Effects of summer robotics activities in libraries on children's interest in robotics and STEM career

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Abstract. As technology advances and the demand for STEM workers increases, libraries are evolving to meet the changing needs of their communities. One way they do this is by providing robotics education opportunities for children. However, there is limited research on robotics education in public libraries, and there is a lack of adequate evaluation methods for assessing the impact of informal STEM learning. This pilot study aimed to investigate the effectiveness of conducting summer robotics activities in UK public libraries and the questionnaire design used to assess children's interest in robotics, STEM and STEM careers. Over three weeks, eight robotics activities were conducted in Leeds Libraries, with eighty-one children aged between 6 and 13 from the Healthy Holidays Programme in Leeds participating. The results of the paired samples t-test showed that the children's interest in robotics and related careers significantly increased from the pre-test to the post-test. However, the robotics activity had little influence on children's STEM and STEM related career. This study contributes to the existing literature by highlighting the need for further research on robotics education in public libraries and the development of better questionnaires that can be well comprehended by primary students and better evaluate the impact of the informal learning experience. Nonetheless, this study highlights that libraries can play a vital role in fostering technology literacy in communities.

Keywords: Robotics education, Informal STEM education, Robotics interest, STEM career interest, Public Libraries.

1 Introduction

The need for STEM-skilled workers is increasing globally, and many countries, including the United Kingdom, are facing a shortage of qualified professionals. Despite the increase in the number of students pursuing STEM majors, the supply of qualified STEM workers is still not meeting the national demand [2]. As highlighted in the UK-RAS White Paper of 2021 [1], the shortage of STEM workers combined with a lack of diversity in STEM education is hindering productivity and the growth of Industry

5.0. According to estimates from the Institution of Engineering and Technology (IET) [3], there is a shortage of approximately 173,000 professionals in the STEM fields, with half of the engineering companies in the UK struggling to fill positions due to a lack of eligible expertise.

To address this issue, the White Paper [1] proposes creating learning hubs around the UK, and public libraries are one of the ideal places. Public libraries are a valuable source of knowledge and learning. They provide resources and opportunities for individuals of all ages to explore new subjects and develop new skills. They also play an essential role in community development by fostering community connection [4] and providing technology resources [5]. While many projects have aimed at getting young people interested in engineering and STEM fields, many lack assessment or impact evidence that they are making significant progress in STEM subject attainment or progression [6]. By utilising public libraries as accessible STEM learning support for young children, the UK can take a step in addressing this shortage and promoting diversity in STEM education.

STEM education in informal learning environments like libraries can be achieved by numerous means; one of the most common approaches is the integration of educational robots in various activities such as summer camps [7][8], competitions [9][10] and formal lessons [11][12]. The general benefits of educational robots in K-12 education are promoting active-learning pedagogy, improving the learning experience, fostering critical thinking and inquiry, enhancing students' construction of new knowledge, increasing students' interest and engagement in STEM fields, and promoting creativity and motivation [13][14][15].

Although the benefits of integrating robotics in STEM education seem apparent, there is a gap in the literature regarding the measurement of learning outcomes in informal STEM learning environments [16]. While imparting knowledge and skills is essential, informal STEM education also ignites curiosity, builds interest, and fosters intrinsic motivation. Therefore, this pilot study aimed to assess the impact of summer robotics activities in a public library setting on children's interest in robotics, STEM, and related careers, as well as the questionnaire design used. Findings from this study have significant implications for libraries and afterschool programs, as they can play a critical role in promoting STEM learning and skill-building for children.

2 Literature review

2.1 Factors affecting children’s STEM career orientation

Children's intention to pursue specific careers is affected by multiple factors, such as their academic achievements and aspirations, self-efficacy, and family configuration [17][18][19]. Moreover, one of the major factors determining a student's career decision and retention, especially in STEM subjects, is their interest [20]. Research has shown that students who demonstrate a greater interest in STEM during their junior years have a higher chance to pursue STEM degrees and careers in STEM fields [21]. Thus, providing support to increase young children's interest in STEM is indispensable to get more youngsters to pursue STEM careers.

2.2 STEM education in UK public libraries

As communities evolve and technology advances, libraries refine their roles and embrace the latest technological advancements to cater to the needs of children and teenagers. In response to this evolving role, the fields and professions of STEM disciplines are receiving more attention in public library services and programmes [22][23].

The library and STEM learning survey in the UK and Ireland [24] revealed that 95% of the library staff respondents had offered STEM events in their libraries, and 52% of them suggested that they offer STEM activities more than once a month. These figures indicate that informal STEM education has extensive coverage in the local areas. The most common STEM learning activity available in libraries in the UK and Ireland is coding., while hands-on learning activity is the top STEM event that they want to offer in the future. Popular tools for STEM events include Micro:bit, LEGO, 3D printers, Makey Makey, tablets like iPads, and Raspberry Pi. Similar to the public libraries in Australia and the US, the primary target of the STEM events is students aged between 6 and 12 years old [25][26].

Although library professionals may not feel comfortable or equipped to offer STEM programming or learning opportunities, 80% of STEM-related events are developed, and 79% are facilitated by library staff [24]. Moreover, most libraries (86%) rely solely on the library budget to fund these programmes and events. Without external funding, it is tough for libraries to organise STEM events regularly or purchase necessary equipment. Other challenges they are facing are insufficient staff time and a shortage of resources. These obstacles hinder their intention to provide STEM activities and related services to the community.

2.3 Effectiveness of informal STEM learning experiences

Informal STEM education is defined as lifelong learning in STEM subjects that takes place outside of conventional classroom settings and encompasses a wide range of designed experiences and settings [16]. It is characterised by non-traditional learning experiences and freedom of choice. Participants have the freedom to choose their learning experiences, and the learning is often brief, voluntary, and emergent. It encompasses various education settings, including libraries, afterschool clubs, museums, and other out-of-classroom learning environment. These settings play a crucial role in promoting STEM learning for individuals of all ages and backgrounds.

This form of education provides engaging and hands-on opportunities for students to learn and retain STEM concepts [27]. Informal learning experiences also address the limitations of traditional lecture-style teaching found in schools. They provide nondidactic, meaningful activities driven by learner initiative or interest and do not involve assessment [28]. This setting allows students to see the relevance and application of STEM knowledge in real-life situations, thereby increasing their interest in STEM and encouraging them to pursue careers in STEM [27].

2.4 Educational robotics and STEM education

Educational robotics has been used to support teaching and learning since the early 70s [29] and has been widely investigated and implemented in K-12 settings since 2000 [13]. Robots seamlessly integrate STEM disciplines, offering hands-on and minds-on learning experiences [30][14][15].

In science education, robots like Lego Mindstorms elevate learning by enabling real-time data sharing through sensors, motors, and programmable hubs, facilitating collaborative exploration of the robot's responses to environmental changes [31][32]. For technology education, these robots offer an ideal platform for delving into computers, electronics, programming, and other digital technologies [33][34]. Moreover, they effectively address the challenge of integrating engineering into K-12 curricula by simplifying the incorporation of engineering concepts [35] and fostering valuable problem-solving skills [36]. The tangible and engaging nature of educational robots extends to mathematics education by serving as a medium for playing mathematics games and learning spatial concepts and geometry while developing the programme and building the robots [37]. In short, educational robots emerge as versatile educational tools, not only imparting STEM knowledge but also instilling a passion for learning and problem-solving among students.

3 Methodology

3.1 Participants

The study employed a convenient sampling strategy to select participants. The participants were eighty-one children from the Healthy Holidays programme, which was a summer programme for young people who receive free school meals in Leeds. However, only thirty-eight children between the ages of six and thirteen completed both the pre-test and post-test. The participants' age distribution showed that the majority were between the ages of eight (26.3%, n= 10) and nine (28.9%, n= 11). Also, the gender distribution revealed that 57.9% (n= 22) were female and 42.1% (n= 16) were male. Detailed demographic information is shown in Table 1 and Table 2.

3.2 Robotics activity

Eight semi-structured robotics activities were conducted over three weeks in three different locations chosen by the Leeds Libraries starting from the second week of August 2023. Full lesson schedule can be found in Table 3. The same instructor led all sessions, and all sessions had 3-5 volunteers or library staff to assist the instructor. Each session had no more than 20 participants.

All sessions followed a similar structure. The lesson started with a brief introduction to using iPads to control robots and build codes. Next, the challenges planned for the day were presented to the children. After that, the kids were given about two hours to learn and play freely with the robots. The study used three types of robots, namely, LEGO Spike Essentials, Micro:bit with Bit:bot expansion, and Sphero Bolts. The study used three types of robots, namely LEGO Spike Essentials, Micro:bit with Bit:bot expansion, and Sphero Bolts. These robots were selected because they are cute and toy-like, which junior grade students prefer [38]. Additionally, Micro:bit was an ideal choice because it is accessible, relatively inexpensive, and has a wide range of add-ons and online resources with hundreds of projects that allow children to continue their learning at home. On the other hand, LEGO Spike is more suitable for younger children than some of the more advanced kits, like Sphero Bolts, as LEGO software has a relatively simple interface.

Table 1. Age statistics

Age	Frequency	Percentage (%)
6	3	7.9
7	5	13.2
8	10	26.3
9	11	28.9
10	3	7.9
11	4	10.5
12	1	2.6
13	1	2.6
Total	38	100

Table 2. Gender statistics

Gender	Frequency	Percentage (%)
Female	22	57.9
Male	16	42.1
Total	38	100

Table 3. Schedule of the summer robotics activities

Venue	Week 1	Week 2	Week 3
Location A	Micro:bit	Sphero	LEGO
Location B	Sphero	LEGO	
Location C	LEGO	Micro:bit	Sphero

During the LEGO sessions, children were paired up and were given a box of LEGO Spike Essentials and an iPad. The instructor introduced the LEGO Spike application and explained the process of selecting a project, navigating the app to read building instructions, finding corresponding coding blocks, and downloading the code. The children were then given about two hours of free time to build as many projects as they wanted. All projects and guidelines were developed by LEGO with detailed building instructions and code.

In the Micro:bit sessions, each child received a Micro:bit and an iPad. The lesson began with an introduction to Micro:bit and instructions on how to pair it with the iPad. Children were then challenged to build a rock, paper, scissors game using Micro:bit. A printed copy of step-by-step instructions was distributed to the children, and they followed along to build the programme and test the game with their friends. After building the game, all children were invited to participate in a rock, paper, scissors tournament. Next, the children were given the task of building a light-following robotic car using Micro:bit with the Bit:bot expansion. They received another printed instruction on how to code the Micro:bit and how the code controlled the Bit:bot's motors using its light sensors. Once they completed the code, they were given a torch to play around with the light-following robot in an open space. The children were allowed to work on their ideas at any time during the lesson.

In the Sphero sessions, each child received a Sphero Bolt and an iPad. The instructor went through the Sphero application with the students and connected the Sphero Bolts to the iPads. The children then tried to navigate the robot to go straight and turn at different angles using coding blocks. After that, they were given masking tape to create a maze for their Sphero on the floor and had to program the Sphero to complete the maze. They were allowed to build and complete as many mazes as they wanted.

3.3 Research design and instrument

Pre-test and post-test design was used to study the differences before and after the sessions, and ethical approval was sought before the study. Since the sessions were delivered in 3 different locations, it was the children's choice to complete how many sessions they preferred. The post-test data was collected after they had completed their last session. In other words, some participants engaged with all three different robots, while some participants only played with one or two.

Data were collected using printed questionnaires. The survey consists of two parts. The first part comprises five items, rated on a 5-point Likert scale, ranging from strongly disagree (1) to strongly agree (5). The second part is an open-ended question about children's career aspirations. The questions for measuring students' levels of interest towards STEM subjects and related careers were designed based on the survey developed by Kier, Blanchard, Osborne, and Albert [39] and were modified to suit this study. The open-ended question was adopted from Hudson, Baek, Ching, and Rice [40].

3.4 Data analysis

SPSS version 29.0 was used for data analysis. Descriptive statistics were used to give an overview of the data collected. The pre and post-test scores were then analysed using the paired t-test to find out the effect of the robotics activities on children's interest in robotics, STEM and related careers.

4 Result

4.1 Interest in robotics and related career

The results in Table 4 showed an increase in pre-test and post-test scores in all five questions. However, according to the paired t-test (Table 5), only the first two items were considered statistically significant. Children's interest in robotics significantly increased from the pre-test to the post-test. The scores significantly rose from a pre-test mean of 3.97 (SD = .95) to a post-test mean of 4.45 (SD = 1.06; t = 3.24, two-sided p = .004, d = .50). Moreover, their interest in robotics-related careers significantly increased (t = 3.24, p = .003, d = .53) from the pre-test mean of 3.27 (SD = 1.38) to the post-test mean of 3.84 (SD = 1.24). A Cohen's effect size value larger than .5 is considered a medium effect size.

Table 4. Pre-test and post-test scores on interest in robotics, STEM and STEM career

	Pre-test score		Post-test score	
Item	Mean	SD	M	SD
Interest in robots	3.97	0.972	4.45	1.058
Interest in robots related career	3.24	1.384	3.84	1.242
Interest in STEM	3.79	1.298	4.08	0.969
Interest in STEM career	3.53	1.289	3.74	1.349
Expectation to learning STEM	3.82	1.111	4.13	1.18

Table 5. Paired t-test results comparing pre-test and post-test values

Item	ΔMean	t	df	p	d
Interest in robots	0.474	3.07	37	0.004*	0.951
Interest in robots related career	0.605	3.24	37	0.003*	1.152
Interest in STEM	0.289	1.64	37	0.11	1.088
Interest in STEM career	0.211	1.052	37	0.3	1.234
Expectation to learning STEM	0.316	1.261	37	0.215	1.544

*p< 0.05, significant following Bonferroni correction for multiple comparisons

4.2 Student Career Interest Writing/ Drawing Activity

Children were asked to complete the sentence "When I grow up, I want to be a __________. Write about or draw yourself in this career". After the intervention, it was observed that there was a noticeable change in career choice for only one participant; they changed their preference from police to scientist. Additionally, a noticeable change was also observed in the drawing of a doctor from another participant. In the pre-test, the drawing of a doctor was just a girl with a handbag, but in the post-test, a computer and some medical equipment was added next to the doctor. However, these are the only two participants showing a change of career interest or having a better understanding of the importance of STEM in their future careers, while other children did not show any changes in their preferences or drawings after the intervention. Lastly, children demonstrated a swift transition from a STEM career to a non-STEM career, which was found in the activity.

5 Discussion

5.1 Significant effect on interest in robotics and related career

The implementation of semi-structured robotics activities during summer has resulted in a significant increase in children's interest in robotics and related careers. According to research [41], informal activities have proven to be effective in increasing children's interest in this field. The fun and interactive nature of robotics activities has a direct impact on participants' interest, especially for those from low-income families who have limited opportunities to play with educational robotics. By attending these activities, children get to explore the exciting world of robots, learn and work with them, and gain valuable experience. Moreover, the impact of these activities goes beyond just increasing interest in robotics. They also open up new opportunities for children who may have been previously unaware of the potential for careers in this field. Through these summer activities, children gain exposure to various careers related to robotics, which inspires them to explore these options further.

5.2 Insignificant effect on interest in STEM and related career

The library activity did not lead to any significant changes in children's interest in STEM and related careers, which did not align with other research findings that participating in short-term STEM activities can increase students' interest in STEM [27][42][43]. This difference could be attributed to the absence of a contextual framework for the STEM disciplines and robotics and the lack of connection between them during the lessons [43]. Consequently, the children may not have realised that robotics is a part of STEM. However, the activities were successful in increasing the children's interest in robotics and related careers. To create a greater impact on students' interest towards STEM and related careers, the lesson materials should be modified to emphasise the relationship between robotics and daily life by giving context to each task. For example, the Sphero sessions can start with a presentation on space exploration and the Mars rover. Then, we will move on to a discussion on how to control the mars rover to move precisely. Giving a theme and context to the tasks will make children more engaged in the activities.

5.3 Data collection

The children were given a questionnaire to complete at the beginning and the end of the study. Unfortunately, more than half of the participants did not complete both tests, and some questionnaires were incomplete or uninterpretable. To address this issue, it is essential to redesign the questionnaire so that it caters to a broader range of participants and has a more user-friendly layout. To prevent children from overlooking specific questions, condensing and putting all questions onto a single page or using an online questionnaire might be helpful. The online questionnaire can guide children through each question step-by-step and provide reminders for any unanswered questions, streamlining the process.

Moreover, observations and an interview might be carried out to validate and better understand the result. Observations and interviews can help understand children's perspectives and uncover the meaning of their experiences, capturing meaningful relations to be interpreted, especially when young children are included in the study, as reading and writing are not favourable to them.

5.4 Questionnaire design

Since the age range of the participants was broad (6-13 years old), some of the questions were too complex for the younger children to understand. For instance, the word "career" posed a challenge for some children. Replacing it with "job" to simplify the question might be better. Similarly, the term "technology" was not well understood by some participants, so providing examples of different technologies, such as computers and iPads, could help them comprehend. Additionally, using icons to illustrate the different levels of the 5-point Likert scale could be helpful for younger children to choose the most suitable answers.

6 Conclusion

The purpose of this summer robotics activity was to (1) provide summer learning opportunities to children from low-socioeconomic households and (2) build students' robotics, STEM interests and related careers. This pilot study has highlighted the impact of robotics activities in public libraries on children's interest in robotics and related careers. Children 's interest in robotics and related careers increased significantly from the pre-test to the post-test, indicating that short-term robotics activities are effective in shaping children's perception of robots and increasing their interest in robotics and related careers. The result also supported the idea that public libraries are ideal spaces for shaping a community's technology literacy. Although the positive changes in children's interest in STEM and related careers are statistically insignificant, the slight increase in their mean scores is a promising result.

Nevertheless, there are several limitations in this study. The study used convenient sampling and was carried out in a specific geographic area with children from similar socioeconomic status, which limits the generalisability of the findings. Moreover, the study only examined the short-term effect of robotics activities using quantitative methods. A follow-up survey can be done in the future to better understand how the activity fosters children's interest in robotics and STEM and trace the long-term effect of the activity. These limitations suggest the need for further research on robotics education in public libraries, particularly on how to effectively design and implement robotics activities to achieve sustained interest in robotics, STEM and related careers.

Despite these limitations, this study demonstrates that public libraries can play a vital role in fostering technology literacy and promoting STEM education in communities. Public libraries are well-positioned to provide access to technology resources and support lifelong learning among children. Robotics education is one such opportunity that public libraries can incorporate into their service, and this study provides evidence of the positive impact of such activities.

In light of the study's findings, public libraries should consider incorporating robotics education into their programming to promote STEM education and foster community engagement. Overall, this study highlights the need for further research on robotics education in public libraries and the potential for such activities to contribute to technology literacy and STEM education in communities.

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