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Robotics camps, clubs, and competitions: Results from a US robotics project

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HIGHLIGHTS

- Robotics camps, clubs and competitions foster youth STEM content knowledge.
- Robotics camps and competitions promote youth problem solving skills.
- Robotics camps are effective in promoting interest in engineering careers.
- Youth reported that the camp activities were more interesting than those in school.

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ABSTRACT

Funded by the US National Science Foundation, the University of Nebraska-Lincoln has spent the last eight years developing and implementing a comprehensive educational robotics program for youth ages 9–14. The program was delivered in informal (out-of-school) learning environments through robotics camps, clubs, and competitions and provided robotics experiences to over 5000 youth and 400 educators. The goal of the project was to positively impact the youths' science, technology, engineering, and mathematics (STEM) knowledge and attitudes — and to foster an interest in STEM careers. Results of extensive research and evaluation showed that youth participation in the robotics activities increased their STEM content knowledge (particularly engineering and computer programming), their perceived problem solving skills and their interest in engineering careers. Youth also perceived that the robotics activities were different from those in school, reporting that the robotics camp was more interesting and involved more hands-on activities.

1. Introduction

Educational robotics represents a powerful, engaging tool for youth learning because they can touch and directly manipulate the robots, resulting in hands-on, minds-on, self-directed learning. Our robotics project was based on a theoretical framework derived from experiential learning, which is similar to problem-based learning in that students learn concepts and principles through authentic experiences and problems, typically in small groups, and with teachers as facilitators [1]. We also situate robotics within an integrated STEM framework, where youth must utilize science (inquiry), technology, engineering and mathematics skills to successfully complete the robotics activities.

Empirical support for educational robotics comes from research showing that robotics can increase learning in specific STEM concept areas [2–4]. Robotics also encourages student problem solving [5–7] and promotes cooperative learning [8,9]. Beyond the potential to influence youth learning, educational robotics is a unique technology platform for increasing student interest in STEM. Internationally, many countries are investing in STEM educational programs to compete in the global marketplace and to increase the number of youth pursuing STEM careers [10]. Studies show that robotics can generate a high degree of student interest and engagement in math and science careers [11,12].

This paper examines how our robotics program – delivered through informal learning environments as summer camps, academic year clubs, and robotics competitions – supports middle school youth STEM learning and motivation. Results are provided for three overarching areas of inquiry:

1. What is the impact of the robotics camps, clubs and competitions on middle school youth STEM knowledge, attitudes, and workplace skills?

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2. What is the impact of the robotics experiences on youth career interests?
3. How do youth perceive the value of the individual STEM knowledge and skills gained during the robotics summer camps? How do the learning experiences compare to those they experience in school?

2. Description of the robotics camps, clubs, and competitions

At the heart of our robotics project is the curriculum, which consists of approximately 40 h of instruction involving the building and programming of robots using the LEGO Mindstorms NXT robotics platform. The format of the activities involves a short introductory presentation by an informal educator followed by hands-on activities supported by structured worksheets. Participants typically work in self-selected, same-sex pairs to complete the majority of robotics tasks. Youth typically select friends or acquaintances as partners; educators assist as necessary to insure everyone has someone to work with. In addition, small groups of three or four students are formed for more advanced challenges. Individual lessons typically take one to two hours to complete; however more complex experiences can last as long as four hours. Sample lessons cover such skills as writing a simple program to display text on the brick, programming the robot motors for movement and various turns, using loops in a program, navigation to avoid obstacles using touch and ultrasonic sensors, and programming the sound sensor and the light sensor to track a line. (A complete description of the curriculum can be found in [13]; samples of the curriculum are on line at http://www.gt21.org).

The camps and clubs utilize the same basic curriculum but educators are given the latitude to modify and adapt the instruction to meet the needs of their participants. The camps are delivered in the summer and typically last 40 h (one week). The clubs, which usually meet during the academic year, vary considerably depending on the organizational sponsor (i.e. 4-H, after school). Some clubs meet the entire academic year, others only a couple of weeks. The longer time frame allows more in-depth exploration of individual topics, but individual sessions can be as long as a week apart, which causes more fragmented learning. Instructors often have to review and refocus youth before proceeding with the instruction. The club format is also more susceptible to having youth drop in and out or miss individual sessions.

The robotics competitions supported through the project are through the FIRST LEGO League, one of the largest educational robotics competitions with 16,000 teams competing internationally. The project began sponsoring competitions in 2010, and the events have grown each year. The event is organized around a real-life science-based issue, with middle school participants assembling robots based on the LEGO Mindstorms kit to perform a set of defined tasks to address this issue. They also prepare an issue-based research project. Data from coaches has shown that team preparation typically lasts around 40 h. The FIRST LEGO League does not have an official curriculum or coach training, but instead provides a handbook for coaches and links to external resources. To help support coaches in preparing youth for the competition, we made the project curriculum available. However, only about 20% of coaches reported using the project resources.

3. Methodology

3.1. Participants

Across the eight years of the project, we collected six years of data from 1825 campers, three years of data from 458 competition participants, and two years from 126 club participants. Camp participants represented a US sample from 23 states, with approximately 70% male, 30% female. Competition participants, on the other hand, were concentrated in the Midwest; gender split was again 70% male, 30% female. The club data primarily came from Nebraska, but data was also collected from youth from seven states. In general, 67% were males; 33% female. Unlike the camps and competitions, the project has less control over club origination, organization, and research participation, and the numbers of club participants were considerably smaller than those for the other two formats.

3.2. Instrumentation

The instrumentation used in the camps and clubs each year was identical, with questions assessing STEM knowledge, attitudes, and workplace skills (Table 1). STEM content knowledge was measured through a multiple-choice assessment covering science (inquiry), mathematics (including fractions and ratios), computer programming (such as looping and conditional statements), engineering concepts and processes (such as gears and sensors), and engineering design. This instrument was modified over the years to be more application oriented and to rely less on factual recall. In addition, early versions of the instrument did not include questions on engineering design and science. The instrument's Cronbach alpha reliability was consistently around 0.82.

The attitudinal instrument [14] contains 33 items that utilize a Likert format ranging from (1) strongly disagree to (5) strongly agree. There are multiple scales, including youth perceived value (importance, usefulness) of mathematics, science, and robotics (e.g. "It is important for me to learn how to program a robot to carry out commands"), as well as their self-efficacy or confidence in performing robotics tasks (e.g. "I am confident I can program a robot to move forward two wheel turns (i.e. 720°) and then stop)". The instrument also contains workplace skills questions focusing on youth use of teamwork (e.g. "I like being part of a team that is trying to solve a problem") and problem solving skills (e.g. "I make a plan before I start to solve a problem"). Unlike the cognitive instrument described above, this instrument was used consistently throughout the project, and showed high reliability as evidenced by a Cronbach alpha of 0.97. The final series of questions asked youth how interested they were in certain STEM-related careers. This section again used a Likert format ranging from 1 = very uninterested to 5 = very interested.

The competition instrumentation was similar to the one used in the camps and clubs, but was shortened because of the time constraints within a competition environment. Even with the fewer number of questions, however, the reliability was high, showing alphas of 0.80 for the knowledge test and 0.92 for the attitudinal survey.

Because our project was designed as an integrative STEM experience, we were interested in knowing how youth perceived the individual science, technology, engineering and mathematics content. Did youth view the camp primarily as a technology-oriented experience? Did they recognize that science and mathematics content was embedded within the curriculum? Did they believe what they learned in the summer camp would transfer into the school environment? To answer these questions, we developed nine generic Likert-type questions (5-point scale) that could apply to each of the four STEM disciplines. For example, one question involved youth use of the separate skills to successfully complete the robotics activities, i.e. "I had to use _________ skills to successfully complete the robotics skills in this camp". The question appeared four times on the survey, with a different STEM area appearing in the blank. Other questions probed youth perceptions of (a) the individual science, technology, engineering, and mathematics skills