

Exploring Skills Gained Through a Robotics Program for Youth With Disabilities

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Abstract

Children with disabilities often have fewer opportunities to engage in science, technology, engineering, and math programs that can enhance their educational and career opportunities. This study explored the quality, experience, and skills learned in a group-based robotics program for youth with disabilities. Survey responses of 23 youth (16 males, 7 females), aged 9 to 14 with a disability, were analyzed using descriptive statistics and thematic analysis. Our results showed that youth with disabilities who participated in a robotics program rated the quality of their experience, perceived impact of the program, and skills gained highly across most items. Children enjoyed participating in the program and especially building the robots and making friends. Clinicians should consider engaging children with disabilities in robotics programs to enhance their participation and skill development.

Keywords

occupation, child, robotics, participation

People with disabilities are significantly underrepresented in science, technology, engineering, and math (STEM) education and careers (National Science Foundation, 2017; Thurston, Shuman, Middendorf, & Johnson, 2017). Engaging underrepresented groups in STEM education is an important component to maximizing economic competitiveness and productivity (Basham, Israel, & Maynard, 2010; National Science Foundation, 2017). However, children, youth, and young adults with disabilities experience many challenges within the education system and the labor force, which limits their full participation in society (Alston & Hampton, 2000). Such challenges include teacher's lack of inclusive education practices (Moon, Utschig, Todd, & Bozzorg, 2011), lack of accommodations (Moriarty, 2007), inaccessible programs (Mutch-Jones, Puttick, & Minner, 2012), lack of encouragement from parents and teachers (Alston & Hampton, 2000), and lack of role models (Lee, 2011). Research shows that simply having access to a regular science classroom does not ensure equitable access to science learning (Mutch-Jones et al., 2012). As such, youth with disabilities are less likely than their peers without disabilities to enroll in science or math courses or to pursue post-secondary STEM majors (Beck-Winchatz & Riccobono, 2008).

Fostering an interest in STEM education and careers among youth with disabilities is salient because they are highly employable fields (Cannon, LaPoint, & Bird, 2007). Given that people with disabilities have much lower employment rates than people without disabilities, STEM-related disciplines offer them a viable opportunity for stable, future

employment (Cannon et al., 2007; National Science Foundation, 2017; Yuen, Mason, & Gomez, 2014). For example, research highlights that graduates with STEM majors report better employment outcomes and higher earnings than non-STEM graduates (Noonan, 2017). Although improving the representation of diverse groups, such as people with disabilities, in STEM fields is a priority for governments and educational institutions (Beckstead & Gellatly, 2006; Government of Canada, 2018), many universities encounter challenges with attracting and retaining underrepresented groups. Therefore, more efforts are needed to introduce youth with disabilities to such fields early on (Cannon et al., 2007).

One potential way to engage youth in STEM fields early on is through robotics programs (Gura, 2012; Lindsay, Rampterab, & Curran, 2019; Rusk, Resnick, Berg, & Pezalla-Granlund, 2008). Participation in robotics programs (e.g., FIRST® Robotics) is one way that youth can develop relevant life skills (e.g., teamwork, problem solving) while also gaining exposure to STEM (FIRST® Robotics Canada, 2015; Lindsay et al., 2019). For example, research focusing

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on typically developing children shows that engagement in robotics programs (e.g., FIRST® Robotics) can help to enhance their critical thinking, problem solving, spatial ability, teamwork, social interaction, and self-confidence (Barak & Zadok, 2009; Benitti, 2012; Huang & Chen, 2015; Ludi & Reichlmayr, 2011; Skorinko & Doyle, 2012). However, little is known about how such robotics programs could help children with disabilities, and particularly their experiences and skills learned within the program.

Among the limited research focusing on youth with disabilities, it shows that adapted robotics programs are a promising mechanism for fostering interest in STEM (Lindsay et al., 2019). For example, among children with visual impairments (Ludi & Reichlmayr, 2011) and cerebral palsy (Adams & Cook, 2014; Howard, Park, & Remy, 2012), research shows their increased confidence in using computers after engagement with robots. Most previous research on engaging children with disabilities in STEM or robotics programs has focused on case studies or a one-to-one format (Adams & Cook, 2014). For example, a recent systematic review of programs and interventions for increasing participation of children and youth with disabilities in STEM education found only 17 studies (Kolne & Lindsay, in review), none of which were group-based robotics programs. The majority of these studies reported at least one improvement in self-advocacy, social skills, independence, preparation for college or employment, and interest in STEM education or careers (Kolne & Lindsay, in review).

Our study addressed several important gaps in the literature. First, few studies have explored a group-based LEGO® robotics program specifically tailored for youth with disabilities (Lindsay & Hounsell, 2017). Most robotics programs are geared toward typically developing children (Lindsay & Hounsell, 2017). Of the limited interventions that include children with disabilities, they are often case studies of individual children interacting with a robot rather than within a group-based setting (Kolne & Lindsay, in review). Focusing on group-based robotics programs is worthwhile because they can help to enhance personal development such as communication and teamwork skills while promoting an interest in STEM (Eguchi, 2016; Harper, Symon, & Frea, 2008) and other 21st-century skills (Melchior, Burack, Hoover, & Haque, 2018). Second, among the limited robotics interventions for children with disabilities, they are often working with pre-built robots (Adams & Cook, 2014; Howard et al., 2012; Taylor et al., 2009) rather than teaching children how to build a robot themselves. Our group-based robotics program that we explored in this study provided an environment that supports participants in gaining knowledge and skill in STEM-related areas in play, exploration, creativity, and interactions in a playful environment (Lindsay et al., 2019). Our aim in this article was to explore the quality, experience, and skills learned in a group-based robotics program for youth with disabilities.

Method

Design

We used a post-survey to understand the quality, experience, and skills gained of a group-based robotics program for youth with disabilities. This study received ethical approval from a research ethics board at a children's hospital and a university.

Procedure

The robotics program is an adapted version of FIRST® Robotics Canada (2015) that focuses on providing after-school robotics programs for children and youth. Adaptations were made to enhance the accessibility of the program to children with various types of disabilities (Lindsay & Hounsell, 2017; Lindsay et al., 2019). Examples of adaptations included learning and educational (i.e., one-to-one support with prompts, reminders, and behavioral assistance), physical (i.e., adapted switch access, bigger monitors or magnifying app, layout and spacing of the tables to make room for wheelchairs, hand-over-hand assistance to pick up LEGO® pieces), and social (i.e., careful pairing of children for optimal participation) modifications (Lindsay & Hounsell, 2017). The program was held at a children's rehabilitation hospital and led by therapeutic recreation staff and volunteers who are trained in how to work with children who have a disability (Lindsay et al., 2019). The purpose of the program was to help inspire young people into STEM fields by engaging them in a group-based robotics program while also building essential skills (Lindsay et al., 2019). The program was offered to two separate age groups, 6 to 8 and 9 to 14, with up to 10 children per group. Here, we focused only on those in the group aged 9 to 14. Within the program, children worked in small groups of two or three while using MINDSTORMS® EV3 to program, design, build, and test a robot (Lindsay et al., 2019). Main concepts learned through the weekly topics included introduction to robotics, engineering design practices, creating strong structures, use of sensors, developing strategies, and meeting the challenge (Lindsay et al., 2019).

Data were collected from November 2017 to November 2018, which involved two separate 6-weekly, 2-hr sessions. A research assistant gave all of the children enrolled in the robotics program ($n = 35$) and their parents an information package inviting them to participate in the study. Those who provided written consent ($n = 23$) were given a questionnaire at the end of the program. The survey could be completed by the child or parent with child, as needed.

Measures

The survey questions asked about demographics, experience and quality of the program, and skills gained (see measures

below). We also had open-ended questions about what they liked most and least about the program (see Supplemental Material). Given that there are no measures that focus on assessing the impact of a robotics program on youth with disabilities, we drew on measures used in FIRST® Robotics programs for typically developing youth. Questions were adapted for relevance to the children participating in this adapted robotics program (Melchior, Cohen, Cutter, & Leavitt, 2005). For example, we only selected the relevant items for our program (i.e., children did not compete in a competition like in other typically developing programs so we did not ask about it).

The first measure included “impact of HB FIRST® experience,” which is an adapted 4-point scale (4 = *strongly agree*, 3 = *agree*, 2 = *disagree*, 1 = *strongly disagree*; Melchior et al., 2005) that assessed the perceived impact of the program (e.g., helped me to understand the value of working in a group, gained understanding of math and science, gained self-confidence; see Supplemental Material). The second measure was the “quality of the HB FIRST® experience,” which is an adapted 4-point scale (4 = *strongly agree*, 3 = *agree*, 2 = *disagree*, 1 = *strongly disagree*; Melchior et al., 2005), assessing decisions made within the group, responsibilities in the team, how much fun they had, and sense of belonging. The third measure included “skills gained through HB FIRST® Robotics,” which is a 4-point scale (4 = *strongly agree*, 3 = *agree*, 2 = *disagree*, 1 = *strongly disagree*) and was adapted from evaluations of FIRST® Robotics for typically developing youth (Melchior et al., 2005). It assesses perceived impact of the program on decision making, responding to suggestions, teamwork, time management, confidence, and science skills (see Supplemental Material).

Data Analysis

Survey data were analyzed using SPSS, Version 25. We used descriptive statistics to describe the sample characteristics using means and standard deviations for continuous variables and frequencies, and proportions for categorical variables. Open-ended questions were analyzed using an open-coding, thematic approach where two researchers independently reviewed all answers (Braun & Clarke, 2006). Our analysis was guided by our research question with the overall goal to understand what children liked most and least about the program. Two researchers, with experience in pediatric rehabilitation and occupational therapy, independently reviewed all open-ended responses while noting key themes and patterns. We then applied an open-coding, thematic approach (Braun & Clarke, 2006) and kept a journal of our data analysis process. We selected quotes that were representative of each theme.

Participants

All children, aged 9 to 14, who registered for the robotics program from November 2017 to November 2018, and their

Table 1. Overview of Sample Characteristics.

Characteristics	N = 23	%
Grade		
4	4	17.3
5	6	26.0
6	5	21.7
7	4	17.3
8	3	13.0
9	1	4.3
Gender		
Male	16	69.6
Female	7	30.4
Disability type		
Autism	15	65.2
Cerebral palsy	6	26.0
Developmental delay	1	4.3
Intellectual delay	1	4.3

parents ($n = 36$) received an information package from our research team inviting them to participate in the research. Those who agreed to take part signed a consent or assent form. Our sample involved 23 (16 males and seven females) in Grades 4 to 9. Fifteen children had autism spectrum disorder, six had cerebral palsy, one had developmental delay, and one had intellectual delay (see Table 1).

Results

Overall, our results showed that youth who participated in the robotics program rated the quality of their experience highly across most items (overall $M 3.46 \pm 0.36 SD$) (see Table 2). In regard to the perceived impact of the robotics program, youth's mean scores were $M 3.12 \pm 0.65 SD$. Areas where youth reported lower scores included gaining a better understanding of how math, science, and technology are used to solve real-world problems ($M 3.06 \pm 0.63 SD$); robotics program helped motivate them to do better in school ($M 2.98 \pm 0.91 SD$) and gained a better idea of what to study in school ($M 2.95 \pm 0.90 SD$) (see Table 3).

Table 4 shows the perceived skills gained through the robotics program. The overall mean for this measure was $M 3.19 \pm 0.45 SD$. Areas where youth reported lower scores included learning new ways of thinking or acting from other people ($M 2.90 \pm 1.11 SD$), learning how to use computers to analyze information ($M 2.86 \pm 0.91 SD$), and using practical math skills ($M 2.75 \pm 0.86 SD$).

Qualitative Experiences

The qualitative, open-ended questions illustrate the areas that youth liked most and least about the program. For example, a youth describes what they liked most: “I like it. It's fun! I like putting the pieces together” (3-01). Another youth shared

Table 2. Quality of the Robotics Program Experience.

Item	M	SD
Kids in my group made the important decisions, not the adults	3.27	0.58
I had a chance to do lots of different jobs in my group	3.39	0.48
I had real responsibilities in my group	3.43	0.53
I had a chance to be both a designer and a builder	3.49	0.52
I had fun working in the robotics group	3.56	0.57
I felt like I really belonged in my group	3.65	0.33
Overall mean	3.46	0.36

Table 3. Perceived Impact of the Robotics Program.

Item	M	SD
The robotics program helped me understand the value of working in a group	3.34	0.58
I gained a better understanding of how math, science, and technology are used to solve problems in the real world	3.06	0.63
I gained a sense of self-confidence by being in the program	3.20	0.69
My interest in science and technology greatly increased as a result of being in the program	3.14	0.69
The robotics program helped motivate me to do better in school	2.98	0.91
I gained a better idea of what I want to study in school as a result of the program	2.95	0.93
Overall mean	3.12	0.65

Table 4. Perceived Skills Gained Through the Robotics Program.

Item	M	SD
The robotics program helped me weigh different issues and possibilities before making a decision	3.32	0.68
I learned how to listen and respond to other people's suggestions or concerns	3.34	0.55
The robotics program helped me to talk with people to get the information I need	3.47	0.55
It taught me to get along with other students, teachers, and adults	3.47	0.57
I learned to work within the rules of a group	3.53	0.77
I learned how to manage my time	3.04	2.23
I learned new ways of thinking or acting from other people	2.90	1.11
The robotics program gave me confidence to work with people that I don't know	3.36	0.26
The robotics program has taught me to stop or decrease conflicts between people	3.01	0.75
I learned how to use computers to analyze information	2.86	0.91
I learned to use practical math skills such as graphs and tables	2.75	0.86
Overall mean	3.19	0.45

a similar example: "It's really fun experience and you get to learn how to program and build interesting robots" (5-07). Others explained that they joined the program because "I want to learn how to program a robot through coding" (3-01). Similarly, another youth described how they wanted "to improve and focus on basic building technology and learn more about programming" (6-01). Meanwhile, other youth described more social reasons for participating in the program, as one youth explains, "so I can make friends" (7-02). Other enjoyable social aspects of the program included the following: "I liked listening to the instructions, collaborating with others in a small group setting" (5-01). Another youth explained, "It's very interactive. I get time to work and

interact with each other. All the teachers and volunteers were great and helpful" (6-01).

In regard to areas for improvement, youth wanted more time for building and designing on their own. For example, a youth mentions how there should be "more opportunities for asking questions, more communication and expressing, more discussion in the group, more opportunities of designing and building robotics" (5-01). Others expressed similar concerns, as a youth explains, "The creativity most of the time you are only allowed to build what the manual tells you to build" (5-04). Another youth had a similar suggestion for improvement: "More time to build own design in addition to structured workshop would be preferred" (6-01).

Discussion

This study focused on children's participation in a group-based robotics program, which is important because youth with disabilities are underrepresented in science and robotics programs (Dunn, Rabren, Taylor, & Dotson, 2012). Children with disabilities often have inadequate opportunities to participate in programs to fully support their personal growth (Stewart et al., 2014) and also encounter challenges in participating in STEM programs (Moon et al., 2011; Moriarty, 2007).

Our results suggest that children enjoyed participating in the program and thought it was a worthwhile experience where they had fun and felt that they belonged. These findings are consistent with studies involving FIRST® Robotics programs for typically developing youth (Melchior et al., 2005). Our findings from the open-ended questions showed that children enjoyed participating in the program, which aligns with our pilot work (Lindsay & Hounsell, 2017; Lindsay et al., 2019). Other research shows that fostering youth's interest in STEM early on can enhance their career aspirations, and educational and employment outcomes later in life (Noonan, 2017). For example, a longitudinal study involving a 4-year follow-up on FIRST® Robotics program with typically developing youth revealed that they continued to show significantly greater average gains on STEM-related attitudes and interests compared with the control group (Melchior et al., 2018).

Our results also highlight that children agreed that the perceived impact of the program was good, particularly with helping them to understand teamwork, solving real-world problems, and gaining an interest in science. Areas where scores were somewhat lower than expected included the program helping to motivate them to do better in school and clarifying what they wanted to study in school. These trends are consistent with FIRST® Robotics programs for typically developing children (Melchior et al., 2005), where youth similarly reported it helped them to gain practical skills such as interpersonal, teamwork, and problem solving, and how to apply academic skills in real-world settings (Melchior et al., 2005).

Our results also revealed that children agreed on the perceived skills they gained through the program which includes listening to others, decision making, time management, and teamwork. Other studies involving children without disabilities show that group-based robotics activities can enhance personal development and social skills (Eguchi, 2016). Other research also demonstrates that STEM interventions for youth can have positive outcomes such as improved self-advocacy, self-esteem, social skills, independence, and interest in STEM (Burgstahler & Chang, 2007; Gregg et al., 2017). Our findings show that areas where youth scored lower (i.e., using computers to analyze information and using practical math skills) were consistent with trends in FIRST® Robotics programs for typically developing children (Melchior et al., 2005).

In regard to the open-ended questions, our findings are similar to FIRST® Robotics programs for typically developing children where we found that children liked building robots and making friends the most. Similarly, reports on typically developing youth highlight that teamwork and making personal connections were important to them along with the competition experience (Melchior et al., 2005).

Limitations and Future Directions

There are several limitations to this study that are important to consider. First, we had a small sample with an unintentional overrepresentation of male participants and also youth with autism. Thus, caution should be used in generalizing the findings. Future studies should aim for larger, gender-balanced samples. Second, the amount and type of support provided to youth during the program may have varied and could have influenced their experiences in the program. Third, the measures that we used were adapted for our purposes and have not been validated for youth with disabilities. Nevertheless, we chose these measures because they were used with similar types of robotics programs for typically developing children. Future studies should consider using validated tools. Finally, the majority of our sample had autism and may have different interests and experiences in participating in a STEM program. Future research should explore whether gender, type of disability, and age influence participation and experience in the robotics program and how this compares with youth without disabilities. Researchers should also consider the longer term impact of the program and explore the extent to which this adapted robotics program can be transferable to other school-based or integrated community settings.

Implications for Occupational Therapy

The results have several implications for occupational therapy practice. Specifically, clinicians should

- advocate for the inclusion of children with disabilities in robotics programs to enhance their participation and development of science skills;
- help create early learning experiences for youth to help foster their awareness of potential career options; and
- engage children with disabilities in an adapted robotics program, which is a promising approach for introducing computing and robotics in addition to helping children work on essential life skills.

Conclusion

Our study addressed an important gap in the literature by exploring participation of youth with disabilities in a group-based robotics program. Developing children's participation

and interest in robotics and science is important for fostering their educational and future career options. Our results show that youth who participated in the robotics program rated the quality of their experience and perceived impact of the program and skills gained highly across most items. Children reported enjoying participating in the program and especially working with the robots and making friends. Occupational therapists should consider engaging children with disabilities in robotics programs to enhance their participation and development of science skills.

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Ethical Approval

Ethical approval was granted by the Research Ethics Board of the Holland Bloorview Kids Rehabilitation Hospital, Toronto, Ontario Canada (#16-677) and the University of Toronto (#35257).

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplemental Material

Supplemental material for this article is available online.

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