2023

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Funder: This work was supported by grant 20-DP-8252 from the Science Foundation of Ireland, who continue to support the research through grant 22-DP-10414

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2023 IEEE World Engineering Education Conference (EDUNINE) | 979-8-3503-2050-3/23/$31.00 ©2023 IEEE | DOI: 10.1109/EDUNINE57531.2023.10102844

***Abstract*—Educational robots allow students deepen their knowledge of mathematics and scientific concepts. Educational Robotic coding clubs provide a learning environment for K-6 students that promotes coding through STEM digital literacy. Students in educationally disadvantaged families may not have the educational and financial capital to engage in STEM learning. Closures of schools and afterschool services during the COVID-19 pandemic increased this digital divide. This research proposes a framework for delivering a virtual robotic coding club in an educationally disadvantaged community. The framework develops young people's emotional engagement in STEM through robotic coding. Synchronous online classes were delivered into family homes using Zoom. Results demonstrate that children achieved emotional engagement as reported through high levels of enjoyment and increased interest after participating in the programme. The research shows promise in increasing children's STEM skills and knowledge, and in improving positive attitudes towards STEM for children and parents.**

Keywords—STEM, robotic coding, emotional engagement, e-learning, action research

I. INTRODUCTION

Research consistently highlights the importance of STEM as an indicator of future academic success [1]. Competence in STEM is essential for functioning in everyday life, as well as for success in our modern technological workplace. However, student engagement in STEM has been found to be lower in schools in disadvantaged communities [2] [3] [1]. Children from disadvantaged communities have been found to be at a greater risk of suffering 'learning loss' due to the restrictions imposed on schools throughout the pandemic [4].

Student engagement is a multi-faceted construct made up of three components, behavioural, emotional, and cognitive engagement [5]. Emotional engagement can be defined as students' positive or negative reactions to their subjects or activities and can also involve an identification or sense of belonging [6]. Emotional engagement is thought to be a motivator for behavioural and cognitive engagement [7] [8] and is positively correlated with active learning [9]. However, there is limited research on student engagement with STEM, particularly in studies focusing on the area of emotional engagement [10].

Educational robotics is a fun engaging methodology to help children learn about mathematics and scientific concepts [11] [12] and has been proven a successful method in supporting diverse learners [13] and students from communities of socio-economic disadvantage [14]. Elkind points out that educational robotics open a door for helping children learn about mathematics and scientific concepts through the method of inquiry, as well as for developing technological fluency [12]. There are many examples of the effectiveness of this approach, face-to-face in schools and other environments, for example at-home science activities have proven both effective and an opportunity to continue STEM discussions at home [15].

STEM programmes with disadvantaged communities have been running since 2008 in the Early Learning Initiative (ELI) in Dublin's Inner-City [16]. These programmes were initially delivered in person, however, following national health guidelines as a result of COVID-19 institutes of education could no longer provide face-to-face service delivery. Thus, the Robotic Coding Clubs transitioned to a virtual learning environment. Research indicated that virtual educational robotic clubs would have to be adapted and carefully re-designed to take family context, interest, and skills into consideration if it was to engage marginalised K-6 students. Adapting the resources, curriculum, and methodology of the existing face-to-face Robotic Clubs to provide social and cultural validation would be important to the success of the project.

The aim of this research is to investigate to what extent a Virtual Robotic Coding Club (VRCC) improves K6 students' emotional engagement in STEM in disadvantaged communities. This study is part of a larger body of work seeking to improve knowledge of and engagement in STEM for families living in an area of socio-economic disadvantage [17] [18]. The major contribution of this research is a novel framework that combines Family Engagement, Synchronous Learning Activities and Asynchronous Learning Activities.

II. Virtual Educational Robotics Coding Club Framework.

Community Action Research [19] was used to design, implement, and evaluate the Virtual Educational Robotic Coding Club. Reflective practice, systematic evaluation and engaging families were key components of the process that aimed to support children to design, write and test code in a manner that engages and excites them through the medium of robotics and technology. The Framework, shown in figure 1, combines three components, Family Engagement, Synchronous Learning Activities, and Asynchronous Learning Activities.

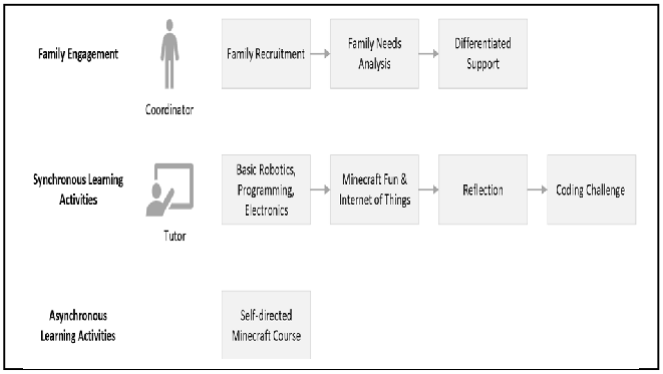

Fig. 1. Virtual Educational Robotics Framework.

A. Family Engagement

Family engagement consists of Family Recruitment, Family Needs Analysis and Differentiated Support. Family Recruitment involves informal relationship building and uses multiple methods to recruit participants namely, referral from ELI's home visiting, family engagement programmes, along with local schools and services. Families may also self-refer hearing of the programme through social-media and word of mouth. Once a family has been identified, they were contacted directly by the Coding Coordinator. Multiple conversations were held with each family to build relationships, allay fears, and encourage participation. These conversations continue with a strengths-based family needs analysis, which identify any barriers individual families might face to engagement. These may include a family's access to technology along with their proficiency in English, digital literacy, educational background, or confidence to engage in STEM, especially online. The family context is also taken into consideration in particular living conditions, number and ages of children, parents' caring and other responsibilities. The level of support is then determined with family vulnerabilities and challenges factored into the programme design and delivery.

Engaging directly one-to-one with families may be required with individual support to access the technology and materials provided in advance of an activity. The number of participants is kept low to address the cognitive and affective difficulties of mastering STEM concepts. This also enables more intense engagement and support. The technology platforms and robotic technology chosen to engage a family should consider the family's ability to use the technology.

Pre-programme engagement is important to support families logging in and accessing resources or live sessions. Discussions should take place around the use of the microphone, camera, chat along with behaviour on-screen. Allaying concerns around internet safety, body and home image requires continuous conversations and check-ins throughout the programme. Ongoing support should be provided through parent check-in meetings to enable parents to discuss any difficulties they are having with e-learning. This also gives parents a voice in the development of the programme and ensures that it is family-friendly and fit for purpose. Families can share their experience and ideas with each other and seek support if needed.

B. Synchrous Learning Activities

Synchronous Learning Activities delivered through the VRCC framework consist of learning activities with accessible and engaging content relating to basic robotics, programming and electronics with mbots and micro bits which they program using Makeblock software. Incorporated into the programme is Minecraft Fun and the Internet of Things (IOT). Minecraft fun enables a greater understanding of coding through developing a Minecraft minigame. Utilising IOT & AI technology on Codey Rocky enables the children to experiment with premade code and develop a greater understanding of a variety of smart devices available to public. These activities also assess the student's comprehension of the work completed to date on the programme and prepare them for the final session. Before completion of the programme facilitators reflect on the individual groups, considering any feedback received from children and parents. Slight adjustments may be made to the delivery of the final stages of the programme and/or additional sessions may be provided if families require additional support to understand and engage with the content. The programme culminates in a Coding Challenge, where each student is given a link to an online survey, where they will have several multiple-choice questions based on the Coding Club course and the Minecraft-themed course.

C. Asynchronous Learning Activities

Asynchronous Learning Activities involve students completing a short online Minecraft-themed course in their own time in advance of the final event. This is a fully interactive course hosted and taught by code.org providing the children the opportunity to advance their skills in functions which they have become familiar with in the synchronous learning activities..

III. Methodology

The development of the activities, framework and their evaluation follow a community action research approach [19] [20]. This research was approved by the Ethics Committee. Informed consent was sought prior to participation.

Children were invited to complete online pre- and post-programme surveys designed by the organisation to evaluate emotional engagement. This was measured through the child's enjoyment and interest. Children were asked questions at pre- and post-programme such as, "Did you enjoy coding club?", and "How interested are you in science and maths?". Parents were also invited to complete a survey at post-programme, which measured their child's emotional engagement, asking if their participating in the programme made their child more interested in learning about STEM.

Data were analysed in Microsoft Excel. Emotional engagement was measured by children's enjoyment and interest. Children stated their enjoyment of the programme on self-report post-programme surveys. Interest in coding was measured by frequency of children rating 3 or 4 on a 4-point scale at pre-programme and at post-programme.

Sixty children signed up to the VRCC between February and December 2021. All families were from an area of socio-economic disadvantage in Dublin's Inner City. All activities were delivered online in the family home. Forty-four of these children completed the pre-programme survey. 34% (n=15) of the students were female and 64% (n=28) were male. The children that completed the pre-programme survey ranged in age from 8 to 13 with an average age of 11. Eighteen children and 19 parents also completed a post-programme survey. The age range of child respondents was 10 to 14 with an average age of 11. Thirty-three percent (n=6) of the child respondents on the post-programme survey were female and 67% (n=12) were male.

IV. Results and Discussion

The aim of this project is to develop young peoples' emotional engagement in a VRCC. This section examines the findings and discusses key components to measuring successful emotional engagement.

Children's enjoyment was measured at post-programme, with 94.44% (n=17) of children reporting enjoying the V RCC. The importance of enjoyment in learning has been highlighted in previous research [21]. In an Irish longitudinal study authors found that nationally 62% of 13-year-olds [22] and 76% of 17/18-year-olds [23] reported enjoying school. Mc Namara and colleagues also found that as the socio-economic status bracket of the student lowered their dislike of school increased [23]. The results presented above provide a favorable comparison to this study with 94.44% of children from a community of socio-economic disadvantage reported enjoying the programme.

All children surveyed at post programme reported they were quite (50%, n=9) or really (50%, n=9) interested in science and technology, this decreased from the percentage of children reporting they were really interested in science and technology at pre-programme (59.09%, n=25), see Table I below.

TABLE I. Children's Interest in Science and Technology

Level	Interest in Science and Technology	
	Pre (N=44)	***Post (N=18)***
Not at all	2.27%	0%
A little	20.45%	0%
Quite	18.18%	50%
Really	59.09%	50%

It is unsurprising that that the majority of those beginning the programme showed a high level of interest as it would be expected that such a programme would attract students with an interest in science and technology. Furthermore, the organisation's prior relationships with some families engaging may have affected their interest in past programmes. It is surprising that there is a decrease in the percentage of children reporting they are really interested in science and technology at post-programme. That said, 89% (n=16) of children that completed a post-programme evaluation reported that taking part in the VRCC increased their interest in science and technology. Thus, it is probable that a number of those reporting a high interest in science and technology at the pre-programme survey were among those who did not complete the post-programme survey. Also, 100% (n=19) of parents reported that participating in the VRCC made their child more interested in learning about STEM. These findings are similar to that of Osborne [24]. The author found that while students began the programme with high levels of interest, on leaving their excitement for the topic increased and the programme influenced their aspirations towards working in a science related career.

This study had some limitations. Firstly, as mentioned previously, the organisation has been engaging with the community since 2008. Prior relationships have been established with some of the families in the study and this prior engagement may have previously influenced children's confidence in their coding skills and their interest in STEM. Additionally, these prior relationships coupled with the self-report nature of the surveys may have led to response bias. Finally, there was a low response rate to the programme surveys, 75% at pre-programme and 31% at post-programme. Thus, not all children provided data on their emotional engagement.

V. Conclusion and Future Work

This research investigated the impact of a Virtual Educational Robotics Coding Club Framework to promote emotional engagement in STEM among K-6 students in a disadvantaged community. Results demonstrate that creating fun and enjoyable virtual robotics coding activities for children has a positive impact on children's emotional engagement in STEM. Children report high levels of enjoyment after participating in the programme and all children completing the programme report high levels of interest in science and technology. This research builds on the minimal literature available of K-6 children's emotional engagement in STEM. Future work could investigate how STEM programmes such as VRCC also affect K-6 children's behavioral and cognitive engagement.

This study is part of a larger body of work seeking to improve knowledge of and engagement in STEM for families living in an area of socio-economic disadvantage. This research can potentially enhance the mainstreaming and extension of robotic coding in disadvantaged communities with the aim of addressing the issue of low student engagement in STEM in these communities [2] [3]. By adopting the Virtual Educational Robotics Framework STEM initiatives can have a greater impact than those more traditionally delivered through schools. Through the focus on family engagement the initiative can address the core issues of family STEM literacy [3] thus having the potential to impact multiple children in the family.

Acknowledgment

This work was supported by grant 20-DP-8252 from the Science Foundation of Ireland, who continue to support the research through grant 22-DP-10414. The opinions are those of the authors and do not represent the policies of the funding agency.

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