Investigating the Impact of Educational Robotics on Underserved Students' Career Interests

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Abstract
Among its many benefits, educational robotics has been found to increase in student completion of STEM degrees and interest in science, technology, engineering, and math (STEM) careers. Given the national and international demand for a workforce trained in STEM areas, increasing student attitudes toward STEM and interest in careers in STEM areas is critical. Educational robotics provides students with an authentic, hands-on way to experience interdisciplinary STEM learning, which increases positive perceptions of these disciplines as well as interest in related careers. Yet the benefits of educational robotics are not always equally distributed for students, and therefore the impact of this curriculum is not well understood for underserved communities. In this study, an educational robotics curriculum was implemented in an urban private school that serves primarily minority students. The students at this school—ranging from third to eighth grade—had no prior experience with robotics, and little to no experience with construction-type toys or programming applications. A pre-survey was administered prior to a 12 week robotics curriculum (differentiated by age group), followed by a post-survey. The survey results on how student interest in STEM careers changed will be discussed. This research project aims to create a small window into the impact a robotics program could have on underserved students in particular to engage and prepare them for a future in STEM.

Keywords: Educational Robotics, STEM, Career Interest, Equity

Introduction

Careers in science, technology, engineering, and mathematics (STEM) are continuing to increase in number and are a valuable portion of the United States economy—23% of the total U.S. workforce in 2019 (NSF, 2021). The contributions of STEM workers should not be under-appreciated. "Individuals in the STEM workforce make important contributions to improving a nation's living standards, economic growth, and global competitiveness. They fuel a nation's innovative capacity through their work in research and development (R&D) and in other technologically advanced activities," (NSF, 2021). However, not all people are represented equally in the workforce. The National Science Foundation (2021) reported that "Hispanic or Latino and Black or African American workers are underrepresented in STEM, with the greater discrepancy being among those with a bachelor's degree or higher than those without a bachelor's degree." Women were also underrepresented. Fortunately, the U.S. STEM workforce has "gradually diversified between 2011 and 2021, with increased representation of women and underrepresented minorities" (NSF, 2023).

The shifting representation within the STEM workforce is in part due to the prior decades increased focus on STEM education. In 2015, the NSF reiterated the crucial importance of Americans acquiring the necessary STEM knowledge and skills in order to partake in an increasingly technology-intensive global economy. The education of our students can greatly impact their attitudes and interests, influencing their future career choices. In order to reduce the inequalities between gender and minority representation in STEM careers, increased focus on STEM education for these groups is necessary.

STEM education faces its own challenges: student perceptions of STEM subjects can begin to decline as early as fourth grade (Unfried et al., 2012). Better supporting students to choose STEM careers also means they need to have positive attitudes toward those subjects. Educational robotics has been increasingly used as a vehicle for STEM education, as it provides a fun, hands-on approach to these subjects in an integrated manner. In a meta-analysis, Benitti et al., (2012) found that generally educational robotics increased knowledge for specific STEM concepts. Researchers have found a spectrum of benefits for incorporating robotics into existing school curriculum, from the development and application of STEM knowledge to computational thinking and problem-solving skills, to social and teamwork skills (Altin & Pedaste, 2013; Bers et al., 2014; Kandlhofer & Steinbauer, 2015; Taylor, 2016). Notably, research across age groups has shown improvements in student interests and perceptions of STEM subjects (Nugent et al., 2010; Robinson, 2005; Rogers & Portsmore, 2004; Ching et al., 2019; deBruyn & Van Campenhout, 2022). Research has also found that when educational robotics improves perception, it also increases school achievement and more students attain science degrees (Renninger & Hidi, 2011; Wigfield & Cambria, 2010; Tai et al., 2006). For many students in high school, robotics has been used to advance college preparedness or technical career skills (Boakes, 2019; Ziaeefard et al., 2017; Vela et al., 2020), another avenue to support students considering STEM careers.

However, there needs to be more research on how to apply educational robotics to these underrepresented populations. Increasing the exposure to and interest in educational robotics for women and minorities could continue to help diversity in the STEM workforce. In a literature review by Anwar et al. (2019), only 16 of 147 studies focused on underrepresented populations and those studies generally focused on increasing availability of robotics or to evaluate overall success of the programs. The goal of this study is to contribute to this area of research by exploring how educational robotics curriculum might influence career interests

for third through eighth grade African American students. This initial research can provide direction for future robotics implementation and educational interventions.

Methods

The students participating in this research are from a private Catholic school in the urban Pittsburgh area. All students in this program are African American. The school receives scholarships through the Extra Mile Foundation and all students are 100% supported by a free/reduced lunch program. An informational letter and consent form were sent home and in total there were 101 students from third to eighth grade included in the study, after parent/guardian approval.

A pre-survey was delivered to students on perceptions of STEM and career interests: the Student Attitudes toward STEM Survey - Upper Elementary School Students (Friday Institute for Educational Innovation, 2012). The survey was recreated as a Google Form and distributed to students to complete on their Chromebooks. Students who returned the consent form took the survey, while the students who did not were given another activity during that time. The instructions were read aloud to students, and some terms were defined when requested. It was reinforced that there were no correct or incorrect responses, but it was simply gathering information of their perceptions and feelings. In this study, only the career interests are investigated in detail.

The teacher (and first author) selected the VEX GO robot kits because:

- The plastic pieces are designed for younger students' motor skills
- The kits could be stored and reused for all grades and classes
- A full standards-aligned curriculum was provided at no additional cost
- Teacher training was available at no additional cost

Each grade received 13 weeks of VEX GO robotics curriculum (each class had one robotics period per week). Some classes were seen more or less often than others due to school events and schedules. Some of the STEM labs and activities were completed by all students, but there was differentiation by grade level. At the end of the school year, students completed the same survey instrument after the curriculum had been completed.

Results

Aggregated Results. After removing students who did not complete both the pre- and post-test, there were a total of 60 students included across all grades, as shown in Table 1. For each question in the career interest portion of the survey, students were given a career description and asked how interested they were in that career. An example is: 'Engineering: People use science, math and computers to build different products (everything from airplanes to toothbrushes). Engineers make new products and keep them working.' For the analysis, the answer choices needed to be recoded to integers in order to calculate means and run statistical tests. The items were recoded as: not at all interested = 1, not so interested = 2, interested = 3, very interested = 4.

	3rd	4th	5th	6th	7th	8th
Students	14	2	11	16	7	10

Table 1. Students included by grade level.

Combining all student responses, the pre- and post-survey responses are compared using independent paired sample t-tests. Variation in mean scores show that ten of the twelve careers increased on the post-survey. However, only medicine showed a significant increase ($p < 0.5$). There are some limitations for looking at the aggregated results, as it combines a wide range of ages who may respond differently to the options. Therefore, the next task is to investigate these career perspectives according to gender and grade.

	pre-survey mean	post-survey mean	*p*
Physics	2.15	2.36	.159
Environmental work	2.32	2.33	.913
Biology	2.51	2.61	.545
Veterinary Work	2.44	2.34	.522
Mathematics	2.05	2.10	.748
Medicine	2.35	2.65	.031*
Earth Science	2.39	2.47	.557
Computer science	2.36	2.36	1.000
Medical Science	2.25	2.48	.216
Chemistry	2.58	2.59	.901
Energy/electricity	2.31	2.53	.198
Engineering	2.50	2.64	.409

Table 2. Aggregated career interest results for all students.

Gender Results. The first subdivided analysis was to investigate how males and females responded to the surveys. The female group (n = 26) showed variation across the careers, with eight of twelve career means increasing on the post-survey (Table 3). Interestingly, the only career change to be significant was a decreased interest in veterinary work ($p < 0.1$).

	pre-survey mean	post-survey mean	*p*
Physics	2.23	2.38	.516
Environmental work	2.42	2.35	.774
Biology	2.52	2.64	.622
Veterinary Work	2.73	2.31	.086*
Mathematics	1.92	1.85	.691
Medicine	2.60	2.88	.183
Earth Science	2.52	2.60	.627
Computer science	2.24	2.32	.664
Medical Science	2.58	2.63	.866
Chemistry	2.77	2.92	.404
Energy/electricity	2.28	2.52	.341
Engineering	2.50	2.50	1.00

Table 3. Career interest results for females.

By comparison, the male group (n = 29) had eleven of twelve mean scores increase on the post-survey (Table 4). The only decrease was in chemistry at 0.04. Three careers had significant increases: physics, medicine, and medical science ($p < 0.1$).

	pre-survey mean	post-survey mean	*p*
Physics	2.11	2.48	0.86*
Environmental work	2.28	2.41	.489
Biology	2.59	2.72	.608
Veterinary Work	2.21	2.39	.433
Mathematics	2.32	2.50	.532
Medicine	2.15	2.52	.086*
Earth Science	2.34	2.55	.406
Computer science	2.43	2.46	.873
Medical Science	1.96	2.48	.074*
Chemistry	2.54	2.50	.873
Energy/electricity	2.39	2.64	.363
Engineering	2.59	2.83	.345

Table 4. Career interest results for males.

Results by Grade. There is a great deal of difference between a third grader and an eighth grader, so grade-level results were also reviewed. Given the small sample size for each grade, only mean scores are reported. For brevity, not all grade levels were reported here. There were not enough fourth graders included in the final analysis to include, so third, fifth, and eighth grade results were selected for discussion.

The third-grade students (n = 14) showed the highest initial mean scores for career interest (Table 5). This is consistent with research showing that young students have the most positive perceptions of STEM topics. There were mean score increases for eight of twelve careers. Environmental work remained the same, mathematics decreased by 0.57, computer science decreased by 0.08, and veterinary work decreased by 0.29.

	pre-survey mean	post-survey mean
Physics	2.71	2.93
Environmental work	2.79	2.79
Biology	2.79	3.14
Veterinary Work	3.00	2.71
Mathematics	3.07	2.50
Medicine	3.00	3.21
Earth Science	2.86	3.07
Computer science	3.00	2.92
Medical Science	2.64	2.77
Chemistry	2.71	2.86
Energy/electricity	2.64	3.08
Engineering	3.14	3.15

Table 5. Comparison of mean career interest scores for third graders.

The fifth-grade student results (n = 1) show slightly lower initial means scores when compared to the third graders (Table 6). They also show increased mean scores for eight of twelve careers. Engineering and biology remained the same, earth science decreased by 0.18, and veterinary work decreased by 0.10. The largest increases (more than 0.30) were in physics, mathematics, and medicine.

	pre-survey mean	post-survey mean
Physics	2.27	2.64
Environmental work	2.55	2.82
Biology	3.00	3.00
Veterinary Work	2.70	2.60
Mathematics	1.82	2.27
Medicine	2.20	2.55
Earth Science	3.00	2.82
Computer science	2.73	2.82
Medical Science	2.09	2.18
Chemistry	2.64	2.82
Energy/electricity	2.55	2.64
Engineering	3.00	3.00

Table 6. Comparison of mean career interest scores for fifth graders.

The results for the eighth graders (n = 10) show the lowest mean initial scores of all grades (Table 7). This corroborates evidence from other research that student attitudes toward STEM subjects decrease as they get older. In total, ten out of twelve careers had increases in mean score. Chemistry remained the same and computer science decreased by 0.10. The careers with increases had some of the largest increases in mean score. Environmental work, biology, mathematics, medicine, earth science, medical science, energy/electricity, and engineering all had mean increases between 0.30 and 0.76. Notably, engineering had the greatest increase.

	pre-survey mean	post-survey mean
Physics	1.40	1.50
Environmental work	1.40	1.70
Biology	1.40	2.00
Veterinary Work	1.70	1.80
Mathematics	1.30	1.70
Medicine	1.60	2.00
Earth Science	1.20	1.70
Computer science	1.50	1.40
Medical Science	1.70	2.40
Chemistry	1.90	1.90
Energy/electricity	1.60	2.20
Engineering	1.44	2.20

Table 7. Comparison of mean career interest scores for eighth graders.

Conclusion

There are limitations that are important to discuss for the interpretation of these results. Only 60% of students who participated in the robotics curriculum were included in analysis due to only completing the pre- or post-survey, which could impact results. Each grade had a small number of participants, and when aggregating all students, the differences in grade level interests make the overall results less meaningful. It is also reasonable to note that third graders may have a more abstract concept of careers compared to eighth graders who are nearing high school.

However, these results do suggest several important findings. First, across all age groups and genders, student mean scores increased the majority of the time for career interest between the pre- and post-survey. This is a generally beneficial result given the limitations discussed. Second, consistent with the literature, student interest decreased as grade level increased. The youngest students had the highest level of interest on the pre-survey while the oldest students had the lowest interest. Third, some career trends were consistent across age groups, such as veterinary work decreasing and medicine increasing.

One of the most positive findings is about the eighth graders. While they had the lowest initial mean scores, they had great improvement on most careers. Attempting to reverse negative perceptions of STEM subjects and careers is one of the primary goals of engaging students in educational robotics. To see such improvement for the oldest students in this study is a very promising result. If more students begin to think of these STEM careers as viable options for themselves, they may continue on to seek degrees and careers in those areas.

The context for this research study is also worth discussing, as it both shaped the results of this study and suggests areas for future research. The first area for future investigation is to better understand how the selection of STEM lab topics impacts student career interest. It was noticed that students had several labs with connections to science and medicine. Could this have created an extra focus on that area that influenced student interests? Similarly, the seventh and eighth graders were the only grades to have STEM labs on simple machine and other engineering-heavy builds, and the eighth graders had a large increase in interest in

engineering. The STEM labs focused on during the year could have a great impact on student interests.

Next, further investigations are needed around how the integration of educational robotics impacts student career interests as well. Would having robotics every day for a quarter be more impactful than once a week for half the year? Also, including more specific examples of related careers in the STEM labs and providing specific examples of people who do those careers could help tie the robotics with real-world examples.

Supporting minority and underserved students in their STEM learning through educational robotics can give them more opportunities to learn about and grow interest in future careers in STEM. By learning from the implementation and results of this study, future research can continue to explore how educational robotics can increase student interest in STEM careers.

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