Preliminary Findings from an Integrated STEM Intervention using Programmable Robotics in Irish Primary Schools: Building a Real-World Integrated Curriculum in STEM

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Abstract: This paper presents the design and implementation of a multi-phase research project evaluating an integrated STEM intervention (BRICS) using programmable robotics (LEGO SPIKE Essentials) in Irish primary schools (*n* = 14) during the 2024-25 academic year. Preliminary findings from Phase One are reported. Prior to engaging with the BRICS intervention, both teachers (*n* = 19), and children (*n* = 338) aged 9 – 12 years, self-reported broadly neutral-to-positive STEM-related attitudes and self-efficacy. Furthermore, both participant groups were found to hold attitudes toward science which were less positive by comparison to other STEM disciplines. Interviews with professional learning leaders (*n* = 2) suggest this may be attributed to teachers holding varying STEM-related confidences.

Introduction

STEM education is a critical issue for education systems globally (Fitzpatrick, 2024; Martín-Páez *et al.,* 2019; Wong Kah Wei & Siti Mistima Maat, 2020), with many countries revising primary school curricula to address this. In Ireland, this is reflected in recent curriculum revisions, including the Primary Curriculum Framework (NCCA, 2023) and the Draft Science, Technology and Engineering Specification (NCCA, 2024), which stress the integration of STEM subjects. Education policy documents, such as the National STEM Education Policy Statement 2017–2026 and the Digital Strategy for Schools to 2027 (Department of Education, 2022), further highlight the importance of igniting children's curiosity to solve real-world problems. While much of the current discourse centers on the affordances of STEM education, the uncertainty that teachers often face, as well as their lack of confidence in delivering STEM education, particularly with regard to implementing integrated STEM approaches, is also foregrounded (Murphy *et al.,* 2023).

To address this challenge, the researchers, in conjunction with the Department of Education's support service for teachers, Oide [1], have devised BRICS: Building a Real-World Integrated Curriculum in STEM. BRICS is an intervention designed to support primary school teachers in implementing an integrated STEM project over the 2024-2025 academic school year. This hands-on intervention, involving teachers, children (aged 9-12), and Professional Learning Leaders (PLLs) [2], aims to foster experimentation and confidence in integrated STEM education through constructionist learning principles and the Engineering Design process, using programmable robotic materials.

The BRICS intervention is currently underway in fourteen Primary Schools in Ireland. The BRICS research project has three objectives: 1) to investigate any changes in teachers' and children's STEM-related confidence and efficacy following the intervention; 2) to identify enablers and barriers for teachers and schools in Ireland engaging

[1] Oide, from the Irish language word for educator, is the support service for teachers and school leaders. Oide is funded by the Department of Education in the Republic of Ireland. See https://oide.ie/ for further information.
[2] PLLs are qualified teachers who have been seconded from their teaching positions to support teachers and school leaders through the organization and provision of professional learning opportunities. PLLs work as part of teams focused upon designated curriculum and/or policy aims.

with integrated STEM initiatives; and 3) to explore the role of on-going professional development, facilitated by PLLs, in supporting an integrated STEM initiative. Additionally, it will explore whether playful, engaging learning experiences, using programmable robotics (LEGO Education SPIKE Essentials), provide significant contexts for children's learning (NCCA, 2024). This paper presents preliminary findings from the research study, including teachers' and children's STEM-related confidence and efficacy, and PLL beliefs prior to the intervention.

Method

Participants

Three categories of participants are involved in this study: primary school teachers, children, and PLLs. The first category includes teachers (N = 27) from the fourteen schools participating in BRICS. Specifically, this includes mainstream class teachers (*n* = 14), and in most, but not all schools, the special education teacher designated to support these classes (*n* = 13). A total of 19 teachers participated in Phase One, six male and 13 female. The majority of teachers had ten years or more of classroom teaching experience (63%), with only one teacher having less than four years of teaching experience. The second category, children, includes the children from classes participating in BRICS. A total of 338 children participated in Phase One, however three participants were removed as surveys were only partially completed. These children were in 3rd – 6th class, and aged between 9 – 12 years of age; 3rd class (*n* = 45), 4th class (*n* = 67), 5th class (*n* = 121), 6th class (*n* = 102). There was a slight gender imbalance in the sample, with more male (56.5%) than female (40.8%) participants. A further 2.7% chose not to disclose their gender. The third category, PLLs, included the PLLs (*n* = 2) who facilitated the BRICS intervention. Interested teachers and schools applied to participate in BRICS, with Oide responsible for selecting the teachers and schools involved in the intervention. Furthermore, as Oide designated the PLLs involved in BRICS, purposive sampling was utilized to identify participants.

Intervention

As this paper reports on the effectiveness of the BRICS intervention, it is necessary to provide an overview of its aim and design. Through the lens of cultural responsiveness, the children in each participating class are challenged to devise a solution to a local problem that they identified. Children use LEGO SPIKE Essential Kits to construct a solution to their problem and will subsequently bring their projects to life using block-based code. An important aspect of the BRICS intervention is the support provided to participating teachers by Oide. Over the course of the 2024 – 2025 academic year teachers were supported to participate in five full-day events. Notably, paid-substitute teacher cover was funded by Oide for each event. This level of paid-substitute teacher cover to engage with ongoing professional learning is not the norm in the Irish context. At the time of writing, teachers have participated in three of the four professional learning days facilitated by PLLs, i.e. 15 of the 20 facilitated professional learning hours. BRICS is due to culminate with a shared learning and celebration day, where participating classes and teachers will share their learning and experiences. Professional learning days facilitated by PLLs have included a range of topics, including computational thinking and coding, culturally responsive education, introduction to LEGO Education SPIKE Essentials, the engineering design process, etc. To protect against potential bias, the researchers have not contributed to the design or delivery of professional learning days.

Data Collection, Generation, and Analysis

A mixed-methods research design was utilized to address the research objectives of BRICS. This involves three distinct phases of data collection and generation aligned with the BRICS intervention, with this presented graphically in Figure 1. Phase One was composed of quantitative surveys conducted with children and teachers, and qualitative interviews conducted with PLLs. These data were collected and generated at the outset of the project (October 2024) to avoid unintentional biasing of data, i.e. teacher attitudes being influenced by the contents of professional learning days. For clarity, quantitative approaches to data collection and analysis are detailed first, followed by qualitative approaches to data generation and analysis.

Quantitative data were collected from two participant groups, teachers and children. First, data pertaining to STEM-related confidence and efficacy were collected anonymously from teachers (*n* = 19), representing a 70% completion rate. The survey instrument employed five subscales from the Teacher Efficacy and Attitudes towards STEM Survey (T-STEM) (Friday Institute for Educational Innovation, 2012). Namely, Science Teaching Efficacy and Beliefs (10 items), Science Teaching Outcome Expectancy (9 items), Mathematics Teaching Efficacy and Beliefs (11 items), Mathematics Teaching Outcome Expectancy (9 items), and 21st Century Learning Attitudes (11 items). Each item used a five-point Likert-type response scale from *strongly disagree* to *strongly agree*. Second, a total of 338 children completed the Student Efficacy and Attitudes towards STEM Survey (S-STEM) (Friday Institute for Educational Innovation, 2014). The survey instrument was composed of four subscales; three subscales measured children's confidence and self-efficacy in all four primary STEM subjects: science (9 items), mathematics (8 items), and engineering/technology (9 items). Each item used a five-point Likert-type response scale from *strongly disagree* to *strongly agree*. A fourth subscale measured children's attitudes toward 21st century skills, using the same five-point Likert-type response scale. For the purposes of tracking responses across Phases One and Three, children were assigned an ID by their class teacher. Anonymity of participants was protected as it was not possible for researchers to identify individual children by ID.

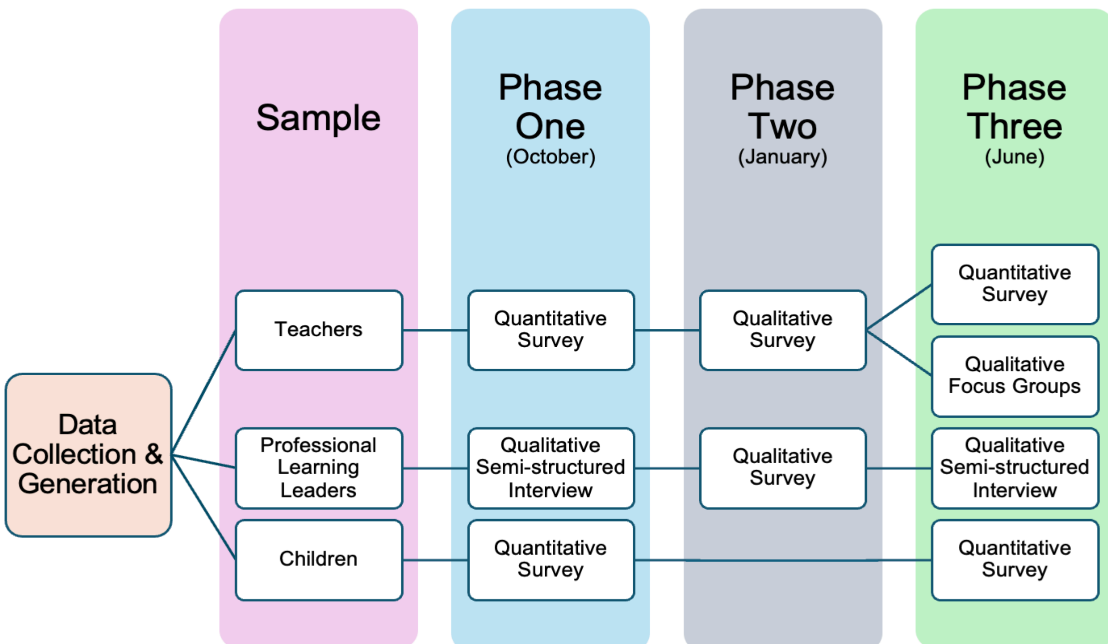

Figure 1: Overview of Data Generation & Generation in BRICS

Prior to analysis it was necessary to recode four negatively worded items. The statistical analysis package SPSS was used to generate descriptive and inferential statistics in order to describe and summarize the quantitative data gathered in Phase One. Overall scores for each subscale were calculated by averaging subscale items. Next, the internal consistency of each subscale was examined. The overall Cronbach's Alpha reliability coefficient for the instrument utilized with teachers was 0.93; Science Teaching Efficacy and Beliefs was 0.64, Science Teaching Outcome Expectancy was 0.90, Mathematics Teaching Efficacy and Beliefs was 0.90, Mathematics Teaching Outcome Expectancy was 0.91, and 21st Century Learning Attitudes was 0.91. The overall Cronbach's Alpha reliability coefficient for the instrument utilized with children was 0.90; mathematics self-efficacy was 0.87, science self-efficacy was 0.79, engineering and technology self-efficacy was 0.84, and attitudes toward 21st skills was 0.85. In each case, Cronbach's Alpha coefficients indicate overall internal consistency.

These quantitative data were complemented by qualitative data generated in semi-structured interviews with PLLs (n = 2). Qualitative data was imported into the qualitative data analysis package NVIVO. The qualitative data analysis methodology adopted by this study is based on the principles of thematic analysis (Braun & Clarke, 2006, 2021). By addressing the "priorities, opinions and ideas" (Denscombe, 2010, p. 192) of PLLs, deeper understandings of the richness of attitudes toward, and expectations for, the intervention were developed. Through this lens, the quantitative data gathered was contextualized in order to explain, complement and enhance the completeness of the findings (Creswell & Plano Clark, 2018; Denscombe, 2010).

Phase Two is due to be conducted at the midpoint of the intervention, following the third professional learning day (January 2025). Phase Two involves two participant groups, teachers and PLLs, completing a short open-ended qualitative survey designed to capture the thoughts, experiences and developing attitudes of participants. Finally, Phase Three is due to be completed following the shared learning and celebration day at the end of the intervention (June 2025). In Phase Three, quantitative data pertaining to attitudes toward STEM will be collected from teachers and children using the established scales previously utilized in Phase One. This will allow for comparison of pre- and post-intervention. Data will be complemented by two forms of qualitative data generation: interviews and focus groups. PLLs will be invited to participate in semi-structured interviews. Purposive sampling will be utilized to identify a sub-sample of teachers with high, average, and low levels of efficacy and attitudes towards STEM, as identified in the Phase Three quantitative survey. These participants will be invited to participate in focus group interviews to explore their experiences of the BRICS intervention.

Preliminary Findings

Phase One of the BRICS research project aimed to establish teachers' and children's STEM-related attitudes, confidence and efficacy prior to beginning the intervention, and to develop initial understandings of the role of on-going professional development, facilitated by PLLs, in supporting an integrated STEM initiative. Findings relating to these two aims are presented in turn, beginning with the results of quantitative analyses.

Teachers' STEM-related confidence and efficacy

In general, teachers self-reported STEM-related attitudes and self-efficacy which were neutral or positive. As shown in Table 1, there were only two subscales where negative attitudes were self-reported, Science Teaching Outcome Expectancy and Mathematics Teaching Outcome Expectancy. The majority of teachers self-reported neutral attitudes in two subscales, Science Teaching Outcome Expectancy and Mathematics Teaching Outcome Expectancy. Conversely, the vast majority of teachers expressed positive attitudes in two subscales, Mathematics Teaching Efficacy and Beliefs and 21st Century Learning Attitudes.

Table 1: Teacher's confidence and self-efficacy in STEM subject content and teaching, and 21st century learning skills before beginning the BRICS intervention

	Proportion of Respondents (n = 19)						
	Very Negative/Negative		Neutral		Positive/ Very Positive		Mean*
Subscale	*n*	%	*n*	%	*n*	%	
Science Teaching Efficacy and Beliefs	0	0	7	36.8	12	63.2	3.63
Science Teaching Outcome Expectancy	1	5.3	11	57.9	6	31.6	3.33
Mathematics Teaching Efficacy and Beliefs	0	0	2	10.5	17	89.5	4.11
Mathematics Teaching Outcome Expectancy	1	5.3	10	52.6	8	42.1	3.44
21st Century Learning Attitudes	0	0	1	5.3	18	94.7	4.56

* *Scored on a scale of 1 – 5.*

Children's STEM-related attitudes

Children were found to self-report generally neutral or positive STEM-related attitudes at the outset of BRICS. As illustrated in Table 2, mean values above 3 were reported for all four subscales, indicating that, overall, children agreed they are interested in STEM subjects. Closer inspection of subscales reveals that the majority of children self-reported positive attitudes in three subscales: Mathematics, Engineering and Technology, and 21st Century Learning. However, the majority of children self-reported neutral attitudes toward Science. Furthermore, the greatest percentage of students self-reported negative or very negative attitudes toward Science (10.7%). The largest percentage of children indicated very positive attitudes for 21st Century Learning (27.8%). This is a notable difference when compared with the second highest percentage of very positive attitudes reported for Engineering and Technology (15.1%).

Table 2: Student attitudes toward STEM before beginning the BRICS intervention

	Proportion of Respondents (*n* = 338)										
	Very Negative		Negative		Neutral		Positive		Very Positive		Mean*
Subscale	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	
Mathematics	4	1.2	24	7.1	110	32.5	154	45.6	42	12.4	3.54
Science	2	0.6	34	10.1	183	54.1	101	29.9	12	3.6	3.28
Engineering and Technology	1	0.3	13	4.1	95	28.1	176	52.1	51	15.1	3.73
21st Century Learning	0	0	2	0.6	40	11.8	202	59.8	94	27.8	4.09

* *Scored on a scale of 1 - 5.*

The role of on-going professional development in supporting an integrated STEM initiative

Thematic analysis of semi-structured interviews with PLLs resulted in the generation of six themes, see Figure 2. Defining STEM education following curriculum specification changes was a recurrent theme within interviews, with PLLs referring both to disciplinary and interdisciplinary (integrated) STEM. Related to this were concerns expressed by PLLs that teachers may lack the confidence and/or competence to facilitate the types of integrated STEM learning activities advocated in recent curriculum policy specifications. Reflecting upon their lived experiences, PLLs suggested that some teachers may not have received adequate training during their initial teacher education. Notably, PLLs emphasized their role as 'changemakers' in supporting teachers to develop their confidence and competence. When asked about the BRICS intervention PLLs were unanimous in their expectations that participation in the project would result in meaningful changes to the professional practice of teachers, "the real hope that they will have a certain confidence in [integrated STEM] this year, and that they'll be able to share that within their school and build capacity in their school. That's the real hope that everyone, in whatever class, will get to experience it" (PLLb). Nonetheless, potential challenges to BRICs, including time and varying digital infrastructure, were raised.

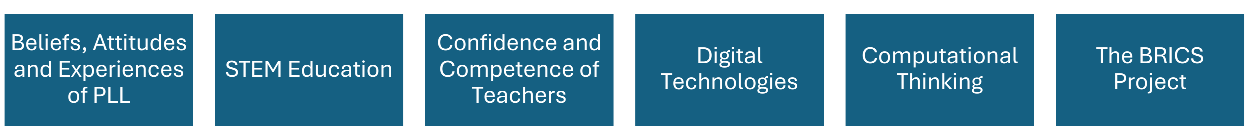

Figure 2: Overview of themes generated

Discussion and Conclusion

The purpose of this paper was to present preliminary findings from Phase One of the BRICS research project. Specifically, this paper investigated the STEM-related attitudes and self-efficacy of teachers and children, and the understandings and expectations of PLLs, at the outset of the BRICS intervention. Teachers were found to self-report STEM-related attitudes and self-efficacy which could be considered generally neutral to positive. Nonetheless, examination of subscales revealed that while teachers self-reported very positive attitudes in relation to 21st Century learning approaches, teachers' self-efficacy in relation to Science was less favorable. When considered alongside references by PLLs to their experiences of varying confidences and competences of teachers, this could align with the lack of teacher confidence in delivering STEM education reported by Murphy *et al*. (2023). Children also self-reported generally neutral to positive attitudes relating to STEM. It is interesting to note that like their teachers, the least favorable attitudes were reported in relation to Science, and the most favorable for 21st Century Learning. It is anticipated that the generally neutral to positive STEM-related attitudes reported in this study will become more positive following engagement with the BRICS intervention. This paper is of particular interest to those working in primary school settings who wish to explore an integrated STEM approach, using LEGO education robotics.

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