots*. Vol. 18(1), pp. 103-127.

[5]Nourbash, Illah, et al. 2006. "The Personal Exploration Rover: Educational Assessment of a Robotic Exhibit for Informal Learning Venues. *International Journal of Engineering Education. Special Issue on Trends in Robotics Education.* Vol. 22(4), pp. 777-791.

[6]Barker, Bradley S. and John Ansorge. 2007. "Robotics as Means to Increase Achievement Scores in an Informal Learning Environment." *Journal of Research on Technology in Education.* Vol. 39(3), pp. 229-243.

[7]Williams, Douglas, Yuxin Ma, Louise Prejean, and Mary Jane Ford. 2007. "Acquisition of Physics Content Knowledge and Scientific Inquiry Skills in a Robotics Summer Camp. *Journal of Research on Technology in Education*. Vol. 40, pp. 201-216.

[8]Barnes, Mary. 1999. "Cumulative and Exploratory Talk in a Collaborative Learning Classroom." Proceedings of the 22nd Conference of the Mathematics Education Research Group of Australasia 53-59, Adelaide, South Australia

[9]Mauch, Elizabeth. 2001. "Using Technological Innovation to Improve the Problem Solving Skills of Middle School Students." *The Clearing House.* Vol. 75(4), pp. 211-213.

[10]Robinson, Mike. 2005. "Robotics-Driven Activities: Can They Improve Middle School Science Learning?" *Bulletin of Science, Technology and Society.* Vol. 25(1), pp. 73-84.

[11]Beer, Randall D., Hillel J. Chiel, and Richard F. Drushel. 1999. "Using Robotics to Teach Science and Engineering. *Communications of the ACM.* Vol. 42(6), pp. 85-92.

[12]McWilliams, Harold, and Paul Rooney. 1997. "Mapping Our City: Learning to Use Spatial Data in the Middle School Science Classroom," Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

[13]Wanner, S. And J. Kerski. 1999. “The effectiveness of GIS in high school education. Paper presented at the ESRI 1999 users conference. http://gis.esri.com/library/userconf/proc99/proceed/papers/pap203/p203.htm

[14]Alsop, Steve., and Watts, M. 2003. "Science Education and Affect". *International Journal of Science Education*. Vol. 25 No.9, pp.1043-7.

[15]Koballa, Thomas. R., Jr., and Shawn M. Glynn "Attitudinal and Motivational Constructs in Science Education." In S. K. Abell and N. Lederman (eds.). 2007. *Handbook for Research in Science Education.* Mahwah, NJ: Erlbaum, pp. 75-102.

[16]Bonvillian, William. B. 2002. "Science at a Crossroads." *FASEB Journal*. Vol. 16, pp. 915-919.

[17]National Research Council. 2007. *Taking Science to School.* Washington DC: National Academy of Sciences.

[18]Nourbakhsh, Illah, Hammer, E., Crowley, K., and Wilkinson, K. "Formal Measures of Learning in a Secondary School Mobile Robotics Contest". 2004. IEEE International Conference on Robotics and Automation (ICRA).

[19]Miller, David. P., and Cathryne Stein. "'So That's What Pi is For' and Other Educational Epiphanies from Hands-On Robotics." In Druin, A. and Hendler, J. (eds.). 2000. *Robots for Kids: Exploring New Technologies for Learning Experiences*. San Francisco, CA: Morgan Kaufmann.

[20]Nugent, Gwen, Bradley Barker, Neal Grandgenett, and Amy Hampton. 2008. “Examining 4-H Robotics in the Learning of Science, Engineering and Technology Topics and the Related Student Attitudes.” *Journal of Youth Development: Bridging Research and Practice.* Vol. 2(3).

[21]Barker, Bradley, Gwen Nugent, and Neal Grandgenett. 2008. "Examining 4-H Robotics and Geospatial Technologies in the Learning of Science, Technology, Engineering, and Mathematics Topics." *Journal of Extension.* Vol. 46(3).

[22] Pintrich, Paul, David Smith, Teresa Garcia, and William McKeachie. 1999. *A Manual for the Use of the Motivated Strategies for Learning Questionnaire.* Ann Arbor: University of Michigan.

[23] Bandura, Albert. 1977. *Self-efficacy. The Exercise of Control.* New York: Freeman.

[24] Sorge, C. 2007. “What Happens: Relationship of Age and Gender with Acience Attitudes from Elementary to Middle School. *Science Educator*. Vol 16, pp. 33-37.

[25] OECD. 2007. *PISA 2006 Science Competencies for Tomorrow’s World. Volume 1: Analysis.*

[26]Jacobs, Janice. E., Stephanie Lanza, D. Wayne Osgood, Jacquelynne S. Eccles, and Alan Wigfield. 2002. "Changes in Children's Self-Competence and Values: Gender and Domain Differences across Grades One through Twelve." *Child Development.* Vol. 73, pp. 509-527.

[27]Fagin, Bary, and Laurence Merkle. "Measuring the Effectiveness of Robots in Teaching Computer Science." February 2003. SIGCSE 2003 Technical Symposium on Computer Science Education. Reno: Nevada.

AUTHOR INFORMATION

Gwen Nugent, Research Associate Professor, Nebraska Center for Research on Children, Youth, Families, and Schools, University of Nebraska-Lincoln, gnugent@unl.edu

Brad Barker, Assistant Professor, 4-H Youth Development, University of Nebraska-Lincoln, bbarker@unl.edu

Neal Grandgenett, Peter Kiewit Distinguished Professor of Education, University of Nebraska at Omaha, ngrandgenett@mail.unomaha.edu

Vaicheslav I. Adamchuk, Associate Professor of Biological Systems Engineering, University of Nebraska-Lincoln, vadamchuk2@unl.edu