The Impact of Robot Projects on Girls' Attitudes Toward Science and Engineering

Jerry B. Weinberg, Jonathan C. Pettibone, Susan L. Thomas, Mary L. Stephen, and Cathryne Stein

***Abstract*— A variety of programs, including robotics, have been created with the intent of both increasing girls' interest in science, technology, engineering and math (STEM) areas and careers. While robotics programs have been successful at getting girls to participate in STEM activities, an overall question still remains: Does participation in such programs have an impact on girls' perception of their abilities and, subsequently, long term career interests? This national project is an in-depth study of participants in a robotics educational program designed to gain an understanding of how such programs may have a short-term effect on girls' perception of their achievements in STEM areas, and whether this translates into long-term career goals. Results of this study show positive changes in both perception of abilities and career interests.**

***Index Terms*—Expectancy-value Theory, Robot, Robotics, STEM education.**

I. Introduction

The gender gap in engineering, science, and technology has been well documented, e.g. [1] [2], and a variety of programs at the k-12 level have been created with the intent of both increasing girls' interest in these areas and their consideration of them for careers, e.g. [3], [4], [5]. With the development of robotics platforms that are both accessible for k-12 students and reasonably affordable, robotics projects have become a focus for these programs, e.g. [6], [7], [8], and there is clear evidence that shows robotics projects are engaging educational tools [8] [9].

While it appears clear that robotics projects energize students toward participating in the activities and learning the science, technology, engineering, and math (STEM) concepts, it is less clear whether such projects translate into long-term interests and perceptions of ability in STEM areas of study and, ultimately, career choices. Extensive studies have been done on various cultural and educational aspects of girls' experience with STEM areas that contribute to forming their attitudes of STEM careers and their self-perceived success in those careers. Studies indicate that negative attitudes begin forming in early childhood and tend to get reinforced along the way [2] [10]. While programs like those noted above have been successful at getting girls to participate in STEM areas, an overall question still remains: *Does participation in such educational programs have a long-term impact on girls' perception of their abilities and interests in STEM areas?*

Over the past year, an in-depth study of participants in a robotics educational program was conducted to determine if such programs have a positive impact on girls' self-perception of their achievement in areas STEM, and whether this translates into career choices. To examine social and cultural issues, this study applied a long-standing model in motivation theory, Wigfield and Eccles's [11] *expectancy-value theory*, to examine a variety of factors that surround girls' perceptions of their achievement (See Figure 1). Expectancy-value theory considers that individuals' choices are directly related to their "belief about how well they will do on an activity and the extent to which they value the activity" [5, p. 68]. The expectancy-value model of achievement performance and choice focuses on individuals' value of the task and their expectations of success to determine achievement-related choices.

The model was initially used to examine achievement in math, and components of it have been used to examine computer attitudes and skills [e.g., 12], as well as involvement in sports [13]. While separate components of the model have been studied extensively, less research has been done on larger portions of the model. Moreover, previous studies have mainly been conducted in the context of math courses and without the application of technology such as robotics [14]. By applying a larger portion of the expectancy-value theory to robotics education, this study provides the most comprehensive view of the many factors involved in a student's experience in a robotics educational program and how it affects self-perception.

As the focus of this study is on the effect of perceptions on achievement-related choices in the STEM areas, constructs in the boxes of the children's perceptions, goals and abilities, and expectations of success will be examined (see shaded boxes in Figure 1 – within each shaded box, constructs of interest are in darker print).

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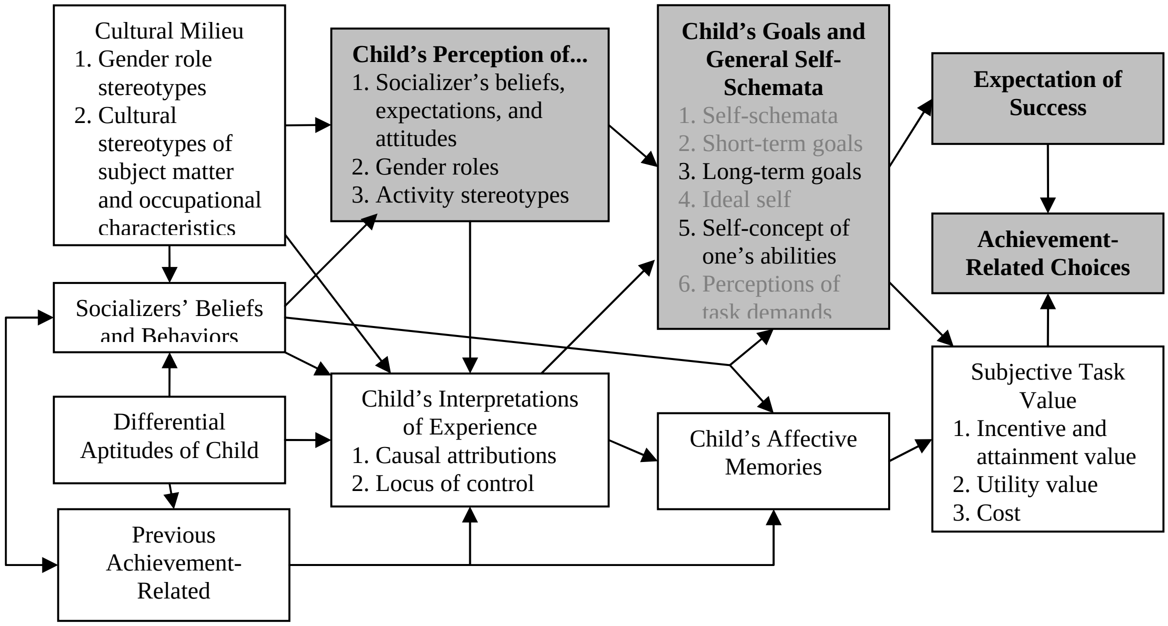

Figure 1: Expectancy–value model of achievement motivation [11].

Based upon the role of environmental and individual factors in STEM self-perceptions, our specific research questions were: What is the utility of the psychological components of the expectancy-value theoretical framework for understanding the role of gender differences in STEM-related choices? In addition, does the gender make-up of the team (all girls vs. mixed-gender) also impact the perceptions, expectations, and choices of the female team members? More specifically with respect to a girl's involvement in the robotics program, what impact does involvement have:

- on her perceptions of: gender roles and STEM activity stereotypes?
- on her long term goals in STEM areas?
- on self-perceived abilities in STEM areas?
- on her expectations of success in STEM areas?
- and on her STEM-related short term and long term academic and career choices?

I. Methods

The study involved participants in the KISS Institute for Practical Robotics' Botball Program (www.botball.org). The Program engages thousands of middle and high school students in regional and national robotics competition in a team-based activity that includes a cooperative component and a competitive component [15]. The Program starts with a hands-on teacher/student workshop. Equipped with this knowledge and a robot kit, teachers mentor students in the development of the project. The students have seven weeks to design, build, program, and document a team of small, autonomous mobile robots to implement the students' strategy to complete the tasks of the open-ended competition. While the competition changes each year, the typical tasks include finding, collecting, sorting, and placing a variety of items (See Figure 2).

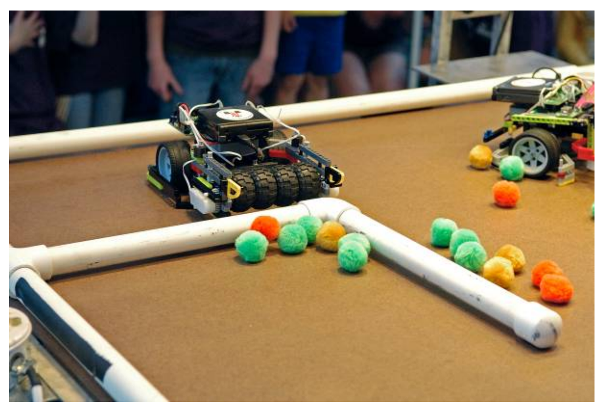

Figure 2: Robots collecting items representing various elements of the game.

The robot kit contains two micro-controllers, and sufficient sensors and building materials to create two robots. The sensors include a color camera with vision processing software, touch sensors, sonar sensors, light sensors, and infrared sensors (See Figure 3). Teams are limited to building robots using only the parts that come in the kit.

Participants in this study were recruited from 7th grade classes who had not previously participated in the Botball program. Twelve all-girl teams and 24 mixed-gender teams comprised the sample. The total number of students involved was 324: 225 females, 99 males. Teams came from 13 states, representing all regions of the country. Using a modified version of the Michigan Study of Adolescent and Adult Life

Transitions [16], participants were tested prior to beginning the program (pre), and immediately following the competition (post). In addition, because perceptions of mentor effectiveness could impact the results, participants did a post competition rating of their mentors using a measured developed by Bennett, Tsikalas, Hupert, Meade, and Honey (1998) for the NSF funded project *Telementoring Young Women in Science, Engineering, and Computing* project [17]. On a 10 point scale ranging from "not true at all" to "completely true", participants rated their mentors on eight positive (e.g., she boosted confidence in my abilities) and six negative (e.g., she couldn't provide the information I needed) statements.

Figure 3: Students preparing their robots for testing at the 2007 Greater St. Louis Botball Regional.

The quantitative study was complemented by a qualitative study that followed four teams: two all-girl teams and two mixed-gender teams. The qualitative study helped us to identify and understand "causal connections in the lived experiences of participants" [18, p. 15]. It also allowed us to gain an understanding of girls' unique and personal experiences and what effects participation may have on their future decisions. Data were collected from several sources, including interviews of parents, mentors and students; observation of team sessions; videotapes by both researchers and student participants of team sessions; and documentation and blog entries produced by the team members. Data from the different sources provided a multi-layered understanding of participants' experiences that enabled us to create thick, descriptive narratives of each team. Trustworthiness of research findings was established through triangulation of data. Triangulation involves cross-checking interpretations and data obtained from multiple, independent approaches and sources [18].

II. Experimental Results

A. Quantitative Study

The quantitative data was examined in a two step process. In the first step, structural equation modeling (SEM) was used to measure the indirect effects that perceptions, goals, and self-schemata have on achievement related choices,. SEM is a technique that allows for the modeling of relationships between multiple variables in complex systems where both direct and indirect relationships exist. In this way, SEM permits us to explore the fit of the expectancy-value model with our data. Overall, the expectancy-value model was a good fit. In support of the model, we found that beliefs in traditional gender roles led to negative self-concepts of ability which in turn led to lower expectations for success in science and math. These lower expectations for success led to less positive attitudes about careers in these areas. Conversely, a rejection of traditional gender roles led to a higher positive self-concept of one's ability in science and math which led to greater expectations for success in these areas and more positive attitudes for these careers.

In step two, we used the results of the model to look for the impact of participation in Botball. Employing a series of Analysis of Variances (ANOVA's), we found that the attitudes of girls towards a career in engineering significantly increased as a result of participation. This increase in positive attitudes toward engineering was due to participation in Botball decreasing the acceptance of traditional gender roles. We also found that girls in the mixed-gender teams with good mentors experienced an increase in self-concept and increased expectations of success in science and math due to the program. Interestingly, self-concept and expectations of success changed little for girls in all-girl teams, regardless of mentor effectiveness.

B. Qualitative Study

The multiple data sources used in the qualitative part of this study enabled us to build descriptive narratives of four diverse settings, teams, and participant experiences. The data enabled us to obtain insights into trends observed in the quantitative part of the study. Among themes that emerged from the qualitative data were the influence, role and style of mentors in girls' experiences on teams with more effective mentors encouraging the girls and providing opportunities for them to learn and master the different components of the process on their own. This approach seemed to neutralize one of the other themes that emerged - the impact of traditional gender roles on self-concept and performance. For example, some girls on all-girl teams had the tendency to downplay their abilities when boys were around. Girls on mixed gender teams were more likely to choose programming over building the robot because they thought programming would be easier. They also chose to do the more verbal tasks of blogging and developing the presentations.

III. Conclusion

The results of this study provide evidence that participation in Botball may help to reduce the gender gap in science and engineering through reducing beliefs in traditional gender roles and increasing positive attitudes about engineering and science and careers in these areas. Given that the Botball program lasts only seven weeks, these results indicate that short-term, well-structured programs that can effectively modify social and cultural beliefs may be particularly promising in encouraging girls to pursue STEM areas for study and careers.

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