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

Ho Ching Cheung[1[0009-0006-3688-8066]], David Cameron[2], Alex Lucas[3[0000-0002-3165-3923]] and Tony Prescott[4[0000-0003-4927-5390]]

[1,2,3,4] The University of Sheffield, Sheffield, United Kingdom

ho.cheunng@sheffield.ac.uk, d.s.cameron@sheffield.ac.uk, alex.lucas@sheffield.ac.uk, t.j.prescott@sheffield.ac.uk

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 shows 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 [1]. As highlighted in the UK-RAS White Paper of 2021 [2], the shortage of STEM workers combined with a lack of diversity in STEM education is hindering productivity and the growth of Industry 5.0. The Institution of Engineering and Technology (IET) [3] further highlights that half of the engineering companies in the UK report difficulties in filling roles due to this shortage of skilled individuals.

To mitigate this challenge, the White Paper [2] proposes creating learning hubs around the nation, and public libraries are one of the ideal places. Public libraries in the UK stand out as ideal venues for STEM activities, due to their widespread accessibility, established community trust, broad resource availability. Unlike other informal learning environments such as afterschool clubs or hobby groups, which may have limited reach or require membership fees, libraries offer a free, inclusive environment supported by trained staff and a variety of learning materials. Their mission to promote community connections, education and literacy aligns closely with the goals of STEM initiatives, making them naturally suited for hosting a wide array of community and educational programs [4][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 robots in library services and various activities such as summer camps [7][8], competitions [9][10] and formal lessons [11][12]. An illustrative example is the deployment of the social humanoid robot, Pepper, in the children's section of the Mohammed Bin Rashid Library in Dubai, which assists in teaching and storytelling. The general benefits of robotics 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.

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 become STEM professionals.

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 around the world [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 includes various education settings, such as 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. It included eighty-one children from the Healthy Holidays program in Leeds, which is a voluntary summer program for young people who receive free school meals. The program offers a range of activities such as drama classes, art workshops, and sports activities, which take place from Monday to Friday. The robotics lessons were part of this summer program. Thirty-eight children, aged between six and thirteen, completed both the pre-test and post-test. Most of the participants were eight (26.3%, n= 10) and nine (28.9%, n= 11) years old. Also, the gender distribution showed that 57.9% (n= 22) of the participants were female, and 42.1% (n= 16) were male. Detailed demographic information is available 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. The full schedule of these lessons can be found in Table 3. All sessions had a maximum of 20 participants, and each session was led by the same instructor who was assisted by 3-5 volunteers or library staff. The workshops' educational content was designed by a Senior Librarian specialising in digital initiatives at Leeds Libraries.

The research team did not interfere with the instructional methodology and material development processes. This decision aimed to evaluate the efficacy of the library's existing STEM educational provisions and understand the limitations and challenges presented by the semi-structured activities designed by librarians without formal training in STEM education. Through this approach, the study can assess the library's contribution to STEM learning and identify potential areas for pedagogical enhancement and curricular refinement.

All robotics lessons followed a similar structure. They began with a brief introduction to using iPads to control robots and build codes, followed by the presentation of the challenges planned for the day. Children were then given about two hours to learn and play with the robots. The study used three types of robots: Micro:bit with Bit:bot expansion, Sphero Bolts and LEGO Spike Essentials. These robots were chosen for their toy-like appearance, which junior-grade students prefer.

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

In the Micro:bit sessions, each child received a Micro:bit and an iPad. The session kicked off with an introduction to the Micro:bit and a demonstration on how to pair it with the iPad. The children were tasked to create a rock, paper, scissors game on the

Micro:bit, guided by printed step-by-step instructions. Upon completion, a tournament for the game was held. Next, they embarked on constructing a light-following robot car by integrating the Micro:bit with the Bit:bot expansion, following printed directions for coding and assembly. With the code in place, the participants tested their robots' light-following capabilities using a torch in an open area. Throughout the session, children had the flexibility to explore their own project ideas.

In the Sphero sessions, each child was provided with a Sphero Bolt and an iPad. The instructor demonstrated the use of the Sphero application and facilitated the connection of the Sphero Bolts to the iPads. An initial exercise had the children coding the robot to move in straight lines and execute turns at varying angles. Subsequently, the participants utilised masking tape to design mazes on the floor, programming their Sphero Bolts to navigate through these mazes. The children were encouraged to create and solve as many mazes as their imaginations allowed.

In the LEGO sessions, children were paired up and were given a box of LEGO Spike Essentials and an iPad. Unlike other sessions, children worked in pairs instead of individually due to the limited availability of the LEGO sets. 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.

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	1.06
Interest in robots related career	3.24	1.384	3.84	1.24
Interest in STEM	3.79	1.298	4.08	.97
Interest in STEM career	3.53	1.289	3.74	1.35
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	.474	3.07	37	.004*	.50
Interest in robots related career	.605	3.24	37	.003*	.53
Interest in STEM	.289	1.64	37	.110	.27
Interest in STEM career	.211	1.05	37	.300	.17
Expectation to learning STEM	.316	1.26	37	.215	.21

*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, no children demonstrated a swift transition from a STEM career to a non-STEM career.

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 the importance of navigating robots 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 necessary to redesign the questionnaire so that it caters to a broader range of participants and has a more user-friendly layout. One way to prevent children from missing specific questions is to condense all the questions onto one page or use an online questionnaire. The online questionnaire can guide children through each question step-by-step and provide reminders for any unanswered questions, making the process more efficient.

Furthermore, to validate and gain a better understanding of the results, observations and interviews may be conducted. Observations and interviews can help to understand the perspectives of children and reveal the meaning of their experiences, particularly when young children are involved in the study, as reading and writing may be challenging for them. Additionally, a delayed post-test should be conducted to determine whether the effects are sustained and identify ways to limit the fall off over time.

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, which suggests that even short-term engagement with robotics can positively influence children's perceptions of and interest in robotics and related careers. Furthermore, the findings underscore the potential of public libraries as critical venues for advancing technology literacy within communities. While the study noted a slight increase in children's interest in STEM and related careers, which was not statistically significant, the upward trend in the mean scores is promising.

Nevertheless, this study has several limitations. 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 to 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 challenges, this study provides evidence of the positive effects of incorporating robotics into library services and shows that public libraries can play a key role in promoting technology literacy and supporting STEM education in communities with appropriate enhancements to current STEM learning activities. With their accessibility and commitment to supporting lifelong learning, public libraries are ideally situated to offer technology resources and robotics education.

Based on these findings, it is recommended that public libraries consider a more proactive approach in integrating robotics education into their offerings to enhance STEM education and encourage community involvement. The study also highlights the importance of providing formal professional training and centralised STEM teaching and learning resources for public libraries to improve the quality of service. In conclusion, this research emphasises the need for continued investigation into robotics education in public libraries and its potential to enrich technology literacy and STEM education in communities.

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