



Developing Primary Teachers' STEM Knowledge for Teaching through Signature Pedagogies

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The National Council for Curriculum and Assessment (NCCA) in Ireland is currently in the process of working with teachers and early childhood practitioners, school leaders, parents and children, to redevelop the Primary Curriculum. Amongst the objectives of the redevelopment is for Ireland to become internationally recognised as providing the highest quality STEM education for all learners across all levels of education. Despite challenges in enacting the existing mathematics and science curricula effectively in classrooms, this redevelopment poses further challenges to primary teachers who are now expected to take an increasingly integrated approach to teaching and learning with the knowledge and skills needed not always being evident. This paper reports on a Continuing Professional Development (CPD) programme the aim of which was the development of primary teachers' STEM Knowledge for Teaching, which describes the pedagogical and content knowledge needed to carry out the work of teaching STEM effectively in the primary classroom. The CPD programme was based on the distinctive signature pedagogies approach, involving critical dialogue, public sharing of work and communities of learners, each of which aims to enable teachers to engage in specific ways of thinking about their own practice in STEM, with the aim of enhancing their pupils educational experiences and outcomes in STEM. Three groups of Irish primary teachers (N=12), each within their own unique school context, took part in the CPD programme over the course of six months. A self-reflection of the researcher, and deliverer of the CPD, on their ongoing professional experience as a teacher educator is reported here in terms of the participating primary teachers' development of STEM Knowledge for Teaching. The findings showed that while teachers participating in the CPD programme enhanced aspects of their STEM Knowledge for Teaching, it was noted that further opportunities to extend and consolidate this learning may be beneficial.

Keywords: *STEM Education, Science Capital, Teacher Continuous Professional Development, STEM Knowledge for Teaching*

Introduction

STEM Knowledge for Teaching

STEM education has been described as “not simply Science, Technology, Engineering and Maths, but a cross-curricular approach focusing on activities relevant to all four areas” [1]. The purported goal of STEM education is STEM literacy. The concept of STEM literacy relates to the knowledge, skills, and dispositions that are acquired and developed as a result of participating in STEM education [2]. An integrated approach to STEM education enables learners to develop STEM literacy thus building and applying knowledge, deepening their understanding and developing creative and critical thinking skills within authentic contexts [2], [3]. While the concept of STEM literacy generally pertains to pupil learning, in relation to the unique and specific knowledge, skills and dispositions required to teach in and about STEM [2],[3],[4], this project proposes that the concept of STEM Knowledge for Teaching (STEMKT) may be more appropriate. The proposed STEMKT conceptual framework (See Figure 1) has its roots in the foundation concepts of subject matter knowledge and pedagogical content knowledge [5],[6],[7]. Subject matter knowledge is considered to comprise two subdomains [9], [10]:

1. Common content knowledge, which describes general subject content not unique to primary school
2. Specialised content knowledge, which pertains to more sophisticated concepts in each subject. These demand a deeper knowledge of these concepts on the part of teachers in order to effectively enable pupils to develop an understanding of these concepts.

Pedagogical content knowledge comprises the expertise required by a teacher to enable their pupils to develop the requisite concepts and skills pertaining to each subject [7],[8]. This expertise includes knowledge of curricula, knowledge of pupils and knowledge of teaching. The proposed STEMKT framework recognises the complexities of teachers' acquisition of STEM subject matter knowledge and the subsequent translation of this into powerful integrated STEM pedagogical experiences for pupils.

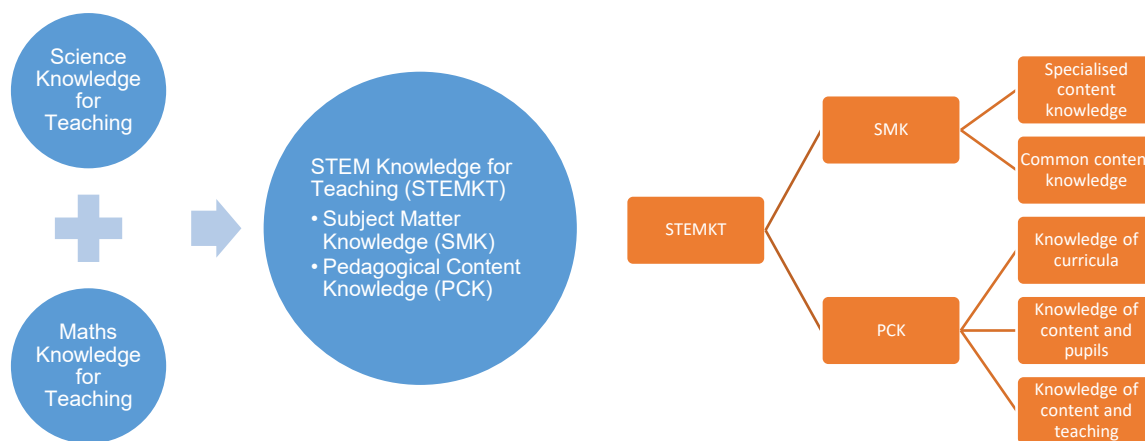


Figure 1. Overview of proposed STEMKT conceptual framework

STEMKT in Irish primary classrooms

Within the current Irish Primary Curriculum, STEM does not exist as a standalone subject. This presents a challenge for generalist primary teachers, who are expected to deliver effective integrated STEM teaching and learning experiences within mathematics and science [3]. Preparations are underway for a redeveloped primary curriculum, which aims to support a more authentic integrated approach to teaching and learning in all subjects, including the STEM disciplines [9],[10]. These proposed curriculum changes risk exacerbating existing difficulties faced by teachers in the enactment of the current primary mathematics and science curricula [11],[12],[13]. It has been suggested that professional development interventions focusing on the development of primary teachers STEMKT may ameliorate to these difficulties [11],[12],[13].

Signature pedagogies

In order to explore primary teachers' development of STEMKT, this project draws on the theoretical framework of signature pedagogies [14]. The continuing professional development (CPD) intervention programme designed by the researcher utilised the signature pedagogies of

1. Critical dialogue (the process of acquiring knowledge through communicative interactions)
2. Public sharing of work (testing out practices in classrooms and sharing ideas with larger audiences, for example, a TeachMeet or through the sharing of artefacts)
3. Communities of learners (collective learning around a shared concern or a passion).

These pedagogies were noted as being particularly effective in the enhancement of teacher practices [14].

Methodology

This projects draws from the methodological framework of self-study action research (SSAR) [15] which places its roots within the paradigm of critical theory [16] The SSAR approach involves the researcher engaging in critical reflection, where data is drawn through four lenses [17]:

1. Autobiographical or the "Self" lens, through the use of a reflective diary
2. Colleagues' experiences or the "Peer" lens (including ongoing dialogue with a Critical friend)
3. Theoretical Literature lens (Reflection using literature pertaining to the subject focus, STEM and teacher professional learning in this case)
4. Learners' eyes lens (the perspective of participating teachers)

Reflection through these lenses allows the researcher to interrogate and critically analyse their practice as a teacher educator, while enhancing rigour through triangulation of data [18].

Data gathering and analysis approach

Convenience sampling was used to recruit three primary schools, with four teachers in each school invited to take part in a CPD intervention programme. A mixed methods approach has been adopted which focuses on qualitative analysis of data. In order to track participants' progress, data was gathered prior to the intervention using an individual anonymised questionnaire instrument. This



instrument comprised a combination of likert-style items and open ended questions, which focused on teachers' perception of their own current STEMKT, current classroom practices and current pupil attainment and experiences in STEM. Further qualitative data is being gathered throughout the intervention using field notes and the researcher's reflective diary. Each school has also been invited to bring visual artefacts (photographs of pupil work samples, lesson plans, teaching resources) with an accompanying rationale for a national shared learning day, where each school will have the opportunity to engage with the other participating schools. Following the CPD intervention, data is to be gathered through semi-structured group interviews with each group of participants within their own school. Post-intervention, individual questionnaires will be readministered to ascertain if there has been any perceived enhancement in participants' STEMKT, classroom practice, pupil attainment and experiences as a result of engaging in the CPD intervention.

Professional development intervention programme design

In response to data gathered through the pre-intervention questionnaire instrument, the researcher's reflective diary, in which the researcher documented accounts and reflections based on critical dialogue with each group, three bespoke CPD programmes have been designed. These are being delivered by the researcher over the course of six months. While programmes were designed to address areas of need identified by each group, each programme features the use of signature pedagogies to support teachers' development of STEMKT. All participating schools are taking part in a Lesson Study cycle pertaining to their subject focus. All participating schools have also been invited to attend a national shared learning day, as earlier described. An overview of the programme devised for and delivered to each school is shown in Table 1.

School Name (pseudonyms)	Subject focus & self-identified priority need	CPD approaches used	Signature pedagogies	Critical dialogue	Public sharing of work	Communities of learners
Oakleaf	Mathematics: Inquiry based learning pedagogies to develop pupils' concept of measurement in mathematics	Demonstration lessons		⊙		
		Lesson Study		⊙	⊙	⊙
		Group meeting with school leaders		⊙		⊙
		Shared learning day		⊙	⊙	⊙
Damson	Science: Developing pupils' science skills	Demonstration lessons		⊙		
		Lesson Study		⊙	⊙	⊙
		Shared learning day		⊙	⊙	⊙
Figtree	Mathematics: Developing pupils' strategic competence in number calculations	Individual meetings with teachers		⊙		
		Lesson Study		⊙	⊙	⊙
		Shared learning day		⊙	⊙	⊙

Table 1. Overview of STEMKT CPD programme design using signature pedagogies

Initial findings

Analysis of data from pre-questionnaires suggests that prior to engaging in the CPD programme, participants perceived their STEMKT to be relatively low, with only 40% of all participating teachers reporting having high or very high STEMKT. While each school's curriculum subject focus was on aspects of either mathematics or science, a majority of individual participants identified "opportunities



for collaboration with colleagues”, “gaining new ideas for innovative teaching and learning approaches” and “Inquiry based learning pedagogies” as priorities.

Initial analysis of data from the researcher’s reflective diary and field notes suggests that the participating teachers’ STEMKT is showing signs of enhancement. However, further analysis of data following conclusion of the CPD programme will ascertain if this enhancement has been sustained.

Limitations and future work

The relatively small-scale nature of this project, the self-reported nature of data from participants and its focus on the researcher’s personal experience mean that findings cannot be generalized. However, this work does offer a tentative and potentially useful framework, STEMKT. This framework, in conjunction with the use of signature pedagogies, may act as potential springboard for the researcher and others to engage in further exploration of effective approaches to developing teacher practices for the benefit of pupils’ learning outcomes and experiences in STEM.

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