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Igniting the Flame: Technology Interests and Spatial Reasoning and Orientation Skills of Female Middle School Students Through Robotics Coding

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SUMMARY

This study explored the interest, outcome expectations, choice goals and choice actions in engineering and technology, collaboration value, problem solving attitudes, and spatial reasoning and orientation skills of 63 middle school females in grades six, seven, and eight. The participants were involved in a five full-day coding robotics summer camp. Data was collected through a pre/post survey and pre/post spatial reasoning and orientation instrument and analyzed using a one-way repeated-measures analysis of variance. Results of the analysis indicated no significant difference in interest, outcome expectations, choice goals and choice actions in engineering and technology, collaboration value, and problem solving attitudes. There was a significant difference in spatial reasoning and orientation skills. Results indicate additional time and/or activities are needed to positively influence middle school female students' interests and attitudes in technology and engineering. Recommendation for future research include examining how to enhance female interests and attitudes in STEM fields and careers.

Keywords: Robotic coding, female, middle school

INTRODUCTION

> *Coding is today's language of creativity. All our children deserve a chance to become creators instead of consumers of computer science.* Maria Klawe (as cited in Project Tomorrow, 2018, p.1).

Creators rather than consumers, a high, but not unreasonable, expectation for students. There is currently an emphasis to encourage children and adolescent interest in science, technology, engineering, and mathematics (STEM) fields (Novick & Gadura, 2020; Staus, et al., 2019). Within this context, a lack of females in STEM fields exists (Babarović, 2022) resulting in the need for strengthening female interest, experience, and success in these areas. Unfried et al. (2014) reported that in 2011 the National Research Council called on K-12 educators to increase the number of students pursuing STEM careers, including women, students of color, and students from low socioeconomic backgrounds. Such calls emphasize a need to increase technology skills and interest of all students. The problem this study addressed is the lack of females in the STEM fields, in particular technollogy and coding.

The International Society for Technology in Education (ISTE) has standards for teaching and learning for educators and students through which the utilization of technology plays an integral role (ISTE, 2022). One of the seven student standards is computational thinker. As a computational thinker, students use technology to collect and analyze data, develop and test solutions, and utilize problem-solving and algorithmic thinking to solve problems. Computational thinking (CT) as defined by ISTE provides a framework on which to build student understanding, skills, and dispositions in technology. An important dimension of the framework involves learning situations that support development of CT. In addition, the *K-12 Computer Science Framework* (K-12 Computer Science, 2016), supported in part by the Computer Science Teachers Association, identified CT as thought processes involving steps or algorithms to solve problems which involve skills that include decomposing problems, creating algorithms, and developing and analyzing processes. Problem solving is an important cognitive process (Caliskan, 2020), and CT helps develop problem solving skills. CT is considered to be a core component of computer science (K-12 Computer Science Framework, 2016).

One aspect of computer science is coding. Coding has been recognized as a means to develop CT (Kynigos & Grizioti, 2018). Recent emphasis on coding has led to the development of new software which uses block based coding which allows the user to code without having to learn complex programming languages (Soyan & Kanbul, 2018) thus providing children and adolescents a means to be successful in coding. This platform allows for students at every grade level the ability to code and write simple programs.

Coding at the middle school level, which for the purpose of this paper is defined as fourth through eighth grades, has been shown to positively influence student knowledge and attitudes. Enjoyment, problem solving, learning motivation, and attitudes toward group work had significant relationships on computational thinking skills of 4th

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and 5th grade middle school students involved in collaborative activities with coding robotics in an engineering class over a 3 month period (Stewart et al., 2021). Fifth through eighth grade students in a computer programming class using block coding demonstrated a high level of CT, whereas students who did not take the course demonstrated a moderate level (Günbatar, 2020). A significant increase ($p<0.01$) was also found in CT skills of "creativity, algorithmic thinking, cooperativity, and critical thinking" of middle school students involved in block based coding of computers which met twice a week over the course of 12 weeks (Günbatar & Turan, 2019, p. 338). After participation in 5-week after school activities using computer block based programming, middle school students understood sequence and the subtasks needed to program simple projects (Kwon & Cheon, 2019). The students also improved in the area of abstraction parallelism skills, but some students were not able to decompose subtasks for more complicated projects or debug errors. However, not all studies have found statistically significant changes in all CT skills. Although 6th grade students' problem solving skills increased significantly ($p<0.05$) as a result of programming robots which occurred once a week over a 9 week period (Caliskan, 2020), Günbatar and Turan (2019) found no significant change ($p=0.439$) in problem solving of middle school students using block based coding. This variance supports the need to better understand how to support middle school students' development of various aspects of CT as well as attitudes towards STEM.

Stewart et al. (2021) recommended providing activities and support to enhance middle school students' competence and self-confidence in CT skills. One such means of addressing this recommendation could be through experiences in coding. Enrollment in a coding education course significantly ($p<0.05$) impacted sixth and seventh grade students' coding self efficacy (Soyan & Kanbul, 2018). In addition, fifth through eighth grade students involved in a computer programming class using block coding had statistically higher ($p<0.01$) self-efficacy than students who did not participate in the class (Günbatar, 2020). Building robots and completing projects "fostered students' self-confidence and creativity" for elementary students up through grade six involved in an afterschool program (Salas-Pilco, 2020, p. 1821). In a similar study conducted with elementary, middle school, and high school students who completed a coding activity, attitudes and self efficacy with computer science statistically increased ($p<0.01$), with the most positive impact on female student attitudes (Phillips & Brooks, 2017). The results indicated even brief exposure to computer science through a coding activity can positively impact students' self-confidence and self efficacy and can be used as a starting point in encouraging students in STEM fields.

Attitudes of middle school students towards coding varies. Coding education had a positive effect on student attitudes, but this effect reduced as grade levels increased (Okal et al.,2020). Self-efficacy scores of fifth grade students showed significant difference ($p<0.05$) when compared to scores of sixth and seventh grade students. Seventh grade student attitudes towards robotic coding were statistically higher ($p<0.05$) than students in eighth grade, however, there was no difference ($p>0.05$) in attitudes of males and females of middle school students (Korucu & Bicer, 2020). Students indicated coding was engaging and fun, and they could code and write programs, make games, design robots, and solve problems (Okal et al., 2020). Thus, Okal et al. postulate students with increased coding knowledge have an increased programming self efficacy. Starting coding education early was recommended in response to the reduction in student attitudes as grade levels increased.

Both male and female students, ranging in ages from seven to fourteen, who participated in STEM workshops had significantly higher ($p<0.05$) attitudes toward those fields than those students who did not participate (Timur et al., 2020). Thus, the workshop had a positive effect on student attitudes and interest. Students were interested in and enjoyed coding, robotics, and maker workshops. An interest in designing projects to solve daily problems was also displayed by the students. However, at middle school and high school, female attitudes toward engineering and technology were lower when compared to male attitudes (Unfried et al., 2014). Males showed a slight increase in interest toward engineering careers where high school females demonstrated very low interest in engineering and technology careers. In examining attitudes towards robotics coding, Korucu and Bicer (2020) found a significant difference ($p<0.05$) according to the class they were in. There was also a significant difference ($p<0.05$) in attitudes according to students who believed they were very competent in the use of technology and those who did not hold that belief.

As mentioned earlier, Stewart et al. (2021) found attitudes toward group work had significant relationships on computational thinking skills of middle school students. Group work was significant in predicting learning motivation for fourth and fifth grade students in a collaborative robotics learning environment. Based on the findings, the authors recommended students should be engaged in collaborative work, especially with a focus on computational thinking, on a regular basis. Intrepid exploration (IE) was hindered when middle school partners did not communicate or distracted their partner (Denner et al. 2021). Other inhibiting behavior included ignoring their partner, taking control of the programming, or rejecting suggestions from their partner – essentially not working together. A partner dominating the work on the task or ignoring their partner also contributed to hindering IE. Recommendations included encouraging 'playfulness' and considering ways to assist students in working together and asking for and utilizing information and ideas from their partner. This would include students asking their partner for information and ideas, even if what is provided is not used. Based on those aspects that hindered

IE, Denner et al. recommended working with students on how to collaborate, share ideas, and acknowledge the input of their partner. Thus, working in groups or with partners can positively influence motivation and knowledge given the right circumstance.

When examining increases in block based programming knowledge, the more confident partner influenced the less confident partner (Werner et al., 2013). A less confident partner influenced their more confident partner only if they were friends. The greatest gain in programming knowledge occurred with confident partners paired with friends who had more knowledge of the block based program. Such gains in knowledge reflect Vygotsky's more knowledgeable other idea which postulates the thought that collaboration and work with others, including peers, who have a deeper understanding can assist the learner in further development of their understanding (Vygotsky, 1978). Thus, Werner et al. recommended teachers look at improving confidence and knowledge. Not only has group work shown to enhance motivation toward and knowledge of coding (Stewart et al., 2021; Werner et al., 2013), value for collaboration was the most significant factor to increase fourth and fifth grade students' interest in future coding, whereas students who thought they are good with playing video games were less likely to express an interest in future coding (Rutherford et al., 2019).

While research exists on the impact of participation in coding activities of middle school students in relation to self-efficacy, interest in future coding, and some CT skills, there is a research gap regarding how participation in coding activities, in particular robotics coding, impact female middle school students' interest in STEM fields as well as their spatial reasoning and orientation skills. Given the current emphasis in supporting student interest in STEM and, in particular, the call to increase female participation, interest, and success in these fields, I became interested in better understanding how experiences in coding support female attitudes in technology and skill development.

Purpose of the research

The purpose of this study was to explore how involvement in a five full day (7 hours/day) coding camp impacts female middle school students' interest, outcome expectations, choice goals and choice actions in engineering and technology, collaboration value, problem solving attitude, and spatial reasoning and orientation skills. I developed the following research questions to guide my inquiry:

1. Is there a significant difference between female middle school students' interest, outcome expectations, choice goals, and choice actions in engineering and technology after participating in week-long coding robotics activities?
2. Is there a significant difference between female middle school students' spatial reasoning and orientation skills after participating in week-long coding robotics activities?

METHOD

A pretest-posttest experimental design was used. Participants completed two online measures; 1) A pre/post interest and attitude survey and 2) a pre/post spatial reasoning instrument titled The Spatial Reasoning Instrument (SRI) (Ramful et al., 2017). The interest and attitude survey questions, which gathered information on interest in engineering and technology, collaboration value, and problem solving attitude, were derived from two surveys, 1) the Student Interest and Choice in STEM (SIC-STEM) Survey (Roller et al., 2018), and 2) the Innovative Technology Experiences for Students and Teachers (ITEST) (Rutherford et al., 2019). The SIC-STEM survey contained Likert-scale questions. Reliability for the instrument engineering/technology subscale revealed a Cronbach's alpha of 0.916 and the Kaiser-Meyer-Olkin value was 0.91. Problem solving and collaboration value survey questions, which were also Likert-scale questions, were from Rutherford et al. (2019) retrieved from ITEST through the National Science Foundation, with an internal consistency (alpha) coefficient of .87. An example of the survey questions as indicated below provided information on six subscales of:

- student outcome expectations of engineering and technology (e.g., The skills I learn while building projects (bridges, cars, robots) will help me in my future job.),
- choice goals of engineering and technology (e.g., I would like to take more engineering/technology classes.),
- choice actions regarding engineering and technology (e.g., I use computers because I know I will need those skills in my future job.),
- interest in technology (e.g., I like to imagine making new projects.),
- collaboration value(e.g., Working with other people on projects is mostly a waste of time.), and
- problem solving attitudes (e.g., I develop my own ways of solving problems.).

Participants responded to 21 questions on a 5-point scale ranging from Not At All True to Very True. Of the 21 questions, six focused on problem solving attitudes and the remaining aspects of outcome expectations, interests, choice goals, choice actions, and collaboration had three questions each.

A pre/post spatial reasoning instrument, the SRI, was used to assess mental rotation, spatial orientation, and spatial visualization (Ramful et al., 2017). The correlation of each of the three dimensions with other established instruments range from .33 to .62, which indicates validity, and the items have a Cronbach's alpha value of .849. The instrument included 30 multiple choice items and was designed for use with middle school students.

The study included convenience sampling of 69 female middle students who participated in one of three 5 full-day (seven hours/day) coding camps during the summer. Students would be entering the 6th, 7th, or 8th grade the following school year. Of the students who participated, one had a disability, 28 were from low-income families, and 30 identified as racial or ethnic minorities. The coding camps were funded through a grant through the state Workforce Commission which allowed students to attend at no cost. No prior coding experience was required to attend the camps. The great majority of the students had very limited experience, such as two or three sessions of coding instruction and practice.

The purpose of the camp was to increase the interest of female middle school students in coding and programming through hands-on experiences and foster interest in STEM related careers. The first day of the camp involved team building activities, as most of the students did not know the other participants. Several activities were designed to scaffold learning of coding. Students started with simple coding movements through a brief use of Bee-Bot and Dash robotics. Beginning on the second day, LEGO ® Mindstorms EV3 robotics were used for the remainder of the activities for more advanced coding. These robots used brick drag and drop coding. Students first learned how to program the motor, followed by building the robot, and then learning how to code the robots. Students worked in pairs throughout the camp and participated in coding activities the majority of the day. The pairs of students were presented with various problem solving challenges, such as coding the robot to complete a maze or to retrieve a small ball and to deliver it to a designated location. Guest speakers or field trips consisting of 20 – 60 minutes each day provided students with information regarding coding, engineering, technology, and careers in these fields. The daily routine involved starting with brief announcements and an overview of the day followed by students being actively engaged in a team building activity (first day) or instruction in coding followed by challenges which incorporated information learned. Lunch was provided so that students could engage in discussions of topics such as careers in technology and coding or listen to and ask questions of guest speakers. Additional coding instruction and challenges were provided after lunch. Students participated in field trips, such as visiting the local university Engineering Department where they observed demonstrations of some of the equipment and participated in a discussion of training needed for careers in engineering. The field trips lasted about an hour and where conducted in the afternoons of the second through fourth days of the camp. This provided students with a break yet still maintained a focus on technology, coding, and careers in these fields. Students completed the engineering and technology survey questionnaire and spatial reasoning instrument the morning of the first day and, again, on the last day of each camp.

FINDINGS

Results are based on a pre data sample size of n = 69 and post data sample size of n = 63. A one-way repeated-measures analysis of variance (ANOVA) was used to compare mean scores of the pre and post assessment.

Table 1. Pre-Post Interest and Attitude Inventory Scores

	Pre_Interest	Post_Interest	Pre_Outcome	Post_Outcome	Pre_Goals	Post_Goals
N	69	63	69	63	69	63
Missing	0	6	0	6	0	6
Mean	9.04	9.11	10.3	9.95	10.7	10.7
Median	9	9	10	10	11	11
Standard deviation	1.48	2.06	2.48	3.02	2.64	2.84
Minimum	6	5	5	4	4	4
Maximum	12	15	15	15	15	15

	Pre_Actions	Post_Actions	Pre_ProbSolv	Post_ProbSolv	Pre_Collab	Post_Collab
N	69	63	69	63	69	63
Missing	0	6	0	6	0	6
Mean	8.19	8.51	20.3	21.3	9.43	9.46
Median	8	9	21	21	10	10
Standard deviation	2.07	2.12	4.50	4.87	1.61	1.58
Minimum	3	4	10	11	6	6
Maximum	12	13	30	30	13	13

For the interest survey, there were no significant changes comparing pre and post data for any of the six subscales (Table 1).

Table 2. Spatial Reasoning and Orientation Results

	Pre_Spatial	Post_Spatial
N	69	63
Missing	0	6
Mean	15.3	16.6
Median	15	16
Standard deviation	5.09	4.89
Minimum	5	7
Maximum	28	27

Table 3. Spatial Reasoning and Orientation Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p	η^2_G
Spatial Test	74.7	1	74.67	22.9	< .001	0.024
Residual	201.8	62	3.26			

Note. Type 3 Sums of Squares

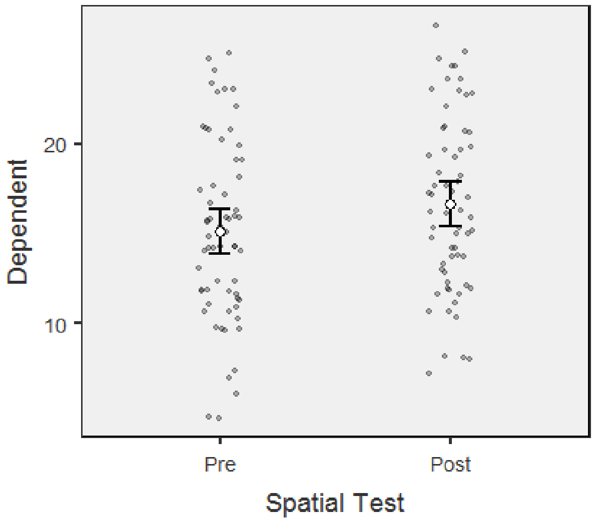

Figure 1. Spatial Reasoning and Orientation Results

As shown in Table 2 and Table 3, there was a significant increase in mean score of the Spatial Reasoning and Orientation Instrument (Figure 1). Cautions for interpretations of the results are needed as spatial skills are ability-dependent and, therefore, relatively resistant to short-term change. The same questions were asked on each administration, therefore, practice effects constitute a realistic internal validity threat and could possibly explain the increase in the mean entirely. The items were designed to be answered dichotomously (i.e., correct/incorrect answer). However, the raw data included a minority of scores that were "-1" which was undefined. Those values were coded as "incorrect responses"; however, an alternative coding might change the results.

CONCLUSION AND DISCUSSION

The findings of this study contribute to educators' understanding of how participation in coding robotics activities impact female middle school students' interest in technology and, ultimately, STEM activities as well as their spatial reasoning and orientation skills. Understanding how middle school female experiences in coding robotics impacts interest in engineering and technology, collaboration value, problem solving attitude, and spatial reasoning and orientation is important to understand and address current efforts to encourage and increase female participation in STEM activities and careers. Findings extend the research of Günbatar and Turan (2019) who found no significant change in problem solving of middle school students using block based coding as results of this study found no significicate change in problem solving attitudes of middle school female students. Future research is needed in how to enhance female middle school students attitudes of problem solving and if that increased attitude would also contribute to the enhancement of problem solving skills. Timur et al., (2020) found middle school students who participated in STEM workshops had significantly higher attitudes toward those fields than those students who did not participate. In contrast, results of this study found no significant change in interest, outcome expectations, choice goals and choice actions in engineering and technology after participating in 5 full-day activities involving robotics coding and exposure to STEM careers. Enhancing female interest in coding, especially at a young age, has the potential to help bridge the current chasm of females entering STEM fields. Results of this study could be used in enhancing coding instruction and as a springboard in examining how to enhance female middle school students' interest in technology, engineering, and future STEM careers. The results of this study also showed a statistically significant increase in female students' spatial orientation and reasoning, which incorporate aspects of CT. This result reinforces the findings of Kynigos and Grizioti (2018) of coding as a means to develop CT. Thus, coding activities involving movement of robotics could be used in an effort to increase female middle school students' understanding of spatial orientation, reasoning, and CT.

Within a 1-week time frame, providing information on technology and engineering and participating in field trips in these areas, participating in problem solving challenges through coding, and collaborating with others to solve those challenges did not change students' interests in those fields. This brings to question if the participants' interests in technology and engineering were already high, which might explain why the students participated in the coding camps. If not, then perhaps additional time, activities, and/or information is needed to influence female middle students' interests in these areas. This begs the question of how to target those female middle school students who do not have an initial interest in coding to participate in prolonged, focused coding activities which are challenging and problem solving based. Additional research is needed on how to enhance female middle school students' interest in technology and engineering. Further research is needed to better understand how curriculum engages and enhances middle school student interest and abilities in these areas. In the current education climate, critical discussions on increasing underrepresented populations, such as females, in STEM fields is particularly relevant.

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