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Keynote Presentations

How should science and mathematics education research be communicated to teachers?

Matthew Inglis

Department of Mathematics Education, Loughborough University

If education research is to have any impact on practice then it needs to be communicated to practitioners in one form or another. Despite this, little research has examined how to present education research in ways that maximise the ability of teachers to make informed decisions. In this talk I first distinguish between two types of research output that we might want to communicate: educational findings and educational theories. I will then report a series of recent empirical studies that my colleagues and I have conducted which explored the effects of various choices would-be communicators of these two types of output can make. I conclude by arguing that research communication is an important but under-researched topic in education.

STEMming the Tide: Nurturing Scientific Literacy for Active Global Citizens

Cliona Murphy

DCU School of STEM Education Innovation and Global Studies and the Centre for the Advancement of STEM Teaching and Learning

Science education, whether standalone or part of integrated STEM approaches, is a fundamental component of primary and post-primary curricula globally. Research indicates that engagement with (integrated) STEM projects enhance students' learning of the STEM disciplines, provides opportunities to focus on problem-solving in authentic situations and supports the development of key competences. However, it is also evident that effective STEM education requires both disciplinary teaching of Mathematics and Science as well as integrated STEM projects. Despite the significance of STEM education, many students worldwide do not pursue science education beyond second level, highlighting the critical role of early years, primary and post-primary science education in fostering scientific literacy and understanding of science's real-world applications. In this paper I will explore the concept of scientific literacy and its development across early years, primary and post primary education. I will reflect on the opportunities teachers miss for developing scientific literacy while implementing science curricula and consider how teachers can maximise opportunities to foster deeper understanding of science and its application and relevance in our everyday lives.

Symposia

Priorities for the Assessment of Mathematics and Science Skills: Developing a Shared Understanding

Marie Brennan[1], Judith Callan-Gough[2], Lorraine Harbison[3], Deirdre Ní Chonghaile[3], Elizabeth Oldham[4], Miriam Ryan[3]

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In mathematics and science education, challenges around implementing meaningful curriculum and assessment reform - especially for problem posing and problem solving - are common in many countries (Harbison, Farrell, & Ryan, 2022; Goldin et al., 2016; Murphy et al., 2023; OECD, 2023; Shimizu & Vital, 2023). Teachers can struggle with formative assessment of students' work in these areas (Burke & Lehane, 2023; Shiel & Dooley, 2022). Seeking to address the issues in an international context, the Science and Mathematics Education Research and Development Community (RDC) – an RDC of the Association for Teacher Education in Europe (ATEE) – is developing an assessment toolkit consisting of a repository of engaging tasks for students together with research-based rubrics to support teachers' assessment practices, encapsulated in a website (https://www.mathscify.org). The "Mathscify" project originated in Ireland, and two local research initiatives are contributing to the development of the toolkit, with an initial focus on the mathematics element. Findings from the three papers are synthesised in an attempt to form a shared definition of what counts as understanding, and to inform discussions in relation to the suitability of problem-posing and problem-solving tasks to engage all learners in working mathematically and scientifically.

The first paper in the symposium traces the evolution of the Mathscify project. It highlights challenges in framing the toolkit design suitably, for example with tasks classified according to descriptors acceptable in many cultural settings and suited to differing national curricula. The cognitive domains used in TIMSS (the Trends in International Mathematics and Science Study), namely "knowing," "applying," and "reasoning," have the advantages of being familiar internationally and applicable to both science and mathematics (Mullis et al., 2021). The domains adopted for the project broadly align with the TIMSS versions, with "communication" being added as important for formative classroom-based assessment (Schoenfeld, 2016).

The second paper addresses the language aspect in an Irish context. It reports on the results of the first phase of a research project ongoing in primary schools in the Irish-medium education (IME) sector. This project seeks to establish current assessment understandings, practices, and priorities of IME teachers as well as the supports and challenges experienced by them. It is intended to draw on these data to develop and refine tasks and supports tailored to the sector as a key part of the Mathscify toolkit. The paper presents the findings and themes emerging from a questionnaire survey administered to schools in the IME sector in the context of the foci of the new Primary Mathematics Curriculum (National Council for Curriculum and Assessment, 2023) and specific issues in the Irish-Medium sector (Gilleece et al., 2012; Nic Aindriú et al., 2021). Context-specific considerations around the development and use of task and assessment resources tailored to specific needs of the sector are discussed.

Paper three reports on the trial of problem-posing mathematics tasks, developed as part of the Mathscify toolkit, in two case study schools, a 6th class in a primary school in Leitrim and 1st year in a post-primary school in Cork. This initiative aimed to develop positive attitudes and motivation to learn (Kaur et al., 2023), thus fostering students' agency and ownership in producing their own mathematical content (Brennan & Harbison, 2023). Results tracked

students' progress along a learning trajectory, showcasing an increase in their sophistication in devising problems, presenting different solution pathways, drawing conclusions, and explaining their reasoning. Findings further demonstrate how formative assessment can best be utilised to assess how, and how well, students perform on non-routine mathematical problems that require them to make decisions, explain and justify their thinking, create new ideas and represent their thought processes in multiple ways.

Supporting Science and Mathematics Education in Early Childhood

Marcella Towler[1], Sandra O'Neill[2], Brenda Lattimore[2], Cathy Steenson[3] and Ramona Mihalka[3]

[1] University College Cork, [2] Dublin City University and [3] the National College of Ireland

Presented by the Early Childhood STEM Network, this symposium will explore science and mathematics education in early childhood (birth to six years) using a number of professional lenses. Ecological factors such as gender, race, community and socioeconomic status that exist at individual, family and societal levels can influence children's achievement in science and mathematics (DE, 2022; OECD, 2023). In this symposium, each presenter outlines their contribution to young children's science and mathematics learning at setting-, community-, and university- level, addressing some of the ecological factors at play.

The presentation from Brenda Lattimore considers young children's learning in EC settings prior to compulsory education. It outlines the essential role of the adult in providing pedagogical commentary to support children's STEM inquiries and explorations. The importance of agentic educators and intentional pedagogy in early childhood settings is acknowledged (NCCA, 2023; Daly and Skehill 2023), but the role of the educator, appropriateness of prescribed curricula, and the formality of science and mathematics content are questioned in EC (Wood and Hedges 2016). An excerpt from practice is used to demonstrate the educator's role in planning a STEM provocation based on the children's interests and the provision of opportunities for children to engage in self-directed exploration. Similar to emerging findings pertaining to play-based, child-led STEM in Australia (Speldewinde and Campbell, 2023) this presentation illustrates how educators can guide children and provide challenging STEM learning, whilst avoiding didactic, adult-led approaches.

Cathy Steenson and Ramona Mihalka present evidence from a community-wide early years mathematics intervention in the National College of Ireland. Literature suggests that prolonged breaks from formal education during school holidays negatively impact children's academic knowledge and skills (Cooper et al., 1996; Alexander et al., 2007) particularly for those from lower socio-economic backgrounds (Downey et al., 2004; von Hippel et al., 2007). In response, the Early Learning Initiative (ELI) seeks to improve children's opportunities for early numeracy and STEM learning and increase parental involvement in their children's learning and education by providing ongoing supports across the community. Recent evaluation of ELI's programmes includes feedback from parents, children and early years and primary school educators. Findings suggest that ELI programmes are successful in improving young children's early numeracy and STEM development, and in expanding parental confidence in supporting their children's learning.

Finally, Marcella Towler reflects on the potential of outdoor learning spaces to foster early childhood undergraduate students' understanding of STEM concepts. Successful STEM educators require alternative types of knowledge and thinking processes (Cohrssen and Garvis, 2021) and teacher education programmes need to address the stereotypes and beliefs that students may have from their past STEM experiences (Delahunty, Ní Ríordáin and Prendergast, 2020). Further, playful interactions have been shown to foster science process skills which lay the foundation for young children's continued science education (Watts and Salehjee, 2020) and emergent curriculum, typical in EC settings, provides significant opportunities for

scientific enquiry (Guarrella, 2021). It is therefore crucial for early childhood undergraduate students to develop an understanding of the potential of an emergent play-based curriculum for fostering STEM skills, and explore their previously held beliefs of what STEM learning entails. Evolving conceptualisations of STEM are evidenced through the provision of Lecturer reflections and examples from student workshop activities in an outdoor learning space. The presentation demonstrates how STEM habits of mind (Bojan and Markovinovic, 2017) are fostered through first-hand experiences within an emergent curriculum and how the science process skills of observing, classifying, comparing, predicting, and checking, and communicating and recording (Guarella, 2021) are nurtured outdoors.

Mathematical Knowledge for Teaching: Baseline insights in the Irish ITE context

Hamsa Venkat [1], Seán Delaney [2], Paul Grimes [1], Lorraine Harbison [1], Stephen Quirke [3]

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In this symposium, we present three papers drawing from baseline data collected in the Initial Teacher Education – Knowledge/Attitudes Mathematics (ITE-KAM) study. The study stems from concerns expressed in recent years about poor conceptual knowledge of mathematics among school leavers and weaknesses linked to higher-order mathematical thinking. The focal area is thus 'mathematical knowledge for teaching' (MKT) in the ITE context, with this study seeking to add depth and detail to what is already known about MKT among pre-service primary teachers in Ireland.

Paper 1: Studying MKT: Instruments and overview outcomes

The ITE-KAM research and development study began with a baseline assessment adapted from the TEDS-M ITE study (Tatto et al., 2013), which included mathematical content knowledge (MCK) and pedagogic content knowledge (PCK) items. This baseline assessment was administered with 1st year PMEP and BEd student cohorts in one institution and followed up with a small cross-attainment sample of topic-specific task-based student interviews to probe understandings and problem-solving approaches.

In this presentation, we offer an overview of the TEDS-M instrument and our formulation of it into an online survey instrument. We explain our choices for selecting a small number of items for follow-up in more in-depth task-based interviews. We also present some quantitative summary analyses of student outcomes from the baseline survey with BEd and PMEP student cohorts, locating some of these outcomes in an international comparative context, and discuss key points of interest from these findings.

Paper 2: Topic specific MKT: Findings from deeper dives into the data

The second paper delves into students' MKT in two topic areas: rational number and pattern. These analyses involve exploration of responses across sets of interrelated baseline assessment items, and to task-based interview responses linked to these topics. On rational numbers, outcomes point towards somewhat narrow ways of working with fractions, with reliance on particular procedural avenues alongside evidence of misremembered procedures. Imprecise use of language was relatively common – for example, stating that 'multiplying by fractions' would give a smaller answer, with no reference to the size of the fraction. There was also some evidence of seemingly contradictory responses when looking across items, and some surprising response patterns across the MCK and PCK items in this topic.

We also studied an MCK/PCK pair of items drawn from the Patterns/Algebra strand. Responses to these two items are used to further understand the relationship between MCK/PCK with overview outcomes of this topic showing – in some ways – a perhaps more predictable success *rate in favour of MCK, with the marked disparity in outcomes across the two categories raising questions about what to prioritise within ITE.*

Paper 3: Reflecting on MKT in Ireland: What does the ITE-KAM baseline data add, and what are priorities for development?

In this paper, Dr Delaney discusses the emerging findings from the ITE-KAM baseline dataset in relation to previous studies that have shed light on the nature of primary teachers' MKT in Ireland. Drawing on his earlier work on assessing mathematical knowledge for teaching, more recent findings in the international MKT field and his experience with primary mathematics initial teacher education in Ireland, he responds with a commentary on two aspects: first, what the findings from the ITE-KAM baseline data on MKT add to what we already know about primary teachers' MKT in Ireland; and second, perspectives on what they suggest as priorities for MKT development.

Oral Presentations

In-service teacher's self-efficacy for learning physics

Stephen Gammell[1], Eilish McLoughlin[1], Paul Grimes[2], and James Lovatt[2]

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Self-efficacy is defined as an individual's belief that they will be successful in carrying out a task. It has been shown to correlate with academic achievement and people's choice of subjects and later careers (Bartimote-Aufflick et al., 2016), is recognised as a reliable and important predictor of university students' achievement across many areas of study (Lindstrøm and Sharma, 2011) and has been found to correlate with study and career choices (Bandura, 1986). Self-efficacy for learning physics has been shown to depend on prior formal physics instruction and gender (Pajares, 2002). This study examines in-service teachers' self-efficacy for learning physics using an existing instrument (Lindstrøm and Sharma, 2011) to determine if there was a significant correlation between self-efficacy and gender and between self-efficacy and prior teaching experience. Participants were 55 in-service teachers completing a two-year upskilling programme to gain qualifications for teaching physics up to Leaving Certificate level. We conclude that self-efficacy of participants for learning physics is high, that evidence for a difference in self-efficacy based on gender is not statistically significant and that prior experience of teaching some subjects correlates with increased self-efficacy.

Keywords: Self-efficacy, physics, gender, teaching experience

Introduction

Issues of teacher supply have long existed internationally (Darling-Hammond, 2010) and more recently in Ireland (O'Doherty and Harford, 2018), with particular subject areas experiencing an acute shortfall in qualified personnel. As a small, open economy, the Irish Government has placed an emphasis on developing a highly-skilled workforce (STEM Education Policy Statement, 2017), however this aim is compromised by a shortage of qualified teachers, including physics teachers. This issue has become so pronounced in the past decade that it has been labelled a crisis (Harford and Fleming, 2024). In 2020, the Department of Education in Ireland set out to address the shortage of qualified physics teachers at post-primary and to reduce the number of teachers teaching physics out-of-field (where out-of-field refers to teachers being assigned to teach subjects which do not align with their education and training), by establishing the Professional Diploma in Teaching Physics (PDITP) programme. The PDITP is a level 8, two-year, part-time programme designed to upskill in-service, post-primary teachers to meet the requirements for teaching physics to Leaving Certificate and is delivered via a collaboration of three universities: Dublin City University, University of Galway and University of Limerick. The programme comprises 75 ECTS[1], with the aim of developing teachers' physics content knowledge (including theoretical and experimental knowledge), their pedagogical content knowledge for teaching physics and their facility for engaging in reflective practice as physics teachers. The programme is delivered in a blended fashion, comprising a mix of online/face-to-face, and synchronous/asynchronous modes.

Self-efficacy is recognised as a reliable and important predictor of university students' achievement across many areas of study (Lindstrøm and Sharma, 2011) and has also been shown to contribute to students' persistence in physics (Sawtelle et al., 2012). In his seminal paper, Bandura (1986) defines self-efficacy as a person's belief in his or her ability to succeed

[1] European Credit Transfer and Accumulation System

in a given situation. Self-efficacy affects a person's behaviour – those who believe they are capable of completing a task are more likely to work harder, persist longer and persevere when they are faced with challenges and uncertainty (Cervone and Palmer, 1990). Given this, it is unsurprising that self-efficacy is shown to correlate with academic success across many areas of study, including physics (Lindstrøm and Sharma, 2011). Bandura (1986) lists four sources of self-efficacy: performance accomplishments, vicarious experiences, verbal (or social) persuasion and physiological and affective states. Performance accomplishments refer to an individual's prior experience of successfully completing a task, which has a positive impact on their belief to complete more complex tasks. Vicarious experiences refer to the process of observing peers succeed through their efforts and to thus see tasks as doable. Verbal (or social) persuasion refers to positive feedback from those in a position to influence while physiological and affective states refer to, for example, the impact of stress and anxiety on a person's beliefs in their ability to be successful. Cervone and Palmer (1990) state that, for subjects with which students are familiar, firm beliefs about their own capabilities are developed and their self-efficacy is, accordingly, relatively stable. For students who are unfamiliar with a subject, their self-efficacy for learning that subject is based on their belief in their potential to succeed and their self-efficacy is likely to change over a period of time as they are immersed in the subject.

There exists a significant body of research on self-efficacy for learning physics, much of which is focused on second-level education settings and at undergraduate level in higher education (e.g. Carroll et al., 2024; Lindstrøm and Sharma, 2011; Marshman et al, 2018; Sawtelle et al, 2012). In their study of undergraduate first-year physics students, Lindstrøm and Sharma (2011) found that both gender and prior formal physics instruction had a significant effect on students' self-efficacy. They also reported that males consistently reported higher self-efficacy and males who had no prior formal physics education exhibited the highest levels of self-efficacy of any group. Furthermore, female students seemed to adjust their self-efficacy, based on the results of physics assessments, at a faster rate than male students. Self-efficacy is task-specific according to Finney and Schraw (2003) and research by Choi (2005) indicates that the predictive power of self-efficacy, in terms of academic achievement, depends on the specificity of the self-efficacy measurement.

Owusu-Agyeman (2019) defines adult learners as those who continue their education after a period of interruption. It has long been recognised that adult learners learn differently and have different needs to younger learners, leading to the development of andragogy as a theory of learning (Knowles et al., 2015). As part of this, the prior experience of adult learners has been identified as an important factor in learning, with potential to impact both positively and negatively on the learning process.

In contrast to the research available on self-efficacy in second-level and undergraduate domains, literature pertaining to the self-efficacy of adult learners is more sparse. Of this, while Jameson and Fusco (2014) found that adult learners self-report lower levels of self-efficacy for learning maths than their undergraduate colleagues, De Fátima Goulão (2014) reported that adult learners, engaged in an online learning programme, had high levels of general academic self-efficacy and that a positive correlation exists between self-efficacy and academic achievement.

We propose that participants in the PDITP programme are most correctly categorised as adult learners and given that there is a dearth of research on the self-efficacy of adult learners, and even less in relation to adult learners of physics, measurement and analysis of PDITP participants' self-efficacy contributes to filling this gap. Accordingly, this research aims to answer the following research questions (RQ):

- RQ1: How does the self-efficacy of in-service teachers for learning physics compare to that of undergraduate students?
- RQ2: How does the self-efficacy of in-service teachers for learning physics depend on gender?

- RQ3: How does the self-efficacy of in-service teachers for learning physics depend on prior teaching experience?
- RQ4: What is the nature of the relationship between academic performance and self-efficacy for learning physics?

Methodology

An online questionnaire was shared at the end of semester one of the PDITP programme in June 2022 with the 55 in-service second level teachers completing the PDITP programme. 54 teachers (30 female, 24 male) completed the questionnaire. At the time of completing the questionnaire the teachers had completed assessments and received grades for their first three physics modules but had not yet commenced the programme summer school. Data was collected on the participants' demographics, self-efficacy, inquiry-based learning, classroom practice and reflective practice. The findings from examining the relationship between self-efficacy and use of inquiry based learning and reflective practice has been reported by McLoughlin et al. (2024).

To measure participants' self-efficacy for learning physics, Lindstrøm's and Sharma's (2011) validated, self-efficacy questionnaire (Figure 1) was used. For each item on the questionnaire, participants were presented with a five-point Likert scale (strongly disagree, disagree, neutral, agree and strongly agree). Cronbach's Alpha was calculated for the self-efficacy scale, with a result of 0.782 indicating a high level of reliability. A self-efficacy score was calculated for each participant by applying unit weighting to each point on the Likert scale and calculating the mean.

Findings

How does the self-efficacy of in-service teachers for learning physics compare to that of undergraduate students?

The results of the self-efficacy calculation (Figure 1) shows that the mean self-efficacy for learning physics for the group is high ($\mu = 3.99$) . In carrying out a similar analysis with undergraduate students, Lindstrøm and Sharma (2011) calculated self-efficacy differently, as the sum of the individual items on the scale. When the mean of this score for the undergraduate group ($\mu = 17.85, \sigma = 2.90$) is compared to a similarly calculated mean for the PDITP group ($\mu = 19.89, \sigma = 2.80$), using an independent-samples t-test we find that PDITP participants exhibit a statistically-significant higher self-efficacy for learning physics than undergraduate students ($p < 0.01$).

How does the self-efficacy of in-service teachers for learning physics depend on gender?

The group was divided into two subgroups based on gender (female=30, male=24) and the mean self-efficacy for each group calculated. Examining the results (Figure 1), it appears that the mean self-efficacy of males is higher than that of females. This trend is also apparent in comparing the individual self-efficacy items across both groups. The mean self-efficacy of both groups were compared using an independent-samples t-test and the differences were not found to be statistically significant ($p > 0.05$). A similar null result was obtained, using a Mann-Whitney U Test, when comparing both groups across the individual self-efficacy items.

Figure 1

Self-efficacy for learning physics results.

	Overall		Male		Female	
	N=54		N=24		N=30	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1. I generally manage to solve difficult physics problems if I try hard enough	.09	766	.21	721	.00	830
2. I know I can stick to my aims and accomplish my goals in physics.	.17	696	.29	690	.07	691
3. I will remain calm in my physics exam because I know I will have the knowledge to solve problems.	.67	879	.79	884	.57	858
4. I know I can pass the physics exam if I put in enough work during the semester.	.33	584	.42	584	.27	583
5. The motto 'If other people can, I can too' applies to me when it comes to physics	.70	854	.87	741	.53	.10
Self-Efficacy Mean Score	.99	579	.12	547	.90	588

How does the self-efficacy of in-service teachers for learning physics depend on prior teaching experience?

The data were analysed to determine if there was evidence for correlation between self-efficacy for learning physics and participants' prior teaching experience overall. Participants selected their prior experience from the following categories: 0 years, 1 – 4 years, 5 – 10 years, 11 – 15 years, 16 – 20 years and 20+ years. In analysing the data, unit weighting was applied to each category (0 years = 1, ..., 20+ years = 6). Applying Spearman's rank correlation, a null result was obtained ($p > 0.05$), indicating that there is no evidence that participants' self-efficacy for learning physics is correlated with prior teaching experience.

The data were further analysed to determine if there was evidence for correlation between self-efficacy for learning physics and prior experience of teaching specific subjects. Although not qualified to do so, some participants of the PDITP have prior experience of teaching Leaving Certificate physics, while others had experience of teaching physics as part of Junior Cycle science. The results (Figure 2) show that there are statistically-significant correlations between self-efficacy for learning physics and prior experience of teaching both physics and maths for Leaving Certificate and Maths for Junior Certificate. Prior experience of teaching other STEM subjects does not appear to correlate with self-efficacy for learning physics. When the data was divided up into female and male subgroups and a similar analysis carried out, it was found that only prior experience of teaching Leaving Certificate physics was correlated with self-efficacy and only for males ($\rho = 0.613$, $p = 0.001$). The absence of statistically-significant correlations between self-efficacy for learning physics and prior experience of teaching mathematics, after the data was divided based on gender, is attributed to reduced sample size.

Figure 2

Self-Efficacy versus prior teaching experience, where ρ is Spearman's rank correlation coefficient and p is the p-value returned by a two-tailed test. Shaded cells indicate results which are statistically significant at the 5% level.

		Prior Teaching Experience							
		Leaving Cert.						Junior Cert.	
		Physics	Maths	Ag. Science	Applied Maths	Biology	Chemistry	Science	Maths
Self-Efficacy	ρ	.405	.293	.150	.228	.042	-.092	.106	.291
	p	.002	.032	.279	.097	.761	.510	.443	.033

What is the nature of the relationship between academic performance and self-efficacy for learning physics?

A mean grade for each student at the end of year one was calculated based on the three physics modules they completed. These grades were compared to students' self-efficacy scores using Spearman's rank correlation. The results show that for the group as a whole there is no statistically significant correlation between the variables ($\rho = 0.269, p = 0.057$), however when the same analysis is carried out on the male and female subgroups, there is evidence of a moderate correlation, but only for the female subgroup ($\rho = 0.396, p = 0.03$).

Discussion and Conclusions

Self-efficacy for learning physics is high amongst PDITP teachers compared to undergraduate students. There are a number of reasons why this may be so. PDITP teachers are adult learners and so come to the programme with much greater life experience and are likely to have a good sense of what learning physics entails. Cervone and Palmer (1990) reported that for subjects with which students are familiar, firm beliefs about their capabilities are well established and relatively stable. Bartimote-Aufflick et al. (2016) argues that self-efficacy influences the activities people choose to involve themselves in. Since PDITP teachers have chosen to major in this subject with a view to teaching it as part of their career, it is reasonable to assume that participants have some degree of expectancy for success, meaning that their self-efficacy may be higher than those who are unfamiliar with the subject and base their self-efficacy on the potential to succeed (Cervone and Palmer, 1990).

There is some evidence of a difference in self-efficacy between genders, with the mean self-efficacy of the male subset exceeding that of females and each item on the self-efficacy scale exhibiting a similar trend, however this is not statistically significant. This contrasts with the results obtained by Lindstrøm and Sharma (2011) in relation to undergraduate physics students. This null result may be due to a fundamental difference between adult learners and undergraduates or it may be due to a comparatively small dataset. It is unlikely that the result is due to the self-efficacy instrument not being specific enough (Pajares, 1996). Further analysis using data from other cohorts of PDITP teachers will help to clarify this.

There is no evidence of a correlation between prior teaching experience (overall) and self-efficacy for learning physics. This may be due to the specificity of self-efficacy as a construct and the four recognised sources of self-efficacy (Bandura, 1986). It is likely that teaching in general has no material effect on self-efficacy for learning physics. There is statistically-significant evidence that self-efficacy for learning physics correlates with teaching specific subjects – namely Junior Cycle mathematics, Leaving Certificate mathematics and Leaving Certificate physics. This is likely due to the overlap between the skills required to teach these subjects and the perceived skills needed to successfully study physics (e.g. solving numeric problems). When the data pertaining to these three subjects was subdivided by gender, a statistically significant correlation between self-efficacy and prior teaching was found only in the case of Leaving Certificate physics and only for the male participants. This result is consistent with previously reported differences in terms of source of self-efficacy (Zeldin et al., 2008), with mastery experience emerging as the most significant source of male self-efficacy and both vicarious experiences and social persuasion being the most important sources for women. Teaching physics provides opportunities for mastery experience, but the isolated nature of physics teaching in schools does not facilitate vicarious experiences or opportunities for social persuasion, resulting in increased self-efficacy for males but not for females.

The correlation between self-efficacy and PDITP semester-one grades is only significant for female participants. Lindstrøm and Sharma (2011) observed that female students adapted their self-efficacy based on feedback quicker than their male counterparts while Bottomley et al. (2022) reported that students' grades at the end of one semester predicted their self-efficacy in semester two. The correlation between self-efficacy and achievement for female participants may be attributed to the fact that the self-efficacy questionnaire was administered to PDITP teachers shortly after they had received their first semester grades.

The results of this study add to the understanding of self-efficacy of adult learners for learning physics, gender differences therein, how self-efficacy is affected by prior teaching experience and the relationship between self-efficacy and achievement. There is evidence that the self-efficacy characteristics of adult learners differ from those of undergraduates, specifically in terms of their self-efficacy levels and differences in self-efficacy due to gender. Similar research, using data from subsequent cohorts of PDITP participants will further clarify these findings.

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Technology-enabled Teaching and Learning Strategies in Rural India Post Covid-19

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During the COVID-19 Lockdown Pandemic (CLP), rural India faced significant challenges in digital online learning due to limited devices and connectivity. Despite this, many teachers adapted to new digital teaching strategies during the CLP. There is little speculation that teachers and students may be more technologically proficient than before CLP or that teaching practices may have changed. However, little research has been conducted on the educational initiatives or strategies implemented in rural areas. This study explores the technology-enabled teaching practices of primary teachers (5th -8th-grade students aged 11 to 14 years) in a rural area of India, the Bhandara district in Maharashtra, post the CLP. The study focused on understanding teachers' practice of technology before, during and post-CLP. Semi-structured interviews were conducted with 28 teachers in the Zila Parishad (Government District Council) Schools. Initial findings show that teachers continued using communication technology, such as instant messaging (IMA) to share subject-related content with the students and new digital resources and national platforms in the classroom. Teachers also reported using IMA to learn how to use digital technologies from their colleagues. However, the barriers to sustaining these practices in the post-CLP were also identified.

Keywords: COVID-19 pandemic, technology-enabled practices, sustainability, post-pandemic period.

Introduction

The COVID-19 pandemic severely disrupted education worldwide, leading to prolonged school closures and a shift towards remote and online education (UNICEF, 2020). The pandemic was perceived by organisations such as the World Bank and the OECD as the 'turning point' for digital education, highlighting the potential for digital education (Azevedo et al., 2021; Batra et al., 2020). However, most published research from India focused on the school system's failure and the learning loss during the CLP. Little research has been conducted on the sustainability and impact of digital initiatives introduced during this time. In particular, little is known about practices in rural areas. This study, focused on two research questions, investigating tech-enabled practices during CLP and post-CLP in a rural area in India:

1. What technology-enabled strategies and interventions were adopted by teachers, and what were their experiences of adopting them during the CLP?
2. Which technology-enabled interventions or strategies were sustained post-CLP and why?

Status of Teachers in Rural India During Covid-19

Online learning in rural India faced significant challenges due to unreliable internet and limited access to digital equipment during the CLP (Mathivanan et al., 2021; Reddy et al., 2020). In a report published by Azim Premji Foundation's field research group (2020), over 80% of teachers struggled to stay connected with students, and around 50% of students experienced significant learning gaps. Several other studies reiterated these findings. Vyas (2020) found that 50% of teachers did not have efficient internet connectivity and that 20% lacked the necessary devices to deliver education digitally. This figure rose to 65% and 80% for teachers in some states (e.g., UP and Chhattisgarh). Moreover, students also had problems with devices and internet access (Vyas, 2020). This lack of digital resources for students, especially in rural areas, worsened the digital divide (Reimers & Opertti, 2021).

The UNESCO Responses to Educational Disruption Survey (REDS) (UNESCO, 2022) reported how schools worldwide adapted and changed their teaching methods during CLP.

School leaders in India reported that while some schools had no teaching and learning activities during the CLP, various modes were used by schools to support learning, including online, television, radio, and worksheets. Teachers relied on their phones as the primary teaching tool, and WhatsApp's social media app played a central role in teaching and learning (Vyas, 2020).

A 2021 study, "Turning to Technology", found that 56% of institutions encouraged the use of video conferencing tools, and 50% recommended messaging and social media for education. Teachers (63%) primarily used messaging services, followed by phone calls to parents (48%). Online lessons were delivered by 47%, and 46% shared printed copies. More experienced teachers (21-30 years) made greater use of digital tools, with 55% delivering online lessons compared to 38% of less experienced teachers (3-5 years) (Pota et al., 2021).

Teacher knowledge also emerged as a significant issue. Most teachers had limited knowledge of digital tools, with only 53% being familiar with online learning platforms (Azim Premji Foundation, 2020). Many teachers did not receive training to teach online, but 90% of teachers were willing to spend 8-10 hours weekly on their professional development for digital technology to support classroom interactions (Singh et al., 2020). A study by Charania et al. (2021) reported that previous experience with technology and project-based learning helped some teachers and students adapt to online methods during the CLP. Many expressed readiness to adapt technology-based teaching methods, believing innovation was necessary during and post-COVID-19 (UNESCO, 2022).

Methodology

The study adopted a qualitative case study approach. It focused on the technology-mediated practices of teachers in the schools in the Bhandara district of Maharashtra, India. The district has seven blocks and 31 government district council secondary schools (5th to 10th standards) and approximately 107 teachers. The government district council runs the schools and follows the state school curriculum. For this study, four adjacent blocks were selected. The selected blocks are predominantly forested rural areas, while one includes a district centre, which is a town. 16 schools were selected from these four blocks, along with all 67 working primary teachers (teaching 5th to 8th standard, age group of 11 to 14 years students).

Twenty-two permanent and six contractual teachers volunteered to participate, and a semi-structured interview was conducted with each teacher at their respective school locations. The interview lasted 20-30 minutes and focused on the teachers' experiences using digital technologies in teaching-learning before, during and after the CLP. The interview tool was piloted in January 2024 with four teachers, and after the tool had been modified, the data was collected in March 2024. The interviews were recorded and transcribed from Marathi to English. The data was analysed using Clark and Brown's thematic approach (Braun & Clarke, 2012). The emergent themes included policy, practices, support, and challenges in using technology in teaching. These are presented in the sections that follow.

Findings

The findings reflect teachers' technology-enabled strategies and experiences before, during, and after CLP.

Teaching and Learning pre COVID-19 Pandemic

Approaches to Teaching and Learning

Before COVID-19, approaches to teaching and learning were primarily direct instructional classroom teaching using lectures and discussions. Teachers employed whole-class teaching using textbooks and the blackboard. Teachers wrote difficult words on the blackboard for language teaching and explained their meanings to enhance understanding. Similarly, mathematics teachers taught by solving problems on the blackboard. For most teachers, the blackboard was perceived as the main and only teaching tool.

> When dealing with numbers, how can one use teaching-learning materials (e.g. poster charts, audio aids). In mathematics, the teaching method involves blackboard work, which means writing on the board. One cannot teach math without a blackboard. (Lpal02, Pos. 2)

Teachers highly valued the face-to-face classroom teaching approach, which they believed was student-centred in that students could communicate freely and ask questions that teachers could answer. They believed this approach helped students learn better.

> Before the COVID-19 lockdown, it was a student-centred method. At that time, we had lots of communication. Students could ask questions. We also gave them answers and communicated with them face-to-face. Students also learned very well at that time. Students could understand. (Lpoh 2, Pos. 3)

Resources for Teaching and Learning

In all schools, teachers predominantly used resources for teaching and learning. These consist of poster charts, pictures, globes, and maps. Every school had a 'math box' and a 'language box' provided by the government. These boxes contained equipment to support practical learning, such as cubes, plastic shapes, compasses for mathematics, flashcards, and word games for language learning. Many schools had televisions provided by the School Management Council (SMC) and the District Council. The teachers used TV to show the rhymes of poems in the language class.

Use of Digital Technology for Teaching and Learning

Teachers' use of technology in schools varied significantly across schools. As reported by many teachers, the schools did not have Internet access. In schools with connectivity, technology use in teaching was infrequent, varying from twice a week to once a month. In some schools, headmasters instructed teachers to use technology.

> All the teachers in our school used it. We never used it daily, but our headmaster instructed us to use it twice weekly; we had assigned periods. (BLM01, Pos. 12)

In schools with connectivity, few teachers used projectors to show educational videos from YouTube, while others used Direct to Home (DTH) TV services. In a few schools, tablets were used to access educational programs, but not all schools had tablets. Few teachers prepared PowerPoint presentations for teaching, and mobile phones were sometimes used to show clips or listen to poems and rhyme. Teachers rarely use other digital educational apps.

Training and Support

Many teachers reported that training covered basic computer skills and the use of tech equipment, but the training sessions did not cover subject-specific integration of technology into pedagogy. However, only a few teachers received training on using digital technologies for teaching. Those without training in using technology for teaching-learning gained knowledge from tech-savvy colleagues, headmasters, or by watching YouTube videos. Some contractual teachers reported not getting training, and only permanent teachers received training on various topics.

> No, we did not get any training. We are contractual teachers. (LB01 C Done, Pos. 19)

Teaching and Learning During COVID-19 Pandemic

Approaches to Teaching and Learning

Most teachers were unaware of government guidelines for continuing education during CLP. They were told that teaching was not compulsory but were encouraged to support students and the Instruction they received on their WhatsApp groups. Many teachers visited students in their villages, collected parents' WhatsApp numbers, and created groups to share educational content.

So, we used to come to the village and take classes in the temple. But all the students did not come to school. Moreover, even parents did not send their children. We used to send videos to them on their phone. We made a group in every class. Around 40-50% of the students had it. (Lpoh 2, Pos. 27-28)

Many rural teachers relied on offline teaching methods, often visiting students' villages and holding classes in large houses, temples, or school grounds. Poor internet connections made online classes difficult.

Use of Digital Technology for Teaching and Learning

Most teachers used WhatsApp to share messages, pictures, and study-related videos. A few created their own teaching videos to share with students. In semi-urban areas, a few teachers could conduct online classes using Google Meet and Zoom.

> We made our own videos and sometimes shared them. Sometimes, we used to teach maths and write on the blackboard and send their photos. Alternatively, we send photos of our homework to their mobile phones. (BLM01, Pos. 29)

> There was a Google Meet. We used to send the link to the students on Google Meet. And the students used to join the link. (BLM02, Pos. 57)

Most teachers said that the government-initiated Diksha app (Digital Infrastructure for Knowledge Sharing) played a crucial role in continuing education. It is a digital platform for India's teachers, students, and parents.

> We visited the Diksha app for a particular chapter we wanted to teach. We watched some videos for it and then told the students about it. We and the students learned the chapter by watching the videos. (BLM01, Pos. 35)

Challenges Faced by Teachers

Most teachers encountered challenges due to the lack of devices and internet connections. In rural areas, many students did not own mobile phones, so teachers relied on parents' phones and created groups using these phone numbers to connect with students. As rural parents worked in the fields and returned in the evening, students did not receive messages in real-time since parents carried their phones to the fields. Some teachers had additional non-educational pandemic-related work, limiting their time for continuous education efforts.

> Yes, there were many challenges; not all students had phones, and (for those who had) we were not audible to them; they tried to join but again disconnected the meeting, and their internet was poor. Some students left the meeting, and this happened most. Since there were no students (physically or on video) before us, we could only inform (verbally communicate) them. (BLM01, Pos. 63)

Most teachers did not receive formal training in digital technologies, but they learned from each other, with support from their schools and tech-savvy colleagues who helped them use technology for teaching.

> We did not get any training. Nevertheless, we talked to each other in person to educate each other. (LP02, Pos. 59)

Teaching and Learning Post COVID-19 Pandemic

Approaches to Teaching and Learning

Post CLP, all teachers resumed face-to-face teaching in their respective classrooms. Many teachers reported that they were happy to return to face-to-face teaching because it allowed interaction with the students, and they could provide immediate feedback. It also enabled them to use interactive methods like question-and-answer sessions, discussions, storytelling, and drama. They could also use material resources such as poster charts, maps, and globes and create artefacts. Teachers were especially pleased to be able to use the blackboard again.

> Now, we have come back to our old teaching-learning. Now, we are doing the same…We are teaching. The children are learning. (BLM02, Pos. 87)

Use of digital technology for teaching and learning

On the other hand, after the CLP, many teachers continued to use digital resources alongside direct instructional teaching methods to make lessons more effective, help explain complex ideas and keep students engaged. Although the government did not provide specific guidelines for using technology in classrooms after the pandemic, most headmasters were supportive.

> We are teaching offline, but we are still using WhatsApp. If we get a good message, we forward it to the students. I am even using these digital boards. So, this is what we are doing now. (Lpoh2, Pos. 142)

Over time, teachers have recognised the value of technology in enhancing education. They used YouTube to develop their professional skills independently and learn new tools with the help of more tech-savvy colleagues.

> There are beautiful videos on YouTube that are already available. Sometimes, they are beyond our imagination. And what happened is that we do not have time to do this (make videos). We spent our time doing additional administrative work at home. (Lpal01, Pos. 102)

WhatsApp groups have been crucial in fostering a community among teachers, allowing them to share educational content, discuss teaching strategies, and support one another beyond school hours.

> There are a lot of different groups (on WhatsApp). We have some training groups and association groups. There is an English foreign language forum within the training group in Mumbai. (BLM05, Pos. 105)

Challenges faced by the teachers

The teachers faced challenges such as time management, lack of formal training, device shortages, connectivity issues, and parental resistance to smartphone use. In this environment, some teachers have emerged as champions of technology, and they are dedicated to ensuring students gain the knowledge to succeed in a technology-driven world. One teacher highlighted this by saying,

> This era is a technological era. Those who have command of computers have demand in the world. *Jyachi Computer Var Command, Tyachi Jagabhar Demand* (Marathi). Today, whoever does not know how to use technology is illiterate. (Ssak01, Pos. 112).

Discussion

The COVID-19 pandemic significantly disrupted traditional education systems worldwide, including rural areas in India, such as the Bhandara district, Maharashtra. The findings revealed that the digital divide presented significant challenges and the unavailability of formal teacher training during the CLP, which was also reported in the literature by Azim Premji Foundation (2021), Reimers & Opertti (2021), and Vyas (2020). CLP accelerated the adoption of new tech-enabled teaching strategies, as reported in the literature by Pota et al. (2021) and UNESCO (2022).

This study contributed to the sustained technology-enabled practices of teachers in the Bhandara district using digital tools like WhatsApp and the Diksha App. However, the continuation of these post-pandemic practices depended on several factors, including the availability of resources, teacher training, and institutional support.

Teachers choose and evaluate technology tools to effectively integrate ICT into their teaching and curriculum (Charania, 2022). The teachers frequently connected to online resources during the post-pandemic period using the internet and apps like 'Diksha.' WhatsApp groups played a crucial role in developing a sense of community and collaboration among teachers, allowing them to share content, strategies, and support. The study revealed that the use of online educational resources in teaching learning and communication technology was sustained during the post-pandemic period. Challenges such as time constraints, lack of devices, and parental resistance were significant barriers during post-pandemic. Despite less use of digital technology in the classroom, teachers now feel more competent and confident in handling technology in their teaching and learning during the post-pandemic. The study also highlights the role of "champion teachers" who believed in the continued use of communicative technology, recognising its importance in preparing students for a digital future.

Conclusion

While the CLP heightened the acceptance of digital tools, the return to traditional classroom settings post-CLP has reversed pre-CLP teaching practices. However, the experiences during the pandemic and post-pandemic, particularly in teachers' collaboration and digital communication platforms (WhatsApp), offer a basis for continuing technology in teaching-learning. To ensure these tech-enabled strategies last, it is essential to address the identified challenges and enable them to connect the potential of digital technologies in education through professional development.

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A Critical Analysis of the Applied Mathematics National Professional Development Programme and its Implications for Transforming Pedagogy in Mathematics Education

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The applied mathematics specification adopted in September 2021 has progressed significantly from a 1970s syllabus taught using abstract procedural methods to one using more innovative pedagogies such as mathematical modelling (NCCA, 2019). Successful curriculum reform requires the provision of professional development to upskill teachers with the pedagogies needed to fulfil specifications' aims (Kennedy, 2014). However, it is yet to be seen if teachers' practice has progressed at the same rate (Johnson et al., 2019) with a lack of empirical studies investigating the design and delivery of these programmes. This study gains insight from attending teachers to determine their perspectives on effective models to transform to a mathematical-modelling pedagogy.

This multi-phased exploratory sequential mixed-methods design gathered data from teachers using semi-structured interviews and focus groups (n = 17) and a national survey (n = 178). The findings revealed that teachers welcomed opportunities to learn new pedagogies but found embracing a new modelling-focussed pedagogy difficult and leading their own professional development challenging. They indicated a preference for expert-demonstrated (modelling mentor) models for unfamiliar pedagogies suggesting that professional development design acknowledges teachers' prior knowledge and the scale of what must be developed.

Keywords: Mathematical modelling, curriculum reform, professional development.

Introduction

Professional development is essential for teachers' professional growth and for enhancing students' educational experiences. Kennedy (2016) argues that while strong theoretical frameworks exist regarding student learning, there is a lack of well-developed theories on teacher learning. In Ireland, professional development has long been a feature of the education system, however, Harford (2010) characterises teachers' experiences as fragmented, ad hoc, and lacking a strong theoretical foundation. It has primarily been reactive, driven by curriculum reform rather than being embedded as a fundamental aspect of professional practice. Since 2010, Project Maths has driven significant efforts to shift pedagogy from procedural methods to problem-solving and real-world applications. However, Johnson et al. (2019) highlight that Irish mathematics teachers continue to struggle with implementing reform pedagogies, indicating a disconnect between professional development and curriculum goals.

This study examines Ireland's national professional development programme for applied mathematics, where mathematical modelling unifies teaching, learning and assessment, aligning with the broader mathematics curriculum's emphasis on problem-solving. The study's findings have implications for the wider mathematics education community and third-level teaching and learning. The research aims to identify the most effective professional development models within mathematics education. The newly introduced applied mathematics specification represents a transformative shift in pedagogical practice, marking the first revision of both the curriculum and its associated professional development programme in the history of Irish education. The study aimed to answer the following research questions (RQ):

RQ1: How should professional development in mathematics education be designed and delivered to transform teachers' practice?

RQ2: Which methodologies utilised by facilitators in professional development events are conducive to enhancing pedagogy?

Literature Review

In Ireland, the primary objective of professional development has historically been to prepare teachers for curriculum reform or to respond to findings from international reports, rather than to facilitate the sustained development of pedagogical practice or the enhancement of student learning (Harford, 2008). If teachers experience only this type of professional development, they may develop a limited and distorted view of its purpose, rather than seeing it as an essential, ongoing part of their careers (The Teaching Council, 2016). The literature identifies various models of professional development, including Kennedy's (2014) spectrum of models, which categorises collaborative professional inquiry as the most transformative approach, while transmissive training models are considered the least effective. Muijs et al. (2014) propose a dynamic unified model, emphasising the role of context and teachers' prior knowledge in facilitating deeper pedagogical change and avoiding superficial engagement. This model resists standardised, one-size-fits-all approaches, which have been shown to be ineffective in meaningfully transforming teaching practice. However, professional development programmes in Ireland frequently adhere to uniform templates, limiting their impact.

Irish second-level mathematics education has undergone substantial reform over the past 15 years, shifting from an emphasis on procedural and abstract approaches toward a focus on problem-solving, making connections, and applying mathematics in real-world contexts. This transition necessitated a fundamental change in teachers' pedagogical approaches (NCCA, 2015). In response, between 2010 and 2014, teachers participated in ten full-day workshops designed to support the adoption of new pedagogical strategies for teaching contextual strands. However, Sims and Fletcher-Wood (2021) argue that such sustained programmes often fail to incorporate repeated practice of specific skills, making them less likely to result in long-term pedagogical change. Following the completion of the programme, the NCCA (2014) reported that teachers continued to require support in designing and implementing tasks that leverage connections between mathematical topics. To address these challenges, lesson study was introduced by the Project Maths Development Team, aligning with Kennedy's (2014) transformative domain of professional development. However, limited funding for this model has resulted in its implementation occurring outside of school hours, thereby restricting teacher participation.

Mathematical modelling serves as the foundation of the revised Leaving Certificate Applied Mathematics specification, integrating concepts across all strands to facilitate the representation, analysis, prediction, and interpretation of real-world phenomena (NCCA, 2019). This represents a significant shift in the approach to the subject, requiring students to develop competencies beyond computational skills, including the ability to transition fluidly between real-world contexts and mathematical representations. Consequently, teachers are expected to transform their pedagogical approaches, necessitating professional development that significantly enhances their Mathematical Knowledge for Teaching (MKT). However, there is a notable gap in research regarding the development of pedagogical skills specific to mathematical modelling within the Irish context. Kit Ee Dawn (2018) found that during professional development in Singapore, teachers experienced difficulties with the iterative nature of modelling due to fixed mindsets about problem-solving and challenges in assessing students' modelling solutions. The study recommends additional support in assessment literacy to address these difficulties, highlighting a key area for further investigation in the Irish educational landscape.

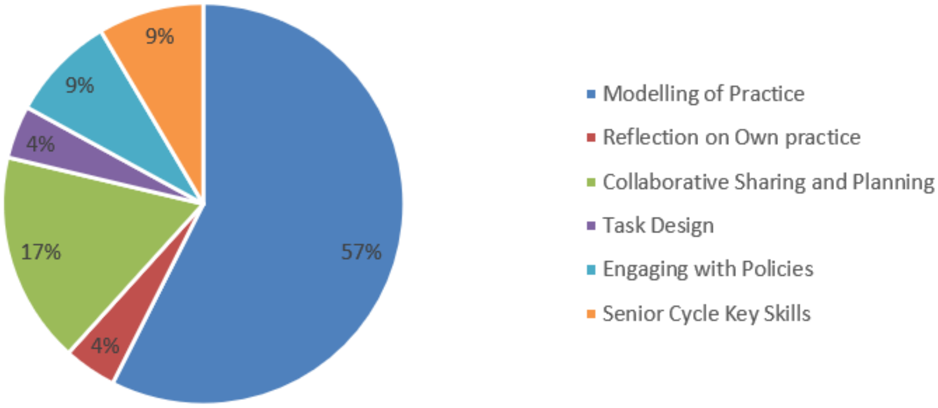
Methodology

A University College Cork (UCC) Educational Research Study Ethics Application was submitted with ethical approval granted by the School of Education Research Committee. A multi-phased exploratory sequential mixed methods approach was taken with two distinct phases consisting of both qualitative and quantitative data collection. This design was adopted to gain a more in-depth understanding of professional development in mathematics education and teachers' experience. The population for sampling was applied mathematics teachers who attended professional development programme.

The national professional development programme was designed and delivered by the Professional Development Service for Teachers (now Oide) with data collected upon the completion of eight national seminars which took place at different centres across Ireland over a three-year period. Regarding population size, a query was made to the State Examinations Commission and the Department of Education and there is no definitive list of active applied mathematics teachers. The first four seminars were online with a mean attendance of 260 teachers and the next four seminars were in-person events with a mean attendance of 186. The methodologies employed by the facilitators during the programme consisted of a range of approaches which are outlined in Figure 1.

Figure 1

Professional development methodologies employed by facilitators during the programme.



These methodologies consisted of a variety of intended purposes with the largest proportion consisting of the modelling of practice to meet the aims of the specification. This consisted of facilitators assuming the role of the classroom teacher and modelling a sample teaching approach of a particular concept. Here, attendees assumed the role of the student and engaged with the intended activities while also having dedicated time during seminar sessions to collaboratively reflect and discuss their application in the classroom with other teachers. Other key features of the programme involved teachers engaging with Senior Cycle key skills such as formative assessment, inclusive education and reflecting on their own practice.

The data collection consisted of two phases. The first phase involved semi-structured interviews and focus groups with 17 teachers. Purposive sampling was used to ensure a diverse representation based on characteristics such as experience and event attendance (Cohen et al., 2018). The second phase employed a cross-sectional national survey, distributed via email to 277 members of the national applied mathematics teacher forum, appliedmaths@googlegroups.com. Only those who attended the professional development programme were invited to participate, with 178 teachers completing the survey, yielding a 64% response rate.

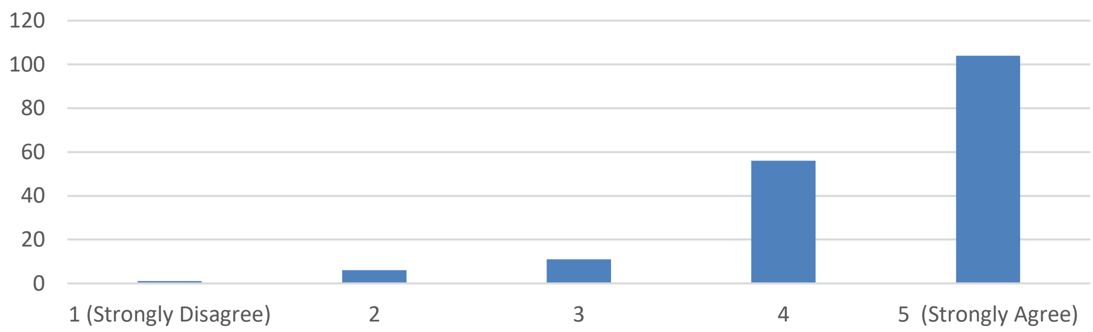
Qualitative data were analysed using Braun and Clarke's (2022) thematic analysis. Initial coding followed an inductive approach to identify common patterns, which were then grouped into themes. Quantitative survey data, collected through five-point Likert scales, underwent descriptive statistical analysis. This approach facilitated both micro- and macro-level insights, enabling structured interpretation using appropriate statistical methods.

Findings

A key element that emerged from the coding and defining of themes was teachers' preference for expert-led sample approaches for the learning and teaching of a specific concept, with the sample approach available to be used, or adapted, by teachers themselves afterwards, as seen in Figure 2.

Figure 2

Responses to the Statement: "I am more likely to implement new teaching approaches if suitable plans and resources are already available to me." (n = 178).



Many teachers expressed that they enjoyed assuming the role of the student and engaging with the activities. Participants emphasised the benefit of collaboratively critiquing the approach from a teacher's perspective with only 5.1% of respondents stating that they did not benefit from collaboration. Teachers stated a particular willingness to learn alternative pedagogical approaches and found it more effective when they had first-hand experience of the approach being applied.

Teachers' responses varied when asked how prepared they felt to develop students' mathematical modelling skills with one teacher stating that "it's very new and I'm lacking confidence in it, though it has built up from 0". From the coding of qualitative survey data related to this, 52% of respondents stated that inexperience with mathematical modelling was the main factor. In both interviews and survey responses, many teachers reported challenges in adapting to a modelling-centred pedagogy. One teacher said that he was quite anxious at the beginning and other teachers expressed that having no personal experience of modelling lowered their confidence. Others admitted to not changing their pedagogy and continuing to teach with little emphasis on modelling. As a result, one teacher reported that they found the modelling project challenging and felt her students were not prepared for it. 42% of respondents reported modifying their methodologies to some degree. One teacher noted "I still find I am teaching many of the topics in the "old" way. I struggle to incorporate the 'modelling process' into my lessons."

A recurring theme among teachers was the belief that they were not doing enough with regard to mathematical modelling. Many approached modelling and mathematical content as distinct components rather than combining them, missing the core specification principle of teaching mathematical content through the lens of modelling. One teacher stated: "I teach the old material as I always did. I teach Mathematical Modelling by means of group projects." Many felt unprepared due to the limited support materials and guidance from policymakers on modelling and the coursework. As a result, they felt unable to provide students with effective formative feedback with one participant requesting: "More help from the examination body and NCCA, as they expect us to have all the answers".

Many felt that the professional development that they received significantly improved their practice with one surveyed teacher stating that the material from the professional development was particularly good because it was "aimed at the student". Experience gained from teaching the specification clearly aided teachers' confidence and preparedness with one surveyed teacher stating, "having gone through the process once and with the training over the roll out of the new course, I feel confident in moving forward with the project", while other teachers felt that having gone through the process of the modelling project helped them to develop their own modelling skills and therefore pass them on to students.

Discussion

A clear outcome of the findings was that teachers' confidence is low regarding developing their own modelling methodologies. They stated a preference for expert-led professional development, connecting with RQ1. This is significant because it contrasts with literature advocating for teacher-led inquiry models, such as Finnish research-based projects and lesson study (Lewis et al., 2019; Niemi, 2015). However, it does align with Takahashi's (2015) view of stages of professional development whereby teachers firstly develop their knowledge for teaching and then gain support in acquiring proficiency in applying new knowledge in the classroom. This study's findings suggest that teachers may not currently have the skills to lead their own development for unfamiliar concepts and find comfort and reassurance in expert guidance similar to Takahashi's (2015) model.

The findings demonstrate the mixed levels of teachers' preparedness to develop students' modelling skills as well as their level of engagement with a modelling-focussed pedagogy. For many, modelling only occurs during the coursework with traditional methods elsewhere while others are aware of its importance but cite time as a barrier. This is in line with the findings of Johnson et al. (2019) who analysed the impact of similar professional development in mathematics, where 91% of surveyed mathematics teachers believed that pre-reform methodologies were adequate to prepare students. However, a key message of the specification is that modelling is the unifying strand through which all learning, teaching and assessment is conducted, but many teachers are not engaging with this approach reinforcing Kit Ee Dawn's (2018) findings regarding teachers' difficulties with the iterative nature of mathematical modelling and beliefs about problem solving.

The results indicate that both experience of teaching the specification and professional development were the main sources of advancing teachers' pedagogy. This demonstrates that when teachers can implement newly acquired methodologies then there is a higher probability of them being embedded, agreeing with Sims and Fletcher-Woods (2021). However, the results also demonstrate that teachers changing to a modelling-focussed pedagogy is challenging. This indicates that teacher-led development may be easier for specifications that are in existence for several years, like mathematics' lesson study, but for new specifications, strong support is needed.

Conclusions and Recommendations

Regarding the design and delivery of professional development to support pedagogical transformation (RQ1), teachers expressed openness to innovative teaching methods but showed a strong preference for expert-led models. These models should demonstrate pedagogical approaches with readily available methodologies and resources for immediate implementation. In terms of effective methodologies for transforming pedagogy (RQ2), the study highlighted the power of collaboration. Teachers benefit not only from working together on activities but also from sharing experiences, offering mutual support and participating in reflective practice.

Based on these findings, it is recommended that policymakers avoid a one-size-fits-all approach when designing professional development programmes. Tailoring these programmes to account for teachers' prior knowledge and the scope of necessary development is essential. Additionally, a crucial component should be the continuous development of teachers' research skills, enabling them to confidently engage in in-school research without relying on expert support.

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Using digital video to support and promote STEM education in the primary school

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Finding opportunities for professional development is particularly challenging given the current financial pressures being experienced by schools and educational authorities. Where in-service training is available it may not always address the needs of a particular school and will require situating within the context of a particular school as well as dissemination across all teachers. This research relates to a project where teachers used video to develop their classroom practice in STEM education. It explores if and how digital video can support teachers' professional development. Using an interpretivist approach, the teachers' experiences and views on their use of video were analysed using a questionnaire and explored to identify what affordances were provided by video with regard to the concepts of teacher reflection and professional development. Video was found to be useful by all the teachers, with the facility to re-watch their lessons and interact and share their recordings particularly helpful. The findings suggest that digital video can add much to teacher education and fulfils many of the requirements for effective professional development. We also propose that the facility to watch and interact with video recordings can greatly develop teachers' reflective thinking and practice.

Introduction

There has never been a time when high quality STEM education has been so important. The Department for Education (2023) has predicted that by 2035, over 1.9 million STEM professionals will be required in the UK. In Northern Ireland, a region with a history of technological innovation and a fast-growing technology sector, it is essential to equip students with the skills and knowledge to excel in these STEM fields. Despite this, over a decade has passed since Johnston (2013) first reported on the decline of primary science and technology in primary schools in Northern Ireland as a result of the revision of the curriculum in 2007 which demoted science and technology from being a core subject to part of one of seven 'Areas of Learning'. Since then, subsequent reports have highlighted the low profile of science and technology within a significant proportion of primary schools and the limited amount of teaching time (ETI, 2015; Welcome Trust 2017; McCullagh and Doherty, 2022). With little prospect of additional public funding to support primary science, schools are more likely to have to rely on 'in-house' professional development This article explores how digital video may help.

Background

The merging of Science and Technology with History and Geography under the Area of Learning called 'The World Around Us' was first reported by Johnson (2013) to have reduced its profile in primary school. The Education and Training Inspectorate's survey of science and technology provision within the 'World Around Us' (ETI, 2015) considered that Science and Technology was underdeveloped in 54% of schools sampled and that "provision focussed on low-level factual learning within isolated topics and lacked purposeful investigative experiences for children" (p.37). The Welcome Trust (2017) reported that in Northern Ireland 27% of primary school teachers do not teach science and technology on a weekly basis. More recently McCullagh and Doherty (2022) found that over three quarters of the teachers in their study only taught a maximum of 30 minutes of science per week. However, the same study found that 91% of the teachers felt that there should be more science in the primary curriculum. Reports over this period also point to a lack of professional development in STEM. Perry and Irwin (2015) found that just over a third of primary teachers had taken part in STEM training and 24% called for further CPD in this area. The TIMSS study of 2019 reports that only between 5% and 30% of NI pupils were being taught by a teacher who had taken part in Science CPD within the last two years.

Video has been used within teacher education since the 1960's and its use has grown with the development of technology and the wider range of recording devices (Sherin, 2004). Professional development programmes which involve video have been shown to improve teachers' ability to implement problem-based learning and hands-on activities, essential components of quality STEM education (Borko et al., 2008). Roth et al (2017) have identified the key design principles for video supported professional development in STEM. Despite the number of studies reporting the benefits of using video (Tripp & Rich, 2012; Marsh & Mitchell, 2014; Van Es & Sherin, 2008) there still remains the need for further research on how video is used and how learning from video is best mediated (Orland-Barak & Maskit, 2017).

Methodology

The aim of the research was to access and explore teachers' views and experiences of using video to develop their STEM practice. The participants were all enrolled on a Post-graduate Certificate in STEM Education course taught at Stranmillis University College Belfast between September 2023 and May 2024. Funding for the course was provided by the Department of the Economy as part of the wider national 'Skills Up' agenda and therefore funding was provided for all teachers.

This professional development programme took the form of a series of seminars and work- shops which focussed on a range of STEM areas, including enquiry-based science, teaching sustainability in the primary school, computational thinking and coding, and engineering. Following this, teachers were required to plan and teach a series of lessons in which they incorporate some aspects of STEM pedagogy covered during the course and to video record a 15-minute part of one of these lessons. The video was then uploaded on to the course's VLE (Canvas) and the teachers were invited to view the video as often as they wanted and to add annotations critiquing and discussing their practice, in light of their understanding of best practice as addressed during their course. The video interface allowed teachers to add time-markers and comments at any part of the video. The annotated videos were then shared with the course tutors who also had the facility to add time-marked responses to the teachers' comments and add further comments of their own.

The research adopted an interpretivist paradigm in order to "best understand the subjective world of human experience" (Cohen, Manion and Morrison, 2011, p.17). Data was obtained from an online questionnaire which comprised fixed response and open-ended questions. A total of 23 (77%) teachers participated in the project. The research was carried out in line with the ethics policy and research protocols of Stranmillis University College Belfast. The study was guided by the following questions:

- Did teachers find digital video useful for developing their teaching of STEM?
- What features of their use of digital video during the project did teachers find particularly useful?

The quantitative data was analysed and yielded descriptive statistics. The qualitative data were independently analysed by each researcher and emergent themes identified. Any divergence in analysis was discussed and resolved.

Findings

Teacher demographic

The sample (N=23) comprised an almost equal number of teachers from Foundation Stage (5-6 Yrs), Key Stage 1 (7-8Yrs) and Key Stage 2(9-11Yrs). Less than one third of the teachers had experienced CPD in STEM within the previous 5 years, and the sample rated their confidence as 'low' for teaching science (75% of teachers) and computational thinking (85% of teachers).

Teachers' engagement with their video recordings

Three quarters of the cohort reported viewing their video three or more times with half the cohort viewing it at least five times. The maximum number of viewings reported was eleven. The number of comments posted by each teacher ranged from 6 to 14.

The nature of teachers' comments fell into three categories; critique of their practice, an affirmation of the value of a particular form of pedagogy or teaching activity, or a suggestion or an idea for modifying practice.

> <u>Critique-</u> "I could have been more explicit in the language that I used and provided more opportunities for creative thought." (T11)
>
> <u>Affirmation-</u> "Using the hula-hoop activity helped support pupils' understanding of this abstract concept, which would be built upon throughout the lesson." (T18)
>
> <u>Suggestion-</u> "This would have been a good opportunity for me to use questioning to scaffold the learning experience." (T5).

Did video help develop classroom practice?

All 23 respondents reported that video was useful in helping them to develop their teaching of STEM. The most frequently reported reason, cited by three quarters of the teachers, was that video allowed teachers to directly observe themselves and see and hear how they were coming across in a teaching scenario. It was clear that video allowed for a stronger focus on the content of their talk and dialogue- the language and explanations, their use of questions and how they responded to their pupils.

> "I could see that I needed to slow down the pace and allow children to answer and then draw on their answers to move things on." (T14)

One quarter commented on the benefits of having the time and opportunity to more closely observe the pupils and their behaviours.

> I could focus on what each child was saying, how they reacted and if they could actually do the task. I realise you can miss so much." (T5).

Almost two thirds of the teachers explicitly stated that video had helped them to evaluate their teaching and engage with the process of reflection.

> "It allowed me to directly see what was working and what needed changing." (T2)
>
> "It is always easy to say I could have been better at some part of the lesson, but the video is more informed and allows me to explore exact points." (T8)

The majority of teachers (83%) felt that watching the video changed their thinking about the lesson.

> "I was surprised by what I was saying compared to what I thought I had said." (T14).
>
> "Pupils' responses were not always as I had remembered them." (T4)
>
> "I saw that I didn't praise the children as much as I perceived I did so I try to praise and encourage them even more." (T9)

Digital affordances

All but one teacher felt the video interaction facility made analysing the recording more useful than just simply watching. The video interface enabled teachers to:

Deconstruct their practice:

> "The time marker forced me to re-visit key moments in the lesson." (T4)
>
> "It helped to pinpoint my observation." (T6)

"Good to analyse my teaching in chunks." (T16)

Actively learn:

> "Rather than passively watching I was much more engaged and objective about my viewing to pull out ideas for reflection." (T12)

Explore and explain their practice:

> "Having to write comments made me think more - be sure and think of a better way." (T5)

One response pointed to the potential for guidance and support from a mentor.

> "It would be better to use it alongside someone who can guide you on what you should be looking for or doing. "(T21)

The value of tutor feedback

The video platform allowed teachers to share their annotated videos with the course tutors, who were able to reply to the teachers' annotations and add new comments of their own. This was considered to be very useful by all teachers, with the following reasons most frequently cited:

Tutors' feedback comments….

- validated the teacher's own analysis.
- reinforced and consolidated current thinking.
- provided a new perspective on the incident.
- provided affirmation, reassurance and enhanced confidence.
- were precise and focussed and therefore more easy to adopt in future.

Video use across the whole school and the primary curriculum?

The majority (78%) of teachers stated that video would be of use to their colleagues with the remaining 22% stating they were unsure. The most popular reasons supporting the use of video were that it allowed for a specific focus on a particular aspect of STEM teaching and facilitated meaningful interaction with the process of learning. A number of teachers pointed out its potential for use in other subject areas. The smaller group of teachers who were still undecided about using it with their colleagues felt it was time consuming, needed input from an expert, and acknowledged that not all teachers are highly reflective. Of the 23 responses only four reported that they had found the process of recording and watching back their teaching awkward and uncomfortable. Half of these teachers went on to say that they still valued the process and that the benefits outweighed the challenges, but acknowledged that some of their colleagues may not take this view. Encouragingly 87% stated they would be happy to use video again in the future, 9% were unsure and only 4% stated that they would not.

Discussion

This study indicates that teachers did find video to be useful in developing their classroom teaching and also identified the features of its use where they felt supported teacher professional development. Our findings are in line with Brouwer's (2022, p.3) view that video facilitates what he calls "visual teaching learning", that is "all forms of competence development in which teachers use video representations of their interaction with learners and content in order to improve their instructional behaviour". Video analysis allows teachers to see and understand how they influence learning and goes beyond changing teachers' thinking to changing their thinking and then their practice. Teachers' knowledge, beliefs and attitudes are formed interactively with classroom enactment and each can influence each other

(Richardson, 1996). Fishman et al (2003) suggest that changes in teachers' beliefs generally follow rather than precede changes in their actions. They therefore must be motivated to change and have the opportunity and a means to directly observe the benefits of new approaches to teaching. The interactivity provided by digital video alongside its 'realness' empowers teachers to slow down and deconstruct teaching scenarios. The facility to pause, replay and re-watch enables the viewer to break down parts of the lesson into more learnable 'chunks' (Le Fevre, 2004). The use of shorter clips ensures that "the often antagonistic goals of presenting complexity and making learning cognitively manageable are simultaneously achieved" (Spiro et al, 2007, p.97). Controlling the detail and the pace with which the lesson is presented to the teacher, ensures that a fine grain analysis of practice is possible without losing any sense of the overall meaning of the lesson.

Video can also bring about an 'as if' experience which approaches the reality of practice but is not identical to immediate live experience. This vicarious experience is referred to as 'resonance' by Goldman (2007) and it can engage the viewer emotionally as well as cognitively in either acceptance or rejection. The teachers often commented how what they actually saw in the recording was not quite as they had remembered it. Perlberg (1988) claims that the video feedback activates a 'dissonance phenomenon' wherein the learner becomes aware of the gap between what they intended to do and what occurred. Once they confront this dissonance, an 'arousal process' begins as they become motivated to narrow the gap. Perlberg (1988, p.8) considers this sequence to be the "main facilitator and accelerator of change and growth". A greater sense of agency and self-directedness is nurtured by teachers' ability to select the particular incidents to which they choose to add explanatory annotations and the facility to respond to the annotations of tutor or peers.

Digital video serves as a resource and a means to situate professional development within a particular classroom, and within the specific needs and constraints of the setting and the teacher. In doing so it can help develop teachers' professional judgement. Heilbronn (2008, p.103) suggests that teachers' professional judgements are subjective and highlights the problems of transferring generic exemplars of best practice (an approach common in in-service training) across a diverse range of situations. As each teacher and classroom are unique, "each teacher experiences their work through their own meaning-making. These personal experiences are the ground on which practical judgement builds and is connected to action". It is our view that digital video meets many of the criteria for effective professional development as identified by Brouwer (2022): coherence with classroom practice; focus on subject-matter pedagogy; involvement of active learning; facilitation of collegial collaboration; and extension over a period of time. In relation to science professional development, Marwick and Reiss (2023) consider meeting the perceived needs of teachers and the provision of time and support for teachers to embed new approaches to be crucial elements.

Our findings indicate that video can support the process of reflection. Engaging in reflective practice is generally considered to be a core standard and benchmark within the teaching profession and a cornerstone of professional development programmes. The concept and practice of reflection provides teachers with the means and a structure to build understanding and construct meaning from within a teaching scenario. Despite its "allure…as something useful and informing" (Loughran, 2002, p.33) encouraging teachers to adopt a reflective approach to their practice can prove challenging. Reflection can seem vague and abstract and teachers may have little evidence of its value. Within the busy school life there is limited time for reflection amidst the many competing priorities. Video provides the time and space for reflection and allows for a detailed thorough analysis of practice. It serves as a resource and a means to support teachers through each of the stages of Plan, Act, Collect Evidence, Analyse Evidence and Reflect, which comprise Pollard's (2019) cycle of reflection.

Rogers (2002, p.234) views reflection as a form of extended enquiry which "keeps at bay this tendency to interpret and react to events by first slowing down to see, then describing and analysing what happened". She acknowledges the importance of the 'description of experience' as a preface to analysis. It is the description of experience which Rogers considers to be the most challenging phase as teachers are keen to move on. However, it is 'the discipline of description' (p 238) which forces teachers to "slow down, to look, and to see the variety and nuance present in such moments before leaping into action." Video makes the time and provides the opportunity for this.

Conclusion

The teachers on this professional development course found that video helped them to develop their future practice and that they would be willing to use it in future. Our findings show how video technology can support professional development both through the technological affordances it brings to the study of teaching and through its potential to mediate the collective construction of knowledge. Given the worsening budget restrictions and limited capacity for externally driven professional development it is more important than ever that schools have the capacity and agency to develop their own STEM provision. Digital video offers a convenient and efficient means to this end.

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Embedding STEAM Education in Youthreach: Supporting educators professional learning

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A key feature of STEAM (science, technology, engineering, arts and mathematics) education is using real-world contexts that encourage learners to increase their understanding and awareness of the everyday applications of STEAM knowledge, skills, attitudes and values. To date, learners completing Youthreach programmes in Ireland have had little opportunity to experience science or STEAM education. Youthreach is a nationwide programme that provides early school leavers (aged 16-20 years) opportunities to progress their education in supportive, alternative settings. It is a crucial part of the education system, including over 6,000 of Ireland's most disadvantaged youth attending 112 centres annually. This paper discusses the design and implementation of a professional learning programme for Youthreach educators to support the national rollout of STEAM education in Youthreach centres. Fourteen educators participated in a six-month professional learning programme that was facilitated through face-to face and online meetings, leading to a micro-credential award. A mixed methods research methodology was adopted in this study. Data was collected via an online survey, and in-person interviews. This paper will discuss how educators developed their understanding of STEAM Education and the influence of the programme on educators' confidence to develop STEAM activities in their own contexts.

Introduction

Youthreach: Alternative educational provision in Ireland

Alternative educational provision (also known as alternative provision/alternative education provision, AEP) is described internationally as programmes set up by local authorities, schools, communities and voluntary organisations to serve young people whose needs are not being met by the traditional or mainstream learning environment (Gutherson et al., 2011). In Ireland, education is compulsory for students aged 6-16 or until completion of 3 years of secondary education (Citizens Information Board, undated) and Youthreach is the government's main alternative educational provision for early school leavers. Youthreach is a crucial part of the Irish education system, providing programmes for over 6,000 of Ireland's most disadvantaged youth attending 112 centres annually (Smyth *et al.*, 2019; Cahill *et al.*, 2020; Kovačič and Forkan, 2023; Citizens Information Board, n.d.). Youthreach centres provide a variety of certified courses including Quality and Qualifications Ireland (QQI) Levels 3 and 4, and the Leaving Certificate Applied (LCA) programme, Junior Cycle and Leaving Certificate programmes (Quality and Qualifications Ireland, 2021). To best serve their local communities, each centre's offerings vary according to local context and the learners' needs (Smyth et al., 2019).

Framework for STEAM Education in Youthreach

STEAM education is a pedagogical approach that merges science, technology, engineering, arts and mathematics, and has a wide range of definitions within literature. A key feature of STEAM education is the use of real-world contexts which encourages learners to increase their understanding and awareness of the everyday applications of STEAM knowledge, skills, attitudes and values (Herranen, Fooladi and Milner-Bolotin, 2021; Perales and Aróstegui, 2024). The *Framework for STEAM Education in Youthreach* was developed to address a gap in the provision of STEAM education in the alternative educational settings of Youthreach (McLoughlin, and Chadwick, 2022). This Framework for STEAM Education was developed through co-creation between researchers and national stakeholders (including staff from National Youth Council in Ireland and three Youthreach Centres) (McLoughlin, and Chadwick, 2022). The Framework (Table 1) identifies characteristics of STEAM; STEAM learning outcomes relating to knowledge, skills/life skills, attitudes and values; STEAM session planning; and STEAM assessment and feedback. The Framework aims to support the engagement of Youthreach learners who are often excluded from STEAM learning and careers, by developing their knowledge, skills/life skills, and attitudes and values of STEAM.

Table 1

Four elements of the Framework for STEAM Education in Youthreach.

A. STEAM Characteristics ● Real-world contexts ● Disciplinary and interdisciplinary learning ● Problem Solving ● Creativity ● Design thinking ● Digital Literacy ● Appropriate Teaching Approaches	**B. STEAM Learning Outcomes** ● Promotes the development of knowledge, skills, attitudes and values of STEAM. ● Learning outcomes are developed interdependently, through the mobilisation of knowledge, skills, attitudes and values within specific real-world contexts as competences/competencies (OECD, 2019).
B. STEAM Sessions ● STEAM scheme planning outlining activity, module focus, a brief overview of STEAM topic, characteristics, learning outcomes. ● STEAM session planning - content, learner activity, educator's role; expected learning outcomes; resources, equipment, materials.	**C. STEAM Assessment** ● Formative Assessment (Assessment for Learning, AfL)); background of STEAM learning outcomes; Learning made visible to both educator and learner; peer- and self-assessment providing feedback for improvement. ● Summative Assessment (Assessment of Learning, AoL)); Judgment of achievement, final examination/s, portfolio.

The Framework for STEAM Education in Youthreach is presented over four interconnected elements that support the design and implementation of STEAM activities in a Youthreach setting (Table 1). The first element, STEAM Characteristics identifies seven core features of STEAM education, e.g. to develop students' creativity and problem-solving skills in real-world settings (Herro & Quigley, 2017; OECD, 2019; Perignat & Katz-Buonincontro, 2019). The second element, STEAM Learning Outcomes recognises the knowledge, skills, attitudes and values, as the competencies learners need to succeed in life, learning and careers, highlighted by OECD (OECD, 2019). The third element, STEAM Sessions, provides the scaffolding for planning STEAM activities, sessions and schemes. The fourth element, STEAM Assessment, supports educators in collecting evidence of learning using both formative and summative assessment practices with a focus on providing regular and effective feedback to learners. The Framework for STEAM Education in Youthreach was used to design a professional learning (PL) programme for educators in Youthreach Centres in Ireland. The design of the PL programme was informed by the literature on effective science teacher professional learning. Several studies report that student outcomes and achievements are directly related to an effective professional development process. Guskey proposes that changes in teachers' attitudes and beliefs depend on teachers' observations of a positive influence on student learning outcomes from changes in their classroom practices (Guskey, 1986). Darling-Hammond (2017) examined teacher education from around the world and concluded that supporting thoughtful professional development to enable teachers to learn from one another and profession-wide capacity building that encourages sharing of research and good practices are two important considerations for successful professional learning (Darling-Hammond, 2017).

This study will address the research question: What is the influence of a professional learning programme on educator's understanding and confidence in STEAM Education?

Methodology

An invitation was issued to all Youthreach centres across Ireland to recruit educators to participate in a six-month professional learning (PL) programme for STEAM Education in Youthreach. 14 participants applied and engaged in a blended learning programme from January to June 2024. The 14 educators' roles and subjects taught in their Youthreach Centres, presented in Table 2, were generally from subjects such as Information and Communication Technology, Mathematics and Arts with many of the participants serving as resource teachers.

Table 2

Educators' roles and subjects taught in their Youthreach Centre.

● Information and Communication Technology, Coding, STEAM ● Communications and Work Experience ● Mathematics and Communications ● Mathematics, Information and Communication Technology, STEAM Resources support ● Mathematics, Graphics and Construction studies ● Information Technology, Personal effectiveness	● Construction and Graphics, Resource teacher ● Art and Resource teacher ● Information Technology, Horticulture, Leisure and Recreation ● Mathematics, Information Technology and Communications ● Art Teacher ● Art and Resource teacher and Information Technology ● Art and Resource Teacher ● Catering and Resource teacher

The aim of this PL programme was to develop educators' STEAM knowledge and skills and support them in designing STEAM activities for learners in their own Youthreach centres. A broader aim of this project was the development of a QQI (Quality and Qualifications Ireland) award for STEAM Education in Youthreach and the education of Youthreach educators was a key step in preparing for the delivery of a new QQI award in Youthreach centres.

The authors (STEM Education educators and researchers) designed and delivered this PL programme as a 5 ECTS (European Credit Transfer System) module "STEAM Education in Youthreach" leading to a micro-credential award accredited by their university. An overview of the activities and focus of the PL programme delivered during January to May 2024 is presented in Table 3. The first meeting of the PL programme was held as a two-day in person meeting in the author's University and focussed on providing opportunities for educators to get to know each other and foster a professional learning community between educators and authors. The educators were facilitated to carry out and share their experiences of completing STEAM activities. Online monthly meetings were facilitated six times over the following four months. This supported the educators to share and reflect on their own experiences of trialling activities in their centres. The final meeting with educators was held in person in the author's university and all educators presented samples of STEAM activities they had carried out with their learners. Interviews were conducted with educators to probe the influence of the programme on their confidence in designing and implementing STEAM activities with their learners.

Table 3

Overview of Professional Learning (PL) Programme for STEAM Education in Youthreach.

Activity	Description

Two-day in-person meeting *(January 2024)*	Introduction to STEAM Education and Framework ● Experience, share and discuss STEAM activities from units: - Building Things - Design thinking in real world contexts - Exploring Light - Hands-on investigations on STEAM concepts - Amazing Water - Sustainability and water - Health & Nutrition - Healthy lifestyle and nutrition ● Plan for implementing STEAM activities in own Youthreach centres. ● Foster a Professional Learning Community.
Six online meetings *(February- May 2024)*	At each meeting, educators were facilitated to: ● share and discuss experiences of trailing STEAM activities. ● share new STEAM activities and resources. ● develop ideas for own unit/lesson activities.
One-day in-person meeting *(May 2024)*	● Educators present design and implementation of their own STEAM units/lessons/activities. ● Educators reflect on the impact of STEAM education on learners and educators.
Module Assessment	● Educator's Portfolio of STEAM Activities/Lessons/Units. ● Educator's Reflections on - how their learners' prior knowledge influenced the design and implementation of STEAM Activities in their centres. - how formative and summative assessment practices supported STEAM learning and feedback in their centres.

Data Collection

A mixed methods research methodology was adopted in this study. Educators completed two online surveys – prior to taking part in the PL programme (Survey One, January 2024) and on completion of the PL programme (Survey Two, June 2024). Interviews were conducted in-person with the participants during the final one-day meeting (May 2024).

Survey One asked educators to respond to questions examining: What were their understanding of STEAM? What were their plans for implementing STEAM in their Centres? What aspects of STEAM Education were they most confident in? What were their main concerns for implementing STEAM Education in Youthreach?

Survey Two asked educators to respond to questions examining: What are their main considerations for delivering STEAM activities? How confident are they in delivering STEAM activities/sessions/units? What are the key challenges for educators and learners in STEAM Education? Had they participated in sharing ideas with other Youthreach staff/centres?

Interviews were conducted to probe educators on: Highlights of participating in STEAM Education in Youthreach programme. Influence of their learners' prior learning on the design and implementation of STEAM activities. Influence of STEAM Education on learners' knowledge, skills, attitudes and values. Assessment practices used to support STEAM learning and feedback. Interviews were conducted by the lead author and lasted 30 minutes.

Findings

The following section discusses the findings from survey one (13 respondents), survey two (10 respondents) and interviews with 14 educators.

Survey One with Educators

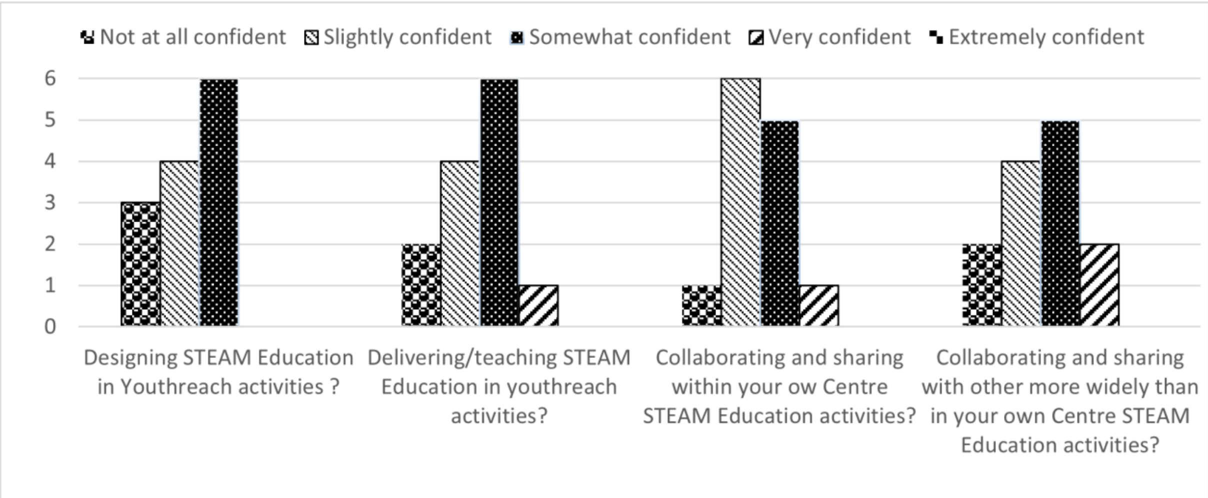
Educators were asked to identify three words they associate with STEAM Education and most responses identified the disciplines of the acronym STEAM - Science (9), Technology (10), Mathematics (12), Art (7), and Engineering (6). Educators also identified that STEAM education is Hands-on (4), involves creativity & visual innovation (3) and it is explorative and interactive (2).

Educators demonstrated an open-minded approach to learning about STEAM Education themselves first and then trying it out with their learners. They identified the need to adopt different teaching approaches and tailor lessons to engage diverse learners. The educators responded that they wanted to create fun classes for learners to experience science and developing STEAM skills, e.g. coding, building bridges.

Educators were asked to indicate their confidence on four aspects of STEAM Education, on a five-point scale ranging from not at all confident to extremely confident, and their responses are shown in Figure 1. The responses show a general lack of confidence in designing and delivering STEAM activities and more confidence towards sharing and collaborating with other educators. Educators identified several factors that influenced their confidence, including STEAM is new, fun and practical; opportunities and enjoyment for their learners; educator's relationship with their learners. One educator expressed: *"My drive is to find something that will engage students, help them develop confidence in experimenting and develop their STEAM skills"*. Educators highlighted several concerns they had that would be a challenge to implementing STEAM Education, including adequate planning time in an already packed programme, finding resources and supplies, not having clear guidelines for designing and implementing activities. One educator stated: *"It's the big unknown at the moment- I'm not too sure what I have to do"*.

Figure 1

Educators' confidence in STEAM Education, 13 responses from Survey One.



Survey Two with Educators

Educators presented increased motivation for implementing STEAM in Youthreach and identified the positive influence STEAM education can have on learners' knowledge, skills, life skills, attitudes, e.g., coding, problem-solving, real-life skills, and reinforced learning. They recognised the importance of keeping the activities fun and keeping learners engaged in the lessons. ***"****Student lead, the ability of the student and the equipment and activities which would engage the student and set them goals"*. They had increased awareness of STEAM characteristics and links to science and research and one educator suggested that it "*Gives them new insights to the real world and effects we have on the environment*. They identified a lack of opportunities for implementing STEAM within existing courses and a lack of science and art based QQI modules as a key challenge. They expressed concerns for having an appropriate budget and the cooperation of other educators in their centre.

Educators expressed increased confidence in designing and implementing STEAM activities with their learners and "*explaining that we do STEAM every day anyway"*. They highlighted the importance of keeping activities fun and engaging for their learners and that their learners enjoyed the fun element without the pressure to hand up work on a certain date.

They identified the need to deepen their own prior knowledge of a topic and ability to adopt cross-disciplinary approaches. As a result of completing the PL programme, they felt they have lots of ideas for future activities and confidence in teaching subjects that they have no experience of teaching.

Some of the key challenges to implementing STEAM education identified by educators included learner resistance (initially) and learner attendance; time constraints and timetable issues; getting support from colleagues; covering classes and setting up experimental activities. The key considerations for effective implementation identified by the educators included: keeping it fun and entertaining for the learners; improving educator knowledge; getting more people on board; allocating budget; timetabling hours for STEAM learning; and developing resources for learners. In general, educators were very open to sharing their experiences and resources with other educators in their own centres and in other Youthreach centres.

Interviews with Educators

The interviews with educators were transcribed and coded to identify key highlights from participating in STEAM Education in Youthreach identified by educators. Four themes emerged:

- Opportunities for new and engaging learning environments.
- Support for student learning and wellbeing.
- Extended understanding of STEAM and its role in addressing real world problems.
- Increased educator collaboration with peers and university researchers.

Three themes were identified from the responses of educators of the influence of their learners' prior learning on designing and implementing STEAM activities.

- Creating a more student led and engaging learning environment for diverse learners.
- Opportunities for interdisciplinary learning and development of life skills.
- Increased learner collaboration with peers and educators.

Three themes were identified from the responses of educators of the influence of STEAM Education on learners' knowledge, life skills and attitudes.

- Increased student engagement and attendance.
- Interdisciplinary learning linked to real applications,
- Improved learner life skills, including confidence, communication, collaboration, resilience, flexibility, expressing ideas, and dealing with feedback.

Educators reported an increase in classroom dialogue with increased questioning from learners and engagement in class discussions. They reported increased use of classroom dialogue to collect feedback from learners and use this data for formative assessment. Teachers recognised the opportunities for using a wide variety of assessment approaches, including questioning sheets, sketch books, creativity products, product feedback sheets, reflection sheets.

Conclusions

The educators identified several benefits for their learner's participation in STEAM activities. They observed that their learner's attendance improved during the implementation of the STEAM activities. By relating these activities to real world contexts and using hands-on and practical activities, learners became more engaged in learning and developed greater appreciation of the role of STEAM in everyday contexts. Learners exhibited increased autonomy and regularly took the lead during activities, through offering suggestions and ideas. Their interpersonal skills improved, with increased collaboration with peers, contributions to classroom dialogue and tolerance towards others.

The educators identified that their own STEAM knowledge and skills had been greatly extended through participation in the PL programme. They observed that using STEAM activities lead to increased dialogue and interaction between educators and learners. Educators reported the use of new pedagogical approaches that linked activities to real world contexts. As the nature of STEAM Education is interdisciplinary, this resulted in an increased collaboration with other educators. The educators reported an increase in their own confidence for designing STEAM activities that provide rich learning opportunities for both them and their learners.

Educators highlighted three key challenges for implementing STEAM Education in Youthreach. 1) Access to appropriate STEAM Education resources - very few, if any, of the Youthreach Centres have access to a science laboratory or a suitable learning space. 2) Curriculum inclusion - STEAM Education needs to be included as a timetabled activity and linked to a dedicated module or award. 3) Professional Learning - the interdisciplinary nature of STEAM Education requires cooperation between several educators and subject experts. This is particularly important to develop understanding and use of different assessment approaches.

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Influence of in-service teachers' self-efficacy for learning physics on their pedagogical practices

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There are several factors that affect teachers' confidence and competence for teaching physics, including their content knowledge, pedagogical knowledge, self-efficacy, and prior classroom experiences (Krakehl et al., 2020). This study examines in-service teachers' self-efficacy for teaching physics (Calkins et al., 2024). The participants were 54 in-service teachers completing a two-year, upskilling programme to gain qualification for teaching physics up to Leaving-Certificate level in Ireland. A quantitative research methodology was adopted in this study. Data was collected via an online questionnaire, which was administered to teachers after they had completed one semester of introductory physics modules and prior to commencing modules focussed on developing their pedagogical content knowledge. Self-efficacy for learning physics was measured using an existing instrument (Lindstrøm & Sharma, 2011). This study reports that teachers' have a high self-efficacy for learning physics and comments on correlations with teachers' understanding and use of inquiry based learning, the nature of their classroom practices and their engagement in reflective practice.

Keywords: Self-efficacy, Teacher Professional Learning, Inquiry Based Learning

Introduction

The lack of qualified science teachers is a major concern for science education across the globe. In many countries, second level science teachers may have to teach outside of their subject specialism and may lack pedagogical content knowledge in particular areas that were not studied at advanced or degree level (Kind, 2009). The phenomenon of teaching outside specialism is common in many countries and commonly referred to as out-of-field teaching (Mizzi, 2021). Out-of-field teaching has been shown to negatively influence instruction and constrain teachers' development – particularly in the case of newly qualified teachers (Nixon, Luft, and Ross, 2017). Second level education in Ireland has experienced a period of sustained growth with pupil enrolments increasing by more than 30,000 over a five-year period and projected to peak in 2024 (Department of Education, 2020). This significant increase in enrolments in second level schools has created challenges in both infrastructure and the availability of qualified second-level teachers. In 2018, the Department of Education and Skills (DES) in Ireland established a Steering Group on Teacher Supply to facilitate multi-agency engagement and lead on a coordinated programme of actions to address these emerging concerns. This Group identified an urgent need for a national upskilling programme in three targeted subject areas - Physics, Mathematics, and Spanish. In response to this finding, DES has funded a national programme - the Professional Diploma in Teaching Physics (PDITP) - to develop in-service teachers' content and pedagogical content knowledge for teaching physics (McLoughlin, 2025). This programme is available to all second-level teachers, with priority given to in-service teachers teaching physics out-of-field.

PDITP is a level 8, two-year, part-time 75 ECTS (European Credit Transfer and Accumulation System) programme designed to upskill in-service, second level teachers to meet the requirements stipulated by the Teaching Council of Ireland for teaching physics to Leaving Certificate. The programme is delivered through collaboration between three Irish universities: Dublin City University, University of Galway and University of Limerick. Four cohorts (154 teachers) have participated in the PDITP since it began in January 2021. The objectives of the PDITP programme are to ensure that teachers:

- Acquire the theoretical and experimental knowledge of physics as well as pedagogical content knowledge that is necessary for effective physics teaching at second level.
- Demonstrate an ability to connect physics content modules and the school physics curriculum.
- Develop a high standard of practical competence in physics teaching as reflective practitioners.

While completing the PDITP programme, teachers remain employed in their schools and undertake the programme via a blended learning approach consisting of online and face-to-face lectures, tutorials, laboratories and workshops. The structure of the PDITP is summarised in Figure 1.

Bandura (1997) defines self-efficacy as a person's belief in his or her ability to succeed in each situation. Self-efficacy affects a person's behaviour – those who believe they can complete a task are more likely to work harder, persist longer and persevere when they are faced with challenges and uncertainty. In their study of undergraduate first-year physics students, Lindstrøm's and Sharma (2011) reported that males consistently reported higher self-efficacy for learning physics while Jameson and Fucso (2014) reported that the self-efficacy of adult learners for learning mathematics was lower than that of undergraduates. In their study of 100+ science teachers, El-Emadi et al. (2019) reported that female teachers performed better during theory lessons while male teachers demonstrated better performance in laboratory-based lessons, suggesting that gender differences may exist when it comes to understanding and use of IBL.

The focus of this study is to investigate what practices PDITP teachers are engaged in and how these are influenced by their gender and their self-efficacy for learning physics. In doing so, the following research questions will be addressed: 1. What are PDTIP teachers' self-efficacy for learning physics? 2. What are the experiences and practices of PDITP teachers - what are their (a) use and understanding of Inquiry Based Learning? (b) classroom practices? (c) Reflective Practices? 3. Is there a correlation between teachers' self-efficacy for learning physics and their (a) use and understanding of Inquiry Based Learning? (b) classroom practices? (c) Reflective Practices?

Methodology

The participants in this study are 54 (30 female, 24 male) in-service teachers completing the PDITP programme 2022-2024. These teachers are already registered with the Teaching Council in Ireland as in-service teachers - mainly qualified to teach mathematics, chemistry and biology and range in teaching experience from 1 to 20+ years. An online questionnaire was shared with teachers at the end of semester one in June 2022. At the time of completing this questionnaire the teachers had completed assessments and received grades for their first three physics modules but had not yet commenced the summer-school pedagogy modules (see Figure 1). Researchers provided an overview of the questionnaire, including its purpose, content and use after which teachers were required to complete an informed consent form. Data was collected on the participants' demographics, self-efficacy, prior teaching experiences, use of inquiry based learning and reflective practice.

Figure 1

Overview of PDITP programme structure.

<table>
<tr><th>Year</th><th>Physics Module (ECTS credits)</th><th rowspan="2">Pre-Questionnaire administered</th><th>Pedagogy Module (ECTS credits)</th></tr>
<tr><td>1</td><td>Mechanics (5),
Waves/Light/Modern Physics (5),
Thermal Physics (5),
Physics Laboratory (2.5)</td><td>Summer School 1 - Pedagogy & Research in Physics Education (5)
Summer School 2 – Practitioner Inquiry in Physics Education (5)</td></tr>
<tr><td>2</td><td>Electricity (5), Modern Physics (5), Environmental Physics (5), Semiconductor Devices (5), Life, the Universe and Everything (5), Physics Laboratory (5)</td><td colspan="2">Practitioner Inquiry (5)</td></tr>
<tr><td>3</td><td>Electricity and Magnetism (5), Optics (5), Physics Laboratory (2.5)</td><td colspan="2">Post-Questionnaire administered</td></tr>
</table>

To measure participants' self-efficacy for learning physics, Gammell et al. (2024) used Lindstrøm's and Sharma's (2011) self-efficacy questionnaire. Teachers were asked to respond to five statements using a five-point Likert scale (strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5)). A self-efficacy score was calculated for each participant by applying unit weighting to each point on the Likert scale and calculating the mean, the results of which are presented in Figure 2.

A questionnaire developed (by the authors) in the 3DIPhE project (De Lange, 2020) was used to examine both teachers use and understanding of inquiry-based learning and their reflective practices. For each item on the questionnaire, participants were asked to choose their level of agreement from a five-point Likert scale (strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5)). To measure participants' perspectives on the extent to which students are engaged in scientific inquiry during their classroom practices, Campbell et al.'s (2010) validated questionnaire was used. For each item on the questionnaire, participants were presented with a five-point Likert scale (almost never (1), not often (2), sometimes (3), often (4), almost always (5)). The mean scores and standard deviation of teachers' responses to the statements from these three instruments was calculated (Figures 2-4). An independent-sample Mann Whitney U-Test was carried out to determine if there was evidence of gender-based differences in teachers' responses to all statements.

The data was further analysed, using Spearman's rank correlation, to determine if any evidence exists for a correlation between an individual's self-efficacy for learning physics and their (a) use and understanding of Inquiry Based Learning? (b) Classroom practices and (c) Reflective Practices.

Findings

What are PDTIP teachers' self-efficacy for learning physics?

Findings reported by Gammell et al. (2024) indicate that this group of PDITP teachers' self-efficacy for learning physics is high (M=3.99, SD=0.58) is higher than that of undergraduate students ($p = 0.01$) and that while the mean self-efficacy score for males (M=4.12, SD=0.55) is higher than that for females (M=3.90, SD=0.59), this difference is not statistically significant ($p = 0.05$).

What are PDITP teachers' use and understanding of Inquiry-Based learning?

Teachers' responses to statements that examined their use and understanding of IBL are presented in Figure 2. The teachers expressed that their understanding of IBL (statement 1) and motivation for using IBL (statement 4) were high. However, teachers responded that they do not regularly use IBL in their practices (statement 2) and expressed a lack of confidence (statement 3) in using IBL. The data was further analysed using an independent-samples Mann Whitney U-Test to determine if there was evidence of gender-based differences in teachers' feelings towards IBL. While males outscore females on five of the six statements (Figure 3), these differences are not significant ($p = 0.05$).

Figure 2

PDITP Teachers' use and understanding of Inquiry Based Learning (IBL).

Inquiry Based Learning (IBL) Statements	All (54)		Female (30)		Male (24)	
	M	SD	M	SD	M	SD
I understand what is meant by the phrase inquiry-based learning.	.11	.57	.07	.52	.17	.64
I regularly use inquiry-based learning when teaching.	.13	.03	.03	.00	.25	.07
I am confident in using inquiry-based learning when teaching.	.20	.02	.13	.86	.29	.20
I am motivated to try different approaches when teaching.	.19	.55	.20	.61	.17	.48
My students learn content knowledge when I use inquiry-based learning.	.48	.09	.33	.06	.67	.13
My students develop skills and competences when I use inquiry-based learning.	.63	.07	.47	.04	.83	.09

What are PDITP teachers' classroom practices?

Teachers' responses (N=52, due to two teachers not answering this part of the questionnaire) to statements that examined their classroom practices are presented in Figure 3. These 20 statements have been validated as a questionnaire by Campbell et al. (2010) for assessing the extent to which students are experiencing inquiry in science classrooms. The most frequent activity reported by all teachers relates to students' active participation in investigations (statement 11) and the most infrequent activity was in relation to investigations being conducted by the teacher in front of the class (statement 10). Teachers indicated that students adopt roles in conducting investigations (statement 12). Teachers are likely to instruct students on how to conduct an investigation (statement 9) and which data to collect (statement 13, 16). Students appeared to have more autonomy to draw and justify conclusions (statements 17,19,20).

The data presented in Figure 3 shows that, for most of the classroom practice statements there is little difference between genders. For further analysis, a mean classroom-practice score was calculated for each teacher (reverse coding was applied to statements 5 & 10 as these were framed in opposition to inquiry practices). The distribution of the mean classroom-practice scores and the scores for each statement for males and females were compared using a Mann-Whitney U-Test. This returned a null result ($p > 0.05$) when comparing the mean classroom practice score for 18 of the statements. However, differences ($p < 0.05$) were observed for two statements - female teachers are more likely to give students step-by-step instructions before they conduct an experiment (statement 5), while male teachers are more likely to conduct the experiment in front of the class (statement 10).

Figure 3

PDITP Teachers' engagement in scientific inquiry during their classroom practices.

Classroom Practice Statements	All (52)		Female (28)		Male (24)	
	M	SD	M	SD	M	SD
1. Students formulate questions which can be answered by investigations	.63	.82	.71	.90	.54	.72
2. Student research questions are used to determine the direction and focus of the lab	.17	.90	.18	.98	.17	.82
3. Students framing their own research questions are important	.69	.67	.61	.69	.79	.66
4. Time is devoted to refining student questions so that they can be answered by investigations	.54	.73	.43	.69	.67	.76
5. Students are given step-by-step instructions before they conduct investigations	.65	.08	.82	.22	.46	.88
6. Students design their own procedures for investigations	.23	.98	.14	.01	.33	.96
7. Students engage in the critical assessment of the procedures that are employed when they conduct investigations.	.44	.98	.46	.84	.42	.14
8. Students justify the appropriateness of the procedures that are employed when they conduct investigations.	.52	.94	.43	.92	.63	.97
9. Students conduct their own procedures of an investigation.	.10	.98	.04	.96	.17	.01
10. The investigation is conducted by the teacher in front of the class.	.75	.84	.54	.74	.00	.89
11. Students actively participate in investigations as they are conducted.	.06	.92	.07	.98	.04	.86
12. Each student has a role as investigations are conducted.	.00	.91	.89	.99	.13	.80
13. Students determine which data to collect.	.02	.96	.86	.89	.21	.02

14. Students take detailed notes during each investigation along with other data they collect.	.58	.04	.54	.11	.63	.97
15. Students understand why the data they are collecting is important.	.00	.77	.04	.79	.96	.75
16. Students decide when data should be collected in an investigation.	.21	.89	.96	.88	.50	.83
17. Students develop their own conclusions for investigations	.81	.82	.86	.76	.75	.90
18. Students consider a variety of ways of interpreting evidence when making conclusions.	.67	.81	.64	.73	.71	.91
19. Students connect conclusions to scientific knowledge.	.98	.85	.07	.81	.88	.90
20. Students justify their conclusions.	.92	.95	.89	.96	.96	.96

What are PDITP teachers' reflective practices?

Teachers' responses to statements that examined their engagement in reflective practices are shown in Figure 4. Teachers indicated very strong motivation for practices that focus on enhancing their teaching (statements 1), including reflecting on their practices (statements 6, 7) and engaging in self-reflection (statement 2). Teachers expressed confidence in their ability to effectively inquire into their own teaching practice (statement 3) and identify ineffective teaching approaches (statement 4). They identified a lack of opportunities for peer feedback (statements 10, 11) and access to knowledge that could improve their teaching (statement 14). They did not feel that inquiries into their practices could be used to inform policy direction at national level (statement 14). A Mann-Whitney U-Test was used to determine if there was evidence of gender differences in the responses to each of the reflective-practice statements, returning a null result (p=0.05) for each statement, and when comparing the mean reflective-practice score. There is no evidence of a gender difference in reflective practice.

Figure 4

PDITP Teachers' engagement in reflective practices.

Reflective Practice statements	**All (54)**		**Female (30)**		**Male (24)**	
	M	**SD**	**M**	**SD**	**M**	**D**
1. I am keen to understand how to enhance my teaching	4.67	0.51	4.70	0.47	4.62	0.58
2. I regularly self-reflect on my practice	4.06	0.81	4.07	0.83	4.04	0.81
3. I am confident I can effectively inquire into my own teaching practice	4.06	0.60	4.03	0.62	4.08	0.58

4. I am able to identify ineffective teaching approaches	4.06	0.53	4.07	0.58	4.04	0.46
5. I regularly challenge my assumptions about my own teaching	3.7	0.82	3.73	0.83	3.67	0.82
6. I am open to looking at classroom issues from different perspectives	4.22	0.54	4.27	0.58	4.17	0.48
7. Reflection helps me keep track of my effectiveness as a teacher	4.04	0.78	3.93	0.91	4.17	0.57
8. When reflecting on my teaching I consider all stakeholders	3.43	1.02	3.30	1.06	3.58	0.97
9. I encourage peers to give feedback on my teaching	3.33	1.03	3.17	1.05	3.54	0.98
10. There are opportunities for peers to give feedback on my teaching	2.83	1.06	2.70	0.99	3.00	1.14
11. I provide feedback to peers on their teaching	2.48	1.01	2.33	0.96	2.67	1.05
12. I engage in dialogue with peers about how to teach effectively	3.7	0.66	3.83	0.46	3.54	0.83
13. I regularly ask my students for feedback on my teaching	3.26	0.85	3.13	0.78	3.42	0.93
14. I often do not have access to knowledge that will improve my teaching	2.61	1.02	2.43	0.94	2.83	1.09
15. I believe that my inquiries into my own practice can inform and support other teachers in their practice	3.72	0.90	3.67	0.66	3.79	1.14
16. I believe that my inquiries into my own practice can be used to inform policy direction at school level	3.17	0.99	3.10	0.76	3.25	1.23
17. I believe that my inquiries into my own practice can be used to inform policy direction at national level	2.83	1.16	2.77	0.97	2.92	1.38

Is there a correlation between teachers' self-efficacy for learning physics and their (a) use and understanding of Inquiry Based Learning? (b) Classroom practices and (c) Reflective Practices?

The data was analysed to determine if there was evidence of correlation between self-efficacy for learning physics and the three other constructs. The findings (Figure 5) show that there is no evidence of a correlation between self-efficacy for learning physics and understanding of and use of IBL; or between self-efficacy for learning physics and classroom practices. In the case of self-efficacy for learning physics and reflective practices, there is a statistically significant, moderate, positive correlation for the male cohort only.

Figure 5

Spearman rank correlation coefficients and p-values for self-efficacy for learning physics and other variables.

Relationship between self-efficacy for learning physics and…	All (54)		Female (30)		Male (24)	
	ρ	***p***	***ρ***	***p***	***ρ***	***p***
Inquiry based learning (N=54)	0.168	0.226	-0.033	0.862	0.307	0.145
Classroom practice (N=52)	0.217	0.123	0.190	0.337	0.204	0.339
Reflective Practice (N=54)	0.157	0.258	-0.183	0.332	0.484	0.015

Conclusions

Self-efficacy for learning physics is high amongst this cohort of PDITP teachers in comparison to that of undergraduate students (Gammell et al., 2024). This can be attributed to the fact that the teachers are adult learners and have successfully completed undergraduate STEM programmes. According to Bandura (1997), mastery experiences have the most impact on the development of a person's self-efficacy. In the case of teachers, mastery experiences consist of teachers' successful experiences performing skills necessary to the running of a classroom (i.e., creating lesson plans, facilitating classroom activities, and managing student behaviour (Calkins et al, 2024). Scientific inquiry as an instructional strategy shows great promise, if it becomes common in science classrooms (Campbell et al. 2010). This study highlights that PDITP teachers do not regularly use IBL in their own practices despite having a high level of understanding of what IBL is and the benefits for their learners.

Becoming a teacher is a lifelong learning process that starts during initial teacher education and continues to develop throughout their teaching career (Mizzi, 2021). In addition, teachers face several challenges when teaching outside their subject specialism. It is crucial to remember that effective professional learning influences both teachers (teachers' individual characteristics and their teaching skills) and student learning outcomes (Sancar, 2021). This study highlights the importance of gathering insights into what specific practices in-service teachers are engaging in, to inform the design of effective professional learning programmes.

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Reimagining Science and STEAM Literacies in the Anthropocene: a post-colonial science classroom experience

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Today, there are calls from several directions for a new social contract for science education, to make the disciplines amenable to women, girls and minorities and to reframe the crucial link between Science Education & Politics for a new scientific literacy that is concerned with forging a democratic public culture for the betterment of the economy, society and the environment. Here, I draw from critical and feminist perspectives, including the theorisations of Nancy Fraser in order to conduct a critical scrutiny of reform efforts in science education concerned with Science-in-Society. My research strategy is guided by the theory and method of Michelle Lazar and Maggie Mac Lure whilst sharing my reflexive positioning within an argument that those working in science education, whether in teaching or research, are unable to claim they are coming from nowhere. My affirmative critique reveals that science education today is deeply contested in the literature. There is evidence of disruption to the post-positivistic stance from several directions. One global movement is concerned with Reimagining Science Education in the Anthropocene as it seeks to humanise the disciplines and to advocate for a values-led and problem-posing approach to scientific literacy for all within a new politics of equality.

Introduction

There is a pressing need today to Reimagine Science Education and to reframe a new scientific literacy for all in a fast globalising world, increasingly reliant on scientific and technological literacies (Tolbert et al., 2024). A globalising world that is contending with a serious diminution in the concept of democracy - government framed as a search for the common good and in the direction of equality and justice – in the midst of the rise of far right fascist ideologies and social and planetary injustices brought about in large part by man-made wars, new patterns of poverty and immigration and by the industrial exploitation of the earth's resources (e.g. climate change).

At the same time, the contemporary global education reform movement in Science Education, and its efforts in connecting science education to civic engagement for a new scientific literacy, in position since the start of this century, largely disappoints given that it is often under-theorised and assumed as a pre-scripted space of human change for a normative consensus of dispositions, skills and knowledge that can readily be categorised and atomised. In this way, science education and scientific literacy have remained firmly within the grasp of disciplinary knowledge and science teachers are tightly confined to its disciplinary borders. For example, a search of the social science database SCOPUS for the keywords 'science education' taken together fails and is quickly reduced to 'science' and 'education' before any search can begin. For example, in Ireland, the national curriculum as specified for Science Education in Junior Cycle (lower secondary education) requires students to research and present the contributions 'that scientists make in scientific discovery and invention' and to 'appreciate the role of science in society' rather than to critique Science-in-Society in affirmative ways that invite students to think anew about contemporary issues (DES, 2015).

Education itself as a discipline and a practice has itself undergone tremendous change in the last two decades rendering the foundational disciplines, and the deliberative traditions from which it is drawn, of less importance, with increasing erasure of the arts and humanities from the debate, especially, the philosophy and history of education and science education (Bazzul, 2022). An evidence-based policy world of science education appears to be increasingly reliant on a normative consensus for a data-driven system of performance management (Selwyn

& Gašević, 2020). This clinical view of science education, and the subsequent framing of scientific literacy, is in urgent need of an affirmative critique for future-proofing decision-making, for assuring that young people are prepared not only to be scientifically knowledgeable but equally capable of becoming active, critical, and (appropriate) risk-taking citizens, with a felt sense of care and justice for themselves, for others and for the environment (Mooney Simmie & Moles, 2024).

It is within this contemporary global education reform backdrop and context that I critically scrutinise the framing of science education and its connectivity to scientific literacy. This affirmative critique is guided by the critical and feminist theorisations of Fraser (2009), Lazar (2007) and MacLure (2003) with a view to highlighting the current framing of science education, and by implication scientific literacy and at the same time advocating for what is now needed if considered from the perspective of an inclusive and de-colonising classroom, with the foregrounding of intersectionality, making science subjects attractive to women and girls and ethnic minorities (e.g. social class, gender, race, disability). My study is positioned within a transformative worldview, whereby I research the problem and at the same time advocate for science teaching and research as emancipatory practices that are inclusive of the affective care, social justice and ecological justice needed for the greater good of a democratic society, a thriving economy and a sustainable environment and the planet.

What is at issue here is whether or not science education as we know it today can make for a better world on its own or whether we need to Reimagine Science Education for a new social and ecological contract, a reframing of a new type of scientific literacy for all within a highly complex scientific world and a future of uncertainty. While science knowledge is necessary, will it be sufficient to make that difference for the greater good of humans, non-humans and the planet? What desirable attitudes, dispositions and ethical values will be necessary? Will a statement of values as a normative consensus in the national curriculum be sufficient to make the difference for the greater good of society and the planet?

Science Education & Civic Engagement for Democracy as a Way of Life

While learning to participate in civil society is necessary for socialisation, will that be sufficient to inspire young people to critically and empathically engage with the controversial ethical and political issues of the day in order to do the dynamic work of constantly remaking democracy with each new generation? The American philosopher, John Dewey, an advocate for experiential learning and for democracy as a way of life, considered education as the mid-wife of democracy and suggested that democracy needed a face lift with each new generation based on the ever changing needs of society and, in this case, the planet (Dewey, 2024/1916).

It is this inextricable link between Science Education and *Politics & Society* that is of deep interest to unpack and to tease out in this SMEC Proceedings 2024. We have already had forty years of efforts to make this link sharper and more critically relevant in Science Education. Bencze et al. (2020) share this history, and show how *Science-in-Context*, *Socio-Scientific Issues* (SSI) and *Critical Science Questioning* were all used as pedagogical approaches in science education, at a European, American and global level to secure this linkage between science content knowledge and the controversial ethical-political dilemmas of the day. At the same time, critical pedagogues in science education, such as Bazzul (2022), Hodson (2003), Sjostrom & Eilks (2020) and others have shown how science education as we know it today has remained highly abstract, reified and tightly fixated on what Bang (2017) calls a 'Dogmatic Image of Thought', a way of doing school science that is far removed from the messiness of real life problems and fails to critically connect with lived experience.

This begs the question of how to accurately interpret the contemporary framing of science education in relation to scientific literacy, in order to assess its effectiveness in relation to paying attention to the awakening of the critical social consciousness needed for the forging of public interest values for an emancipatory and transformative view of learning. Freire

(2018/1971) argued for an emancipatory view of education as an open practice of human freedom rather than a colonising practice of domestication and neutralisation.

Therefore, when desirable ethical values are laid down for schools by external policy actors in ways that fail to interrupt the discourse, to sap power and to require science teachers and their students to engage with the uncomfortable work of critical debate and reflexivity then it becomes harder to see how young people are going to experience at first hand their interdependency with other humans, non-humans and the planet and to accept their subsequent ethical obligations and responsibilities to care for others in ways that support the building of solidarity, care, community, rights and justice for just and fair societies and the environment (Bazzul, 2022). After all, democracy is never about getting on well with those who are like us, it is always about doing the hard work of negotiation in order to reach sound working agreements (beyond consensus) and live in harmony with people who are not like us (Edling & Mooney Simmie, 2020; Mooney Simmie & Edling, 2019).

I have structured the article as follows. First I draw from the theorisations of critical and feminist scholars to provide a suitable lens to conduct an affirmative critique of the framing of contemporary science education today, and its relation to scientific literacy in a fast globalising world. Second, I share the research methodology approach selected for this philosophical and critical study of the literature, as a scoping literature review (Arksey & O'Malley, 2005). Third, I critique recent literature to show the contested nature of science education and scientific literacy today and to reveal the growing movement in relation to Reimagining Science Education, and scientific literacy for all, in ways that humanise the disciplines, problem-posing ways that put the human at the centre in a care based and accountable way and, at the same time, 'storying science' with a mixed review rather than from a naive position of uncritical appreciation. Finally, I summarise my critical insights from the study in relation to where policies and practices need to draw the line in relation to science teachers' democratic assignment for the development of a de-colonising science classroom, inspiring an empowering and transformative practice for all students, especially for women, girls and minorities in highly scientific and pluralist democracies.

Theoretical perspectives

Government policies in education, and in science education reveal a fast changing orientation in relation to the positioning of knowledge and the knower and its relation to a constantly changing world (Arendt, 2018, 1958; Lynch & Crean, 2019; Tolbert et al., 2024). In the academy of higher education and in UNESCO reports, there are fresh calls for all disciplines to be placed on an equal footing, to move from a restricted view of the primacy of the economy and to take seriously social, cultural, ethical, political and environmental consequences (UNESCO, 2021). This calls for fresh thinking in relation to educating young people for sustainable living in a highly scientific and technological world with others, the environment and the planet.

Here I draw from the theorisations of Nancy Fraser (2009, 2022), a renowned critical and feminist scholar to provide a suitable lens to conduct this philosophical and affirmative critique of contemporary science education, and the framing of scientific literacy in a fast globalising world. Fraser (2022) unpacks capitalism and materiality to reveal the confluence between a human capital theory of the economy and how this works hand-in-glove with a patriarchal view of human relations ('wait until your father gets home') and the subsequent diminution of the importance afforded to the moral and political concept of the public sphere – for lively critical debate in the public forum and the necessity for listening and responding to the unique, diverse and collective needs of the people for the greater good of the commons, for democratic society rather than a market place and a commodity.

Fraser (2009) provides a cultural historical insight into the multiple waves of feminism to date. While the first wave of feminism was concerned with recognition of gender based oppression and the subordinate positioning of women and girls in the polity, the second wave of feminism concerned itself with interrogating the need for a redistribution of resources in a just, caring and decent democracy so that there was at the very least an agreed floor below which no one fell. Today, a new third wave of feminism is calling for critical scrutiny of the framing of social science problems that affect the gendered construction of human relations, in families and in the wider world such as in the scientific education of women, girls and ethnic minorities.

Research Methodology

The research methodology selected for this study was guided by the critical and feminist theorisations of Lazar (2007); Mac Lure (2003); and Pillow (2003). The aim was to critique current framings of science education and scientific literacy while opening new spaces, contents and values that foreground intersectionality and humanise the science disciplines. Humanising the science disciplines has traditionally been a serious challenge in schooling given the essentialist framing of these subjects where the human being is left outside the frame as a detached observer at all times. This framing continues today by the adoption of a hyper-masculinities framing of education as an evidence-based practice that can readily be reduced to management and numerical objectification (Selwyn & Gašević, 2020). Science subjects, science educators, and science education researchers are presented in this post-positivistic stance as neutral and objective. In this way the vested interest of those who hold privilege and act as power brokers, often exerting influence over others, often remain hidden and go unrecognised. Besides the affective labour involved in the work of teaching the sciences to young people is equally unrecognised, care work that is traditionally associated in culture and society with the labour of women and minorities (Lynch & Crean, 2019).

Mac Lure (2003) reminds us that the framing of policy text and policy talk is interlaced with discourses of power and shot through with differential power relations and always reflects the needs, wishes and desires of dominant actors. Therefore, conducting a feminist discourse analysis of any discourse, whether text or talk is always more than an in-depth examination of the language, syntax and grammar used. Mac Lure (2003) asserts that what is most revealing about conducting a feminist discourse analysis of a text or talk may not so much be about what is included but is more often about what is often excluded, forgotten, or otherwise silenced.

Lazar (2024) shows how to conduct a critical and feminist discourse analysis, not only foregrounding intersectionality and, in this case, the needs of women, girls and minorities in science education, but also the human rights and justice considerations of associated living with others in the direction of equality, care and justice for all in a pluralist democracy, the public interest needs of a fast changing society, economy and environment.

Besides ethical and critical capacities to look outward on the world, with a gaze of critical social consciousness for the greater good of fellow humans, non-humans and the planet, Pillow (2003) argues that we equally need to do the often uncomfortable work of reflexivity as qualitative researchers and educators. People who work in science education, as teachers, teacher educators and researchers come to their practices with an intentionality to either turn the gaze of their students in a stated direction, or toward interrogating the extent to which the students turned their gaze in a stated (reform-minded) direction. The argument here is that there is no branch of social science research, in science education or elsewhere that is coming from nowhere.

Taking the research design features of this approach to critical and feminist discourse analysis I will critically scrutinise the contested nature of Science Education today and its increasing potential to be reimagined in ways that secure a stronger vision of scientific literacy for all than heretofore. This time with affordances to explicitly teach young people science as a sociological project with capabilities to awaken the critical social consciousness needed to live well with others in a just global world and planet.

It is not intended that the literature review conducted here is a comprehensive or even a systematic review. It is in fact a scoping literature review. According to Arksey & O'Malley (2005), a scoping literature review seeks to identify gaps in the mainstream research literature through deploying broad-based questions, rather than tightly defined questions, and to reveal areas of the literature that are currently positioned more at the edge rather than at the centre. This review therefore seeks alternative studies in science education, studies that have grown exponentially since the coronavirus pandemic and that are reimagining science education today, especially in relation to the framing of the construct of scientific literacy for all.

Reimagining Science Education

As stated earlier, the cultural historical review by Bencze et al. (2020) shows how multiple efforts have been tried to date within an essentialist (positivist and post-positivist) framing of science education in order to make an explicit link between Science Education & Democracy and Science Education & *Science-in-Society*. However, the success of these pedagogical approaches in science education to engage students in a rich interplay between science and controversial socio-scientific issues remains highly elusive and can be shown to be limited and modest at best. The policy emphasis appears to be based on giving students an 'appreciation of science' and the work of scientists. It appears that the 'Story of Science in Society' presented in the school science curriculum is about one-sided success where being a 'scientist', and students behaving as mini-scientists, is reduced to following a rather simplistic view of the scientific method. An unproblematic inquiry-oriented method that is devoid of explicit attention to ethical dilemmas, values, reflexivity, power and politics (Bazzul, 2022).

However, this rather naive position of uncritical appreciation is deeply contested within the current literature in Science Education. Critical and feminist scholars argue for other ways of seeing science play out in the science classroom, ways that are problem-posing, philosophically grounded and connected to critical consciousness, care and action for the greater good of society and the planet. Yacoubian & Hansson (2020) provide a collected volume that speaks to the Nature of Science and Social Justice. Sjoström (2018) and Sjoström and Eilks (2021), and an increasing number of science education theorists and researchers are calling for deep change away from the more traditional 'dogmatic image of thought' that underpins much of the curriculum of science education and the Nature of Science (NOS). Literature in the history and philosophy of science education, shows how a consensus view of NOS falls short when it comes to establishing a de-colonising science classroom experience that foregrounds intersectionality, equality, diversity, care and justice.

It is clear that science education, and the reframing of scientific literacy for all requires a productive interplay with a multiplicity of disciplines, and other ways of knowing that are inclusive of the arts and humanities and imbued with an openness to critical reflexivity and the collective social consciousness needed for public interest values (Pillow, 2003). This sophisticated and nuanced approach will be necessary, if not sufficient if we are to undertake an authentic journey of interdisciplinarity and transdisciplinarity in science education for the greater good of humanity (social justice) and the planet (planetary justice).

There is currently a new and growing global social movement, involving science education researchers in the US, New Zealand, Australia, UK and Canada with advocacy for Reimagining Science Education in the Anthropocene – the term given to the geological footprint in the planet largely coming from man-made exploitation of the Earth's natural resources (Tolbert et al., 2024; Wallace et al., 2022). This collection of papers and interviews reveals the inherent dangers in continuing to view the social sciences, and science education in reductionist ways as if they were the natural sciences or the applied sciences. The collection advocates for a relational care-based and problem-posing approach to science education which can humanise the discipline and leave sufficient open spaces for learning about the importance of scepticism, and for learning about the importance in science education of the ethical, the aesthetic, the immeasurable, social justice, planetary justice and the not-yet-thought (Butler, 2017). Overall collection recognises the power and limits of scientific reasoning and the distinction between what is often defined as science and the arts and what is regarded as a narrow ‘scientism’ (Hyslop-Margison & Naseem, 2010).

Conclusion and Summary

In this study, I conducted an affirmative critique of science education and the framing of scientific literacy as currently in play in mainstream policy and research at a global level. The scoping literature review, using critical and feminist lenses, reveals how this mainstream essentialist stance is deeply contested within contemporary literature in science education. While there is a new global post-covid imperative from UNESCO 2021 to develop a new social contract for education in the direction of care, justice and sustainability, there is equally evidence of a new global movement intent on reimagining science education and scientific literacy for all and what this might mean for democracies, for care, justice and sustainability.

Critical insights from the study reveal that reimagining science education for a new framing of scientific literacy for all needs to be a whole of school and relational experience that humanises the sciences across the curriculum, in border-crossing and transformative partnerships with policy actors, such as science teacher educators and educational researchers (Mooney Simmie, 2023; Mooney Simmie et al., 2024). Moreover, the critical insights suggest that a relational, care-based and problem-posing approach will work to keep science education sufficiently open to scrutiny and thereby provide safe spaces for inclusive experiences to occur in de-colonising science classrooms. This requires new capabilities for science teachers' democratic assignment, so that science teachers can learn to engage students in critical and ethical dilemma debates of controversial socio-scientific topics and to bring such debates to closure in nuanced and discerning ways that can name areas of agreement and respect areas of difference.

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Gender differences in mathematics achievement: an examination of PISA results in a time of curricular change.

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National and international research has highlighted the underrepresentation of female students at the highest levels of mathematics education (Society of Actuaries in Ireland, 2023; Keller et al., 2022). Data from the Programme for International Student Assessment (PISA) provides information on how the performance of male and female students in mathematics has changed between 2012 and 2022, two cycles of the study that focused primarily on mathematics. Results for Ireland show that, on average, male students significantly outperform females in mathematics in 2012 and 2022, and this pattern holds across all mathematical content areas assessed. In both cycles, females were more likely than males in Ireland to perform below baseline proficiency in mathematics. The percentage of males performing below baseline proficiency has increased meaning this gender difference is narrower than in 2012. Conversely, more males than females performed at the highest levels in both cycles. While the percentages of males and females reaching the highest levels declined significantly since 2012, the decline was greater among females, meaning the gender gap among higher-performing students has widened.

Introduction

Concern has been raised in recent times about widening gender gaps in mathematics achievement at the highest grade (A1/H1) of mathematics among Leaving Certificate (LC) students (The Society of Actuaries in Ireland, 2023). Data from recent cycles of Programme for International Student Assessment (PISA), an international study which assesses the reading, mathematics and science achievement of 15-year-old students every three years,[2] also show that, on average across OECD countries, male students significantly outperform female students in mathematics and this gender gap widens further among the highest achieving students (OECD, 2023a, 2019, 2013). A number of possible reasons have been hypothesised to explain the relative underperformance of female students in PISA mathematics, especially at the higher end of the distribution, including lower levels of mathematical self-concept and confidence among female students as well as greater levels of general and mathematics-related anxiety (OECD, 2015). Additionally, students' opportunity to learn mathematics may also be related to performance. Analysis of PISA 2012 data show that while the average gender gap in PISA mathematics was 11 points in favour of male students, it widened to 22 points when male and female students with similar levels of familiarity and experience with mathematics were compared. This suggests that a greater level of investment in mathematics studies among female students may contribute to narrowing the gender gap in some countries (OECD, 2015).

In each cycle of PISA, one domain (reading, mathematics and science) is measured as the main domain and the other two domains are assessed as minor domains. In the last cycle of the study, in 2022, mathematics was the main domain, meaning that performance in mathematics can be explored in more detail including for mathematical content areas. Mathematics was also the main domain in PISA 2012 which allows us to examine in more detail how mathematics achievement in Ireland, including the achievement of male and female students, has changed since 2012.

The period from 2012 to 2022 was also a time of curricular change in mathematics in Ireland (see Table 1). The post-primary mathematics syllabus underwent a major national reform with the roll out of Project Maths to all schools between 2010 and 2015. Subsequently,

[2] PISA has taken place every three years since 2000 but the eighth cycle of the study, due to take place in 2021, was delayed by one year due to the COVID19 pandemic.

Junior Cycle mathematics under the Framework for Junior Cycle was introduced on a phased basis to First Year students in September 2018. It should be noted that while PISA offers an opportunity to explore changes in mathematics performance during a time of curricular change in Ireland, PISA is not designed as an evaluation of curriculum.

It should also be noted that due to the phased introduction of some curricular changes, and because the PISA sample draws students from across a number of different grade levels, not all students in a given cycle would have had the same level of experience with new elements of the curriculum. In PISA 2012, 15% of students in Ireland had experienced some of the Project Maths syllabus by the time of PISA testing, and none had experienced Strand 5 which focused on Functions. All PISA 2015 students experienced Strands 1 to 4 of this syllabus, while approximately 25% had not yet experienced Strand 5. By PISA 2018, all students were experiencing the full Project Maths syllabus. From September 2018, First Year students were engaging with Junior Cycle Mathematics under the Framework for Junior Cycle. While all PISA 2022 students were taught Junior Cycle Mathematics, much of their experience occurred during the disruptions to schooling from 2020 to 2022.

Table 1

Mathematics curricular change in Ireland between 2012 and 2022.

Project Maths	
Introduced	September 2010 (Strand 1 & Strand 2 rolled out to all schools)
PISA 2012	Approx. 15% of PISA 2012 students had some experience of Project Maths (none had experience of Strand 5)
PISA 2015	All PISA 2015 students had some experience of Project Maths (62pprox.. 25% had not experienced Strand 5)
Junior Cycle Mathematics	
Introduced	September 2018 (on a phased basis)
PISA 2022	All PISA 2022 students had experience of Junior Cycle Mathematics

This paper uses PISA data (between 2012 and 2022) to explore the changes in mathematics performance on average, for males and females in Ireland, at the lower- and upper-end of the distribution (lower- and higher-achieving students) and for each of the mathematics content areas.

Methods

Data from four PISA cycles (2012, 2015, 2018 and 2022) were used to examine changes in mathematics achievement among students in Ireland.

Sampling and Participants

PISA selects nationally representative samples of 15-year-old students using a two-stage stratified cluster design. Firstly, individual schools are selected, followed by a random selection of 15-year-old students within those schools. Students that participate in PISA are distributed across a number of different grade levels. Table 2 presents details of the samples for Ireland in each of the above mentioned cycles of PISA.

Table 2

Number and grade distribution of students in Ireland that participated in PISA from 2012 to 2022.

	PISA 2012	PISA 2015	PISA 2018	PISA 2022
N	5,016	5,741	5,577	5,569
% First/Second Year	1.9	1.8	1.8	0.2
% Third Year	60.5	60.6	61.6	26.1
% Transition Year	24.3	26.5	27.9	57.0
% Fifth/Sixth year	13.3	11.1	8.5	16.7

Note. PISA testing in Ireland, which has traditionally taken place in spring, was moved to autumn in 2022, meaning the grade distribution of students in this cycle differed from earlier cycles (Denner, 2022)

Measures

The mathematics achievement of 15-year-olds was measured using tests which contain stimulus materials followed by a number of questions. Questions were multiple-choice, closed constructed-response or open-response items. Open-response items were manually coded by trained experts, using an internationally agreed coding guide. Performance is reported on a scale for each domain which was set to have an OECD mean of 500 and a standard deviation of 100 when the domain was first assessed as the main domain (i.e., PISA 2003 for mathematics). Adaptive testing was used for the first time in PISA mathematics in 2022.

As well as describing overall performance in mathematics, student performance is also described across four mathematics content areas: Change and Relationships, Space and Shape, Quantity, and Uncertainty and Data (OECD, 2023b). PISA mathematics also reports performance in terms of six proficiency levels that describe the skills and competencies that students within each level have. Proficiency level 2 is considered the baseline level of proficiency needed for full participation in society and students performing below this level are considered to be lower-achieving students. Levels 5 and 6 represent the highest levels of the test and students achieving at these levels are considered to be higher-achieving students.

Results

Ireland's mean mathematics performance remained relatively stable between 2012 and 2018 with no statistically significant changes in Ireland's mean score. Between 2018 and 2022, Ireland's mean mathematics score declined significantly by eight score points (Table 3).

Table 3

Mean mathematics scores for Ireland, PISA 2012 – 2022, and change from the previous cycle.

	Mean score	Change in mean score from previous cycle
PISA 2012	501.5	–
PISA 2015	503.7	+2.2
PISA 2018	499.6	-4.1
PISA 2022	491.6	-8.0*

Note. * indicates a statistically significant difference.

In Ireland, male students significantly outperformed females in 2012 and 2015 (Figure 1). The mean scores of the two groups remained relatively stable between 2012 and 2015, with no significant changes noted between the two cycles. A large decline in the performance of male students in 2018 narrowed the gender gap to a non-significant gap of six points. From 2018 to 2022, the gender gap widened to 13 points as a result of a non-significant drop of five points for male students and a significant drop of 12 points for female students in Ireland.

Figure 1

Mean mathematics scores of male and female students in Ireland, PISA 2012 – 2022.

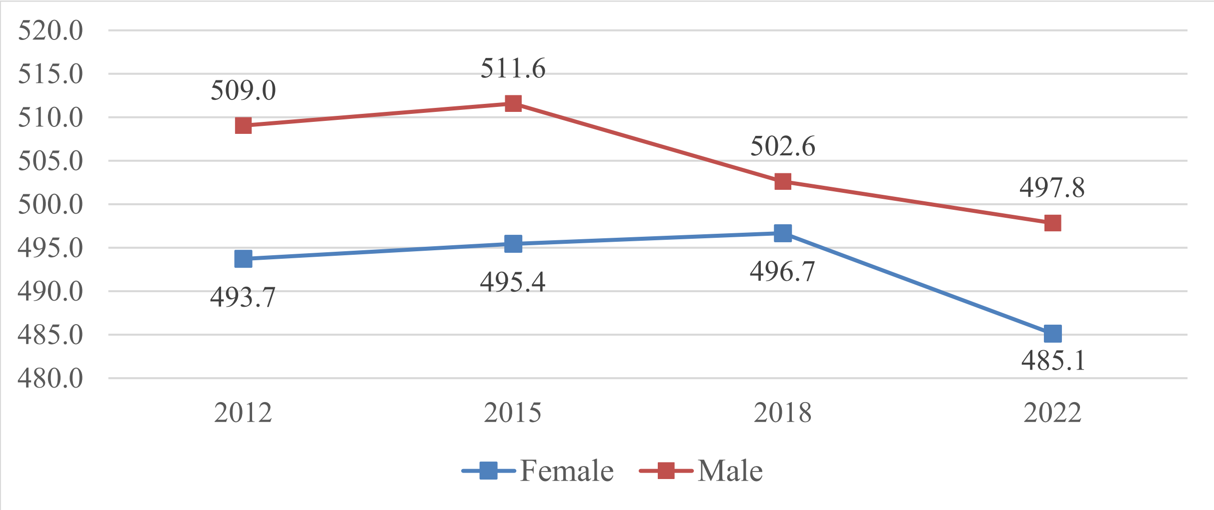

Figure 2 outlines the percentages of lower- and higher-achieving female students in mathematics in Ireland between 2012 and 2022. While the percentage of lower-achieving female students declined by about three percentage points between 2012 and 2015, this was accompanied by a slightly smaller decline in the percentage of higher-achieving females. The rate of lower- and higher-achieving females remained stable between 2015 and 2018. However, a further decline of about two percentage points in higher-achieving females and an increase of about four percentage points in lower-achieving females was observed in 2022.

Figure 2

Percentages of lower- and higher-achieving female students in mathematics in Ireland, PISA 2012 – 2022

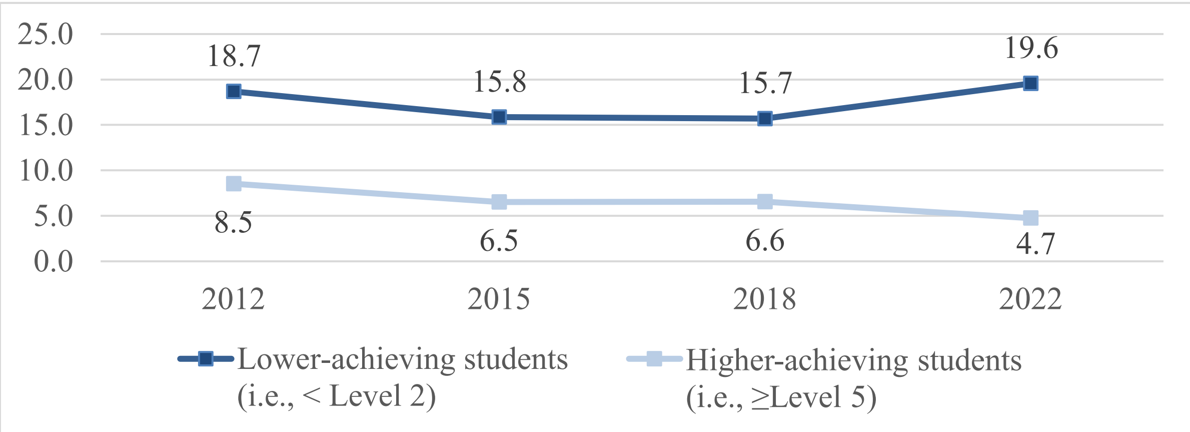

Figure 3 presents the corresponding data for male students in Ireland. A slight decline in the percentage of lower achieving male students occurred between 2012 and 2015, while the percentage of higher-achieving males remained stable during this time. The percentage of lower-achieving males increased slightly in 2018 and was followed by a larger increase in 2022, meaning that the percentage of lower-achieving male students in mathematics in Ireland was over four percentage points higher in 2022 than in 2015. During the same period, the rate of higher-achieving male students dropped by three percentage points in 2018 but remained stable between 2018 and 2022.

Figure 3

Percentages of lower- and higher-achieving male students in mathematics in Ireland, PISA 2012 – 2022

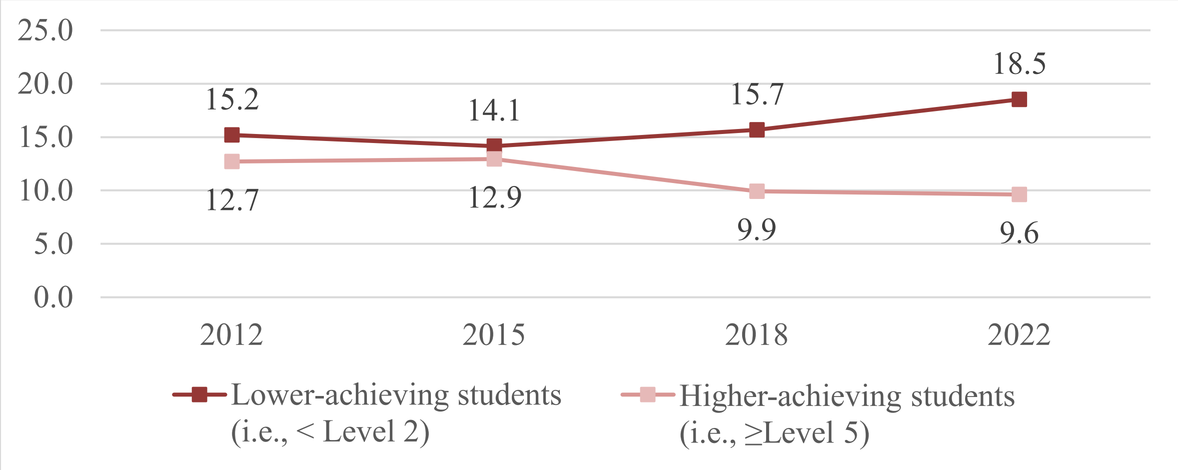

Table 4 presents the mean scores for male and female students in Ireland across the four mathematical content areas in PISA 2012 and 2022. Across all content areas the decline in average performance since 2012 is larger for male than female students. The average performance of female students in Space and Shape remained stable between 2012 and 2022, while males' average performance declined by almost seven points. The larger declines among male students led to a narrowing of the gender differences across all content areas.

Table 4

Mean mathematics scores for male and female students in Ireland, PISA 2012 and 2022.

	Change and Relationships		Space and Shape		Quantity		Uncertainty and Data	
	Male	Female	Male	Female	Male	Female	Male	Female
PISA 2012	507.7	494.3	489.9	465.2	512.1	498.0	515.7	501.5
PISA 2022	496.5	486.6	483.2	465.3	499.6	487.2	504.8	492.1
Difference	-11.2	-7.7	-6.8	0.1	-12.5	-10.8	-10.9	-9.4

Discussion

The average mathematics performance of 15-year-old students in Ireland remained relatively stable between 2012 and 2018 but declined significantly in 2022. This decline was larger for female than male students. However, looking at longer-term trends, male students in Ireland have seen a larger decline in average mathematics performance compared to female students, since 2012 and this is the case across all four mathematical content areas assessed.

The declines, among male and female students, are driven by changes at both the highest and lowest levels of the performance distribution. The percentages of male and female students in Ireland performing at the lowest levels in PISA mathematics are higher in 2022 than in 2012 and this increase is greater among male than female students. Furthermore, the percentages of male and female students in Ireland reaching the highest levels in mathematics has decreased since 2012 and this decrease has been greater among female than male students. This means that the gender difference among lower-performing students has narrowed in Ireland but it has widened among higher-performing students.

Results indicate that while attention needs to be paid to declining performance among both male and female students at the higher end of the performance distribution, this is of particular importance for higher-achieving female students, given their long-standing relative underperformance compared to higher-achieving males, and the larger decline among higher-achieving females when compared to their male counterparts in recent years. The increase in the percentage of male students performing below baseline level in mathematics also deserves attention. An encouraging finding is that, while performance in other areas dropped, the average performance of female students in Ireland in Space and Shape has remained stable since 2012, leading to a considerable narrowing of the gender difference in this content area. This is an area of mathematics where female students have performed considerably less well compared to their male counterparts in Ireland since PISA 2003 (OECD 2004, 2013).

Further research on how the relationship between gender, self-beliefs and anxiety around mathematics, and mathematics performance may have changed in PISA since 2012 is necessary and may provide further insight into the changing mathematics performance of male and female students in Ireland.

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What do the children think? Using Embodied Cognition to Learn Science in Infant Classes

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This paper presents findings from a project that explored the impact of teachers' engagement in a continuing professional learning (CPL) programme which focused on the use of embodied cognition principles in the design and delivery of science lessons for young children. The CPL programme aimed at developing teachers' pedagogical content knowledge in using Embodied Cognition (EC) teaching strategies. Drawing from the literature on EC, the general principles of EC were addressed throughout the CPL, with a specific focus on four of its key EC underpinnings: Movement; Emotion; Smell and Touch.

Teachers from four Irish primary schools representing urban, rural, small, large and Delivering Equality of Opportunity Schools (DEIS)[3] *participated in the CPL programme. Data from children's focus groups indicate that the active nature of EC activities, prompted them to say they enjoyed the lessons, were very positive about using their bodies to help them learn about science and asserted that using their bodies to learn was more enjoyable than writing or using school books. While many EC activities were included in the lessons, EC principles of movement and emotion were notably voiced. Children's data revealed that EC activities appeared to have been valuable in supporting the development of children's scientific knowledge and observation skills. The findings suggest a reimagining of how children engage in science lessons.*

Introduction

Project Background

This paper presents data gleaned from a research project in 2022 entitled '*Science in Action for Infant Learning'*. Given that the use of EC is not a specific feature in the delivery of Irish Primary Science Curriculum, the project's success hinged on effective and purposeful CPL. The project involved 2 CPL days with teachers. These CPL days were preceded by a zoom meeting with the teachers to introduce the project and to give them a sense of the project's evolution prior to their 2 full days of CPL. The first day of CPL provided the teachers with an overview of the project, the principles of Embodied Cognition (EC) and examples of how they could apply EC to their science lessons. After they delivered a minimum of 2 Science lessons using EC principles, the teachers were invited to a second day of CPL. Somewhat similarly, the second day examined the principles of EC, but also focused on additional exemplars of EC in science education for infant classes. The second CPL day also involved a workshop which focused on participants' experiences of using EC in Science lessons. These were discussed with a view to further developing teachers' efficacy in using EC in science lessons.

What is Embodied Cognition?

While EC has emerged in the past two decades as a 'new kid' on the block largely due to advances in neuroscience, it is not necessarily new as a view of education. Dewey (1938), and Montessori (1976) both cited the value of 'experiential' and 'active' learning. Indeed some connections between contemporary research in neuroscience and the EC principle of movement are also in sync with the active learning principles suggested by Montessori (Politi, 2023). Froebel's advocacy of the use of 'gifts' (block play) and 'occupations' (e.g. hands-on activities) in early learning (Teichert & Helbig, 2024) is very much in line with the EC principles of touch

[3] DEIS schools are schools designated as disadvantaged by the Irish Department of Education. Under the DEIS programme, schools with the highest number of students at risk of educational disadvantage get extra resources.

and movement. Despite this long-standing and current evidence for the use of active learning and EC principles, there are many who argue that cartesian dualism (e.g. Evans et al. 2009) has and still does influence modern education. In short, modern learning experiences are still rooted in perceptions that all traffic for learning is governed by the brain only.

The idea that our brain is like a computer which governs the body and which is largely detached from the actions of legs, arms, hands and all bodily interactions with the environment has been criticised by proponents of 'embodied cognition'. They argue that our physical interactions with the world shape our cognition of the world (Glenberg 2008). Our thoughts are shaped by the types of perceptual and motor experiences we have as we interact each day with the world and as such, ''cognition is for action" (Glenberg 2008, p. 43). For example, strong links have been established between the use of gesture and language acquisition (Colonnesi et al. 2010). As the human speaks, their body movement is synchronised with what they are saying in what is often called 'self-synchrony' (Dittmann 1972). It is argued that such bodily movements, and in particular the use of gesture movements, can have benefits for the speaker in assisting them to retrieve information from memory and also to reduce the cognitive working load while speaking (Chawla & Krauss, 1994).

Embodied Cognition and our Project

Against this backdrop, we developed our project through the lens that cognition is not restricted to the brain but arises from the body as a whole and its interaction with the environment. In particular, the following features of human interaction with the environment were singled out for use in the project.

Movement

As the work of Alibali et al. (2001) indicates, movement is closely linked to cognitive functions in the brain. As a result of the generous space they occupy on the sensory and motor strips of our neocortex almost anything a hand does holds potential as a sign. We respond to hands and their gestures with an extreme alertness because specialized nerve cells in the lower temporal lobe respond exclusively to hand positions and shapes (Kandel 1991). As Kandel (1991) notes: "for cells that respond to a hand, the individual fingers are a particularly critical visual feature" (p. 459). Equally, the movement of other limbs such as arms and 'bodily cues' have been shown to have positive effects on learning (Abrahamson et al., 2014). Hence, in designing EC activities, a particular focus was placed on movement of the body, with a focus on hand, torso and limb movements.

Emotion

We identified emotion as one of the features of embodied cognition for this project, based on our research in the literature, and in particular, because emotion is experienced in the body. For example, Paul and Mendl (2018) suggest that emotion is a multicomponent response to a stimulus or event. This involves subjective, physiological, neural, and cognitive responses. Others take a broader view of emotion as a state of the nervous system that is provoked by extrinsic or intrinsic stimuli (Anderson & Adolphs, 2014). Hence, emotion as a feature of the physiological responses to stimuli, and in our case, science learning, was selected. In examining emotion as an embodied and physiological 'activity' this particular examination of the literature (e.g. Herz & Cupchik, 1995) also took us directly to smell.

Smell

It is widely known that olfaction, or smell as we commonly know it, is one of the oldest human senses. It is even active before birth (Brai and Alberi, 2018). It is connected to primitive parts of the brain and carries directly to limbic areas of the mammalian brain via nerves running from the olfactory bulbs to the septum, amygdala and hippocampus (Givens & White, 2021). Indeed, among other species, smell is one of the critical features of existence and "odor learning and memory are remarkably resistant to decay" (Jacobs, 2023 p. 60). In fact, there are some who argue that the olfactory system (smelling) may be a unique and quite unconscious learning and memory system (Plümacher & Holz, 2008). Hence, with these deep evolutionary and primal roots in the brain, smell was identified as a field for EC activities.

Touch

Touch is one of the earliest forms of stimulation within the human experiences. It has primal origins and as Sachs (1988) observes "Touch, in short, is the core of sentience, the foundation for communication with the world around us and probably the single sense that is as old as life itself" (p. 28). According to the American neurologist Marsel Mesulam, there exists a "magnetic effect triggered by objects" that originates with the brain's innate grasping reflex (Mesulam, 1992, p. 697). Subsequently, it involves a balance between the parietal lobe's control of object fancy, and the frontal lobe's inattention to material goods. Hence, touch and its potential for learning was specifically identified as one of the EC principles for the research.

Key Principles Distilled for Our Project

Building from this research literature, the project distilled four key principles / activities which Infant Teachers could incorporate into their Science lessons as follows:

1. Movement (e.g. pretend you are butterfly emerging from the chrysalis)
2. Emotion – often through drama (e.g. do you think a magnet is happy when it finds a piece of metal? Do you think the butterfly is happy when it emerges from the chrysalis?)
3. Smell (e.g. Planting - do the seeds have a smell?)
4. Touch (e.g. how does the bubble wrap feel?)

Research Aim

The research had a singular, overriding aim: to explore the perspectives of junior and senior infant pupils about the value of using embodied cognition principles / activities, as above, to learn science in their classes.

Methods

The data was derived from seven focus group interviews, conducted with Junior and Senior Infant pupils in four different participating schools. Data comprised verbatim transcripts of children's perceptions of their experiences of EC principles in science lessons. Focus group questions were rooted in previous science lessons undertaken by the pupils. These questions afforded an open ended discussion on this content. They provided for an inductive and deductive analysis of pupils' recall and reference to previous lesson content. Using a Miles et al. (2014) framework, inductive and deductive approaches to data analysis were undertaken involving thematic coding and categorisation of data. Two key themes emerged and are subsequently discussed below.

Key findings

Strong Recall and Knowledge

Overall, pupils demonstrated strong knowledge about topics covered during science lessons. Given the age groups being interviewed and the time lapses since they had undertaken the lessons (at least 1 week for all pupils), almost all children seemed able to recall aspects of EC lessons. They also revealed quite an impressive level of recall of a variety of science lessons and associated EC activities. This suggests a high level of engagement with the activities and good retention.

Aspects of EC which features in Students' Responses

Particular aspects of EC were identified by pupils in various lesson contexts and with variance on how each child 'weighted' different EC activities. The data indicates that emotion was an important variable both for how the children felt during lessons, and also when making inferences. For example, one child commented on the dramatisation of the life cycle of a butterfly as follows: "after you're the caterpillar out of the egg you might feel a bit "ridiculous". As indicated earlier, enjoyment was an emotion which featured in much commentary. This was particularly connected with drama activities. Many pupils enjoyed the drama features of lessons - for example, pretending to be a butterfly, or hugging another piece of metal (magnets).

Data and the topic in Question

While the interview questions were piloted and indeed involved the reframing of a number of questions, the abstract nature of the concept in question and the age of the pupils involved would suggest the need to conduct focus groups with this age group immediately after a lesson, and with visual aids to assist language usage.

Conclusions

This project was ambitious in its work. Unlike other research in the field of EC and learning which typically adopts a specific angle such as the use of gesture or auditory stimuli, this project adopted a more holistic approach, focusing on four possibilities for the employment of embodied cognition techniques. The data is most encouraging, indicating that the use of these approaches seems to promote children's enjoyment of science. Despite their age and language acumen, children revealed an impressive range of scientific vocabulary, and an understanding of some scientific concepts. For example, they were able to recall and discuss the lifecycle of a butterfly, referencing caterpillars and cocoons and they understood in practical terms how magnets worked, with one child noting: "And we had North and South and then we couldn't put them together if they were the same". Some children understood the interrelated nature of butterflies, bees, and honey.

Children displayed a high level of enthusiasm and engagement and spoke positively and excitedly about their experiences of EC lessons. Children demonstrated very good recall of lesson activities and remembered many of the key points. We do not have a way to compare recall from these EC lessons against recall from a more typical lesson. However, based on what was recalled in the interviews, there seems to be at least some evidence that EC may have helped them retain information. However, it is not possible within the realms of this study to specifically state that EC activities directly contributed to pupils' learning of science.

In considering the children's engagement with EC activities themselves, it is notable that on occasion, the children singled out a specific EC activity such as smelling, touching and emotional responses. However, as originally planned, this project endeavoured to take a more holistic approach to EC, and within this context, it is evident that such lessons were much more preferred as they involved actions and not the "harder" task of reading. This latter observation by a child, does also point to the potentially very valuable contribution which EC can make to learning at younger class levels. At ages 4 - 7 years, children's language and their capacity to read is very much in development. The employment of EC techniques which tap into the human's hard-wiring, as mentioned above to engage with their environment would seem like a more natural and obvious choice of pedagogical approach for younger children. The research also foregrounds the possibilities of intertwining EC principles with play-based methodologies, where play is "the instrument" to create an interaction between the body and language learning (Reggin & Pexman, 2021, p. 17). Play through the lens of EC offers a link between the physical world, children's actions with their hands and body and cognition (Reggin & Pexman, 2021). This important link has notable potential in many current early childhood curriculum frameworks. For example, in Ireland the Aistear Early Childhood Curriculum Framework (NCCA, 2009, p.7) is firmly rooted in "active learning, play and hands-on experiences". This sample connection exemplifies the potential for EC-informed theory and practice across multiple teaching and learning interfaces within our primary schools.

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Students' understanding of the Laplacian in the heat equation

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The 2D heat equation is a common application of differential equations in physics. It describes how the temperature distribution in a 2D plate evolves due to heat conduction. To understand the 2D heat equation conceptually students must coordinate mathematics and physics concepts, e.g. heat conduction, partial derivatives, and Laplacian. The Laplacian of the temperature may be understood as indicating the difference between the temperature at a point and the average temperature of the surrounding area, as the divergence of the temperature gradient, and as a quantity proportional to the net heat flux density at a point. Our goal is to design a research-validated learning path that supports students in coming to a conceptual understanding of the 2D heat equation.

We have used the APOS framework. We designed a hypothetical model (a "genetic decomposition") of the mental constructions students need to make to understand the Laplacian of a temperature distribution. The model integrates insights from the researchers, the literature on math-physics interplay, and students' understanding of related concepts. It includes distinguishing heat and temperature, understanding Fourier's law, understanding the concavity of a 3D graph, interpreting 2nd partial derivative as rate of change of rate of change, comparing slopes of tangents near a point, and coordinating the differentials with the divergence of a temperature gradient vector field and with the rate of change of the rate of change. We hypothesized that through this coordination students may interpret the Laplacian of the temperature as a quantity proportional to the net heat flux through a closed 2D boundary.

We designed questions that probe these mental constructions. In this talk we will present findings from task-based think-aloud interviews with eight students. They confirmed that our approach is viable, but also that some students used a different path to understand the 2D heat equation.

The integration of STEAM areas through engineering design in the context of 3D printing

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STEAM Education is seen as an instructional approach that favors authentic problem solving from an interdisciplinary perspective (English & King, 2019). Several studies report that it promotes the development of abilities such as problem-solving/critical thinking, creativity, communication, collaboration, along with content knowledge and attitudes. However, the disciplines involved are not always effectively integrated, and one of them tends to be over-emphasized. The potential of the engineering design (ED) process, associated to its cycle, has been highlighted as an opportunity to guarantee the representativeness of STEAM areas in problem solving (Hester & Cunningham, 2007; Vale et al., 2023). The use of 3D printers allows students to have experiences that involve design/construction of models, contributing to a deeper understanding of abstract concepts (Khurma & Khine, 2023). This technological resource facilitates hands-on experiential learning, bringing designs to life and fostering

creativity. This paper reports on a study carried out with seventy-two future elementary pre-service teachers (3-12 years old), in a Didactics of Mathematics unit course, which aims to understand how they solve an artefact problem with 3D printing, using the ED cycle and how they perceive the role of each of the STEAM disciplines. We adopted a qualitative methodology and collected data through participant observation, documents (written report) and photos (Erickson, 1986). Seventy future teachers took part in this study and solved a problem involving the construction of a boat intended to support the most weight, using 3D printing and design in Tinkercad. The results show that: they understood the problem, identifying constraints by doing experiments with two presented models; they tried to identify possible models by brainstorming and research; they didn't value planning through sketches, merging this stage with the construction stage in Tinkercad, and experimenting with different designs; they tested the models created and assessed the reasons for their (in)effectiveness; some showed difficulties in communicating the process in writing; they were able to identify the representativeness of Science, Mathematics and Technology more easily than the other STEM areas.

Graphing the learning journey of students' mathematical experiences across the transition from primary to post-primary

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The transition from primary to post-primary has long been considered a crucial time in a student's educational journey. As well as being confronted by new learning experiences, students must negotiate new understandings about what it means to be a learner. In mathematics terms, research in the Irish context has shown that one's experience of the transition can impact subsequent perspectives towards learning (Smyth, 2017), as well as academic performance (Ryan, 2018). Additionally, attitudinal results towards mathematics, revealed in international assessments, point to worrying trends for Irish students at this time (e.g. Perkins et al., 2020).

This longitudinal study conducted whilst pursuing a PhD, aims to delve deeper into the students' lived experience of the transition, specifically in terms of their relationship with learning mathematics. In exploring this relationship, mathematics identity is selected as a pertinent entity, seen to greatly influence both how students learn and also the types of relationships they develop with mathematics (Black et al., 2010). Set within a sociocultural framing, the definition and conceptualisation of mathematical identity in the study is presented as a fluid, accessible measure that can be revealed through the narratives shared by students.

Fore-fronting the voice of students themselves, it follows a cohort of 17 students across a two-year period, utilising both semi-structured interviews and learning journey graphs (visual representations of students' relationships with mathematics) to capture students' mathematical identity, as they navigate this important step in their educational journey. With data collection complete and analysis work ongoing, early insights reveal deeply individual trajectories that students take across the transition. Factors including assessment, pedagogical continuity, relationships with peers and teachers all appear to have a significant influence on participants' mathematical identity. The authenticity of students' voice provides much to consider as we seek to improve the transition experience for all.

Goals for and evidence from online primary mathematical knowledge for teaching development in South Africa

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UNESCO analyses reported in 2017 that 84% of children and adolescents in Sub-Saharan Africa were not meeting minimum proficiency levels in mathematics (UNESCO Institute of Statistics, 2017). South African evidence suggests further downturns during Covid in mathematical learning outcomes in the early primary grades (Ardington, Wills & Kotze, 2021). These outcomes sit amidst broader concerns with levels of teachers' mathematical knowledge, poor coherence and connection in early grades' instruction, and limited evidence of progression beyond the use of rudimentary counting-in-ones strategies in number calculations well into the middle grades.

Our focus in this paper is on how to support primary teachers' mathematical knowledge for teaching (MKT) development in this context. The teachers in this study are involved with a South African NGO that has developed a model and materials for after-school mathematics clubs for children in Grades 4 & 5. The club sessions are focused on fundamental mathematical concepts linked with early number learning, often seeking to remediate gaps related to content drawn from Grades 1-3. In most cases, the teachers leading these mathematics club sessions are primary teachers in the school where the clubs are located.

Given the geographic dispersal of clubs across the country, the WhatsApp platform is being used for the MKT development course, coupled with two in-person sessions in the year-long professional model. The mathematical foci of the MKT course run parallel with the fundamental mathematical concepts in the clubs programme, with underpinning features responsive to the problems identified above: attention to progression, connection, representation and the need to check for student understanding. In the presentation, we detail our foci for growth in the MKT base linked to early number for teachers with likely gaps and disconnections in their own understandings of this content and share our analysis of baseline and interim course assessment data.

Space in between: Exploring entanglement in Shape and Space (An Art and Maths perspective)

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This paper draws on shared experiences of planning and facilitating continuous professional development workshops to present a collaborative ethnographic study (Roy & Uekusa, 2020) between a Visual Art education researcher and a Mathematics education researcher. Three 3-hour professional development workshops for primary teachers were organised to explore how to support teachers using integrated approaches, a key component of the new primary curriculum (DoE, 2023a). While the curriculum framework foregrounds Science, Technology, Engineering, and Mathematics (STEM) education, we considered that the increased expectations for Shape and Space in the new primary mathematics curriculum, particularly the new 'Transformations' strand (DoE, 2023b), might be productively explored through Art and Mathematics integration involving print and pattern. Workshops involved teachers engaging in pattern-making and print, trialling these ideas in their classrooms and sharing their experiences and samples of children's work in the follow-up workshops.

In this presentation, we discuss the nature of the material-dialogic space (Cook et al., 2019) that emerged during the project, for researchers and for participants. Informed by Barad's new materialism (Barad 2007), and Wegerif's (2019) conception of dialogic space, we draw on data collected during our planning and reflections, to discuss the nature of entanglement. In *particular, we attend to entanglement of Art and Mathematics content (for example, pattern, print, symmetry and transformation) in the planning and enactment of our workshops. We draw on our observations of teachers' engagement and their reflections on their enactment in classrooms to describe the entangled pedagogy which emerged in this project, where outcomes are contingent on complex relations (Fawns, 2022). We identify the importance of 'space in between' planning, doing, relating, presenting and enacting to consider the possibilities of new ways to disrupt (curricular) boundaries and connect learning.*

Data Collection Tools for a STEM Curriculum Intervention

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Educating pupils in the disciplines of science, technology, engineering and mathematics (STEM) is deemed vitally important by societies for maintaining economic growth and technological progress (DES, 2016). Therefore, as integrated STEM education becomes increasingly prevalent in primary and secondary education globally, there is a requirement for a more universal understanding of what exactly integrated STEM education entails and how it should be implemented in the classroom.

Following an extensive review of STEM education literature, certain paradigms and characteristics that outline exemplar STEM tasks were identified and implemented in a primary classroom. This paper discusses the STEM education curriculum intervention that was carried out, and the data collection tools which were utilised throughout this intervention.

Data collection tools consisted of an engineering content assessment (Crotty et al. 2017), a science content assessment based on standardised Irish Primary Achievement Test (IPSA-T), a STEM attitude and career interest survey (Kurt and Benzer 2020), a 'Draw Yourself Doing STEM' activity adapted from Quane et al. (2023), the 'Diet Cola Scientific Process Test' (Fowler, 1990), and an observation protocol adapted from Dare et al. (2021) that was used to assess students' engagement with STEM tasks. These data collection methods were employed both pre and post intervention to determine students' knowledge, interest in and attitudes towards STEM education. Data collection tools used throughout the intervention included samples of students' work, photographs, observation rubrics and researcher reflections.

It is expected that this research will make contributions to the incorporation of engineering along with mathematics and technology disciplines into science education. Additionally, it is intended that this study will provide important information on the development of pupils' 21st century skills, along with a framework to guide teachers on design-based STEM education implementations and assessment.

Investigation into Students' Understanding of Qualitative Graphs representing a Physics Scenario

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Graphs play a large role in our everyday lives, and yet they remain largely under researched. From overviews by Leinhardt et al (1990) and Glazer (2011), it is clear that there is a particularly sparse amount of research in the area of constructing qualitative graphs. For that reason, we decided to study undergraduate students' thought processes when drawing qualitative graphs in a physics context.

We devised a series of questions relating to different hypothetical physics experiments, where students were given a diagram and a piece of text describing an experiment and were then asked to complete a partially drawn graph of the predicted outcome. Along with drawing the graph, students were asked to explain why they had chosen that way to do so.

Initially our research focused on how students represented equal spacings on a track, beaker or wire on their graph. We saw that some students drew unequal intervals on the position axis to indicate a lengthening or shortening of time.

In this talk we present an analysis of the shapes students drew. Across all contexts, a large number of students drew a straight line where a curve would be correct. We posed the same hypothetical experiment in a variety of ways such as multiple choice, or providing a detailed narrative explaining what was going on. Our results were quite surprising, as they showed that the phrasing of the question had little effect on the number of students who drew a curved graph.

We have analysed the accompanying explanations by means of a codebook, which was designed iteratively. We each took a sample and independently used the codebook before comparing with each other and refining it until a high inter-rater reliability was attained. Our studies show that students who explicitly refer to the graph in their reasoning are far more likely to draw a curved graph than those who don't.

Teacher and child agency as central to the redevelopment of the new Primary Mathematics Curriculum in Ireland

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The ongoing review and redevelopment of the Primary School Curriculum in Ireland is progressing significantly. Building upon the launch of the Primary Curriculum Framework (DE, 2023a) in March 2023, the recent introduction of the new Primary Mathematics Curriculum (DE, 2023b) marks a pivotal step in this process.

Central to this comprehensive process of review and redevelopment is the emergent concept of 'agency', which holds profound relevance for both teachers and children in primary school (Burke & Lehane, 2023; Walsh et al., 2023). The Primary Curriculum Framework (2023a) delineates the vision, principles, key competencies, and components of the redeveloped curriculum. It envisions a teaching paradigm characterised by teacher agency, in which teachers use their professional judgement based on the interests, curiosities, and prior learning of children, as well as considering the curriculum and whole-school approaches. The framework emphasises the imperative of fostering child agency, wherein children are empowered to engage in and direct their learning through independent decision-making. Additionally, the inclusion of an online toolkit, used to house supports and resources for each redeveloped curriculum, provides teachers with useful tools to support the decisions they make regarding children's learning, and allows scope for flexibility in responding to future research and developments. In developing the Primary Mathematics Curriculum and toolkit, NCCA engaged in a robust consultation process (NCCA, 2023), drawing on the feedback of a wide range of educational stakeholders.

This paper will offer an overview of the research, deliberation, consultation, and collaborative work with school communities that have contributed to the emergence of the concept of 'agency' within the new Primary Mathematics Curriculum. Consistent with the theme of the conference, this paper recognises the significant role that teacher and child agency holds to ensure the adaptability and resilience of the curriculum to meet evolving educational needs in the future.

A study of changes in the level of reasoning required to succeed in Leaving Certificate mathematics since 1925

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In recent years there has been considerable evolution of the topics covered on the Leaving Certificate Mathematics papers, with changes both in the areas covered and the style of question asked. In order to study these changes, we have gathered together all of the Leaving Certificate mathematics papers since the first examination in 1925 and have also created a repository of the mathematics textbooks which have been used in Irish classrooms over the last century. To understand the level of challenge posed to students, we have picked two topics that have always been present on the syllabus since 1925: complex numbers and trigonometry. We used Lithner's Reasoning Framework [1] to analyse questions on these topics from a range of examinations. The examinations have been chosen so that at least one paper from each version of the syllabus has been studied in conjunction with textbooks from the relevant era. We report on the proportion of imitative and creative reasoning tasks in the assessment tasks and on trends evident in the data.

The Impact of a National Professional Development Programme on the Upskilling of Out-of- Field Mathematics Teachers

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In 2009 an investigation was conducted to determine the prevalence of out-of-field (OOF) teachers of mathematics in post-primary schools in Ireland (Ní Ríordáin and Hannigan, 2009). This investigation also outlined the deployment of such OOF teachers of mathematics within the school setting. As a result of such investigations a national professional development programme to upskill OOF teachers of mathematics was developed; the Professional Diploma in Mathematics for Teaching (PDMT). The programme, which is government funded, is still in operation today. This paper will provide details of the impact of the PDMT on the upskilling of out-of-field mathematics teachers over a twelve- year period. It will also provide insights into the uniqueness of the PDMT in terms of the cultural context in which it was developed (Governmental support, Teaching Council regulations, teacher shortages, employee contracts etc) and how it compares to other such programmes internationally. In-depth mixed-methods research conducted at various stages examining how the PDMT, its design, structure and implications of accreditation requirements impacted on the experiences of graduates will be included. Data sources incorporate several questionnaires/surveys, mathematical knowledge for teaching assessments, and interviews. Details of how the initial prevalence of OOF teachers was determined are outlined along with comparison figures from a follow up survey 2018.

Outcomes include a reduction of the prevalence of OOF teachers in post-primary schools in Ireland along with details of how the design, structure and accreditation requirements impacted on the experiences of graduates (Ní Ríordáin et al 2022). Findings also include consideration for the pros and cons of a large-scale upskilling programme such as the PDMT. Key lessons learnt/emerging from the Irish experience can provide useful insights to those not only examining the OOF phenomenon but more generally examining best practice in pre and in-service teacher education nationally and internationally.

Laboratory work in undergraduate chemistry studies – a look back and forward!

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Most, if not all, undergraduate courses in chemistry have a significant portion of time devoted to practical work in the laboratory. Why? There is almost universal acceptance that laboratory work is an essential part of chemistry and is necessary for students to develop the practices that allow them to be a successful chemist (Hofstein &Mamlok-Naaman, 2007).

Generally, laboratory work is identified as important to support theory, develop conceptual understanding, provide opportunities for critical thinking and problem solving, as well as developing particular skills in use of specific apparatus and equipment and increasing student engagement. However, laboratory work is costly to implement, is time consuming, there are safety issues to consider, and it involves many staff both technical and academic.

Therefore it is important that the activities that are conducted during the laboratories (both virtual and hands-on) are designed and assessed in accordance with the aims of the laboratory (Bretz, S. L., 2019)

In this presentation, particular focus will be on introductory chemistry laboratories. The focus will be on addressing the general mismatch between the purpose of laboratory work and the activities conducted, drawing on experience of how even small changes to the activities can be beneficial in achieving the aims. Examples of activities addressing different aspects will be highlighted. An important aspect also addressed is the appropriate assessments of the laboratory work (Agustian, et al., 2022).

A model of integration of aims, learning outcomes, activities and assessment will be presented that can be used to interrogate and develop (or adapt) laboratory activities to increase their effectiveness. Can the past experience help in future proofing the laboratory work?

Interventions to promote STEM teacher education: Optimising design to maximise impact

Michelle Fitzpatrick and Aisling Leavy

Mary Immaculate College, Limerick

The new Irish Primary Curriculum Framework introduces STEM as one of five broad curriculum areas, and a draft primary Science, Technology and Engineering specification is currently under consultation. Traditionally, STEM content has been taught as discrete disciplines across the sectors, with initial teacher education (ITE) being no exception (Huang et al., 2022; Lo, 2021; Zhang & Zhu, 2022). Given that few teachers have been exposed to integrated approaches as learners, many report being unable to imagine what this looks like in the classroom (Dare et al., 2018; Shernoff et al., 2017). The new focus on integrated and interdisciplinary approaches, therefore, creates an impetus to re-examine how we explore the STEM disciplines in ITE. This paper presents an action inquiry to prepare preservice teachers for the new demands of STEM education. Participants were two groups of preservice teachers (PSTs) (n=30 and n=28) undertaking a mathematics education specialism as part of their undergraduate programme. Drawing on a range of qualitative (including pre-/post-intervention surveys and STEM task analyses, story-line graphing exercises and participant interviews) and quantitative data (Survey of Attitudes Towards Statistics survey), we report on

two 12-week integrated STEM interventions. While both modules differed in their approach, common themes were generated throughout. Findings across both modules indicate that purposefully designed, interdisciplinary STEM education experiences at the ITE level can create informed, confident STEM teachers ready to take on new integrated teaching roles. Opportunities to engage as learners of integrated content supported participants in developing the required STEM literacies and exposed them to the rich and ambitious pedagogies necessary for effective classroom implementation. Collaborative field practices corroborated this learning as they witnessed theory play out in practice and observed the benefits for children. Challenges were also noted as the PSTs negotiated the blurry boundaries of STEM education. We report on the difficulties in positioning meaningful mathematics within integrated tasks. Responsive to these challenges in the first iteration of this module, the subsequent design forefronted mathematics as the central discipline. Journeying with these preservice teachers from the lecture room to the primary classroom and back allowed us to examine their evolving understanding of STEM education over time and observe the development of their STEM teacher identities. Implications for ITE and STEM education are discussed.

Would you like to make a battery?: Addressing misconceptions through public engagement

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Almost a decade ago, the RSC's public attitudes to chemistry report found that most people were unable to see chemistry as being personally relevant to them, lacking examples of concrete applications. A quarter felt that school turned them off chemistry and nearly half felt that the chemistry learned at school wasn't useful to them.[1] A recent public attitudes survey from Ireland by SFI also found similar attitudes to science, with chemistry mentioned alongside physics as a "difficult subject", once again associating it with school and formal learning.[2] It has therefore become crucial to break this stereotype through the provision of relevant applications which are reflective of chemistry's broad nature. This is in addition to the well-established goals of outreach such as tangible and diverse role models, a sense of belonging and improving self-confidence, among others.[3,4]

An underutilised chemistry application which has become increasingly relevant to everyone's life is 'energy'. In addition to the aforementioned established goals of outreach, the Current Chemistry Investigators (CCI) public engagement programme also aims to reduce misconceptions and improve understanding of energy science through the chemistry of batteries.[5,6] In particular, batteries have become key to stabilising the inconsistencies of renewable energy like solar and wind.[7,8]

Due to the lab based nature of chemistry, much outreach takes place in formal spaces such as schools, higher education institutions or museums, which may contribute to the formal image of chemistry.[9,10] Here we will outline how we have addressed misconceptions and showcased tangible role models informally, through a new activity designed to "spark" conversations. Feedback was obtained at multiple public engagement events to determine participant level of "enjoyment". Using a "smiley face stand", over 1,000 participants to date were asked to rate their experience on a 5-point Likert scale. 56 people were also selected across different age groups to partake in a more detailed survey. This group was asked 5 additional questions, where answers were a mixture of yes/no, multiple choice and 5-point Likert scale.

STEM making and making sense of STEM

Lulu Healy and Alex Hadwen-Bennett

CRESTEM, King's College, London

This contribution will present results from an ongoing research programme based in the Centre of Research in Science, Technology, Engineering and Mathematics (CRESTEM), and focussed on designing and investigating inclusive STEM learning scenarios. By sharing snapshots from different projects within this programme, we will outline how Vygotsky's work with disabled learners and his concern for social justice inspired us to treat disability as a potential strength rather than an inevitable deficit (Vygotsky, 1993). As we re-visioned his work from the 1920s and 30s, it became aligned with aspects of Papert's constructionism (Papert, 1980; Papert & Harel, 1991), along with contemporary views from both embodied cognition (Barsalou, 2008) and disability studies (Valle & Connor, 2011). We will describe how these perspectives were operationalised in our own work with disabled learners and their teachers in a series of design-based studies. Participants engaged in STEM learning opportunities designed to be congruent with the diverse ways that they sense and make sense of STEM knowledge, by adopting making as our pedagogical approach and by providing learners with access to tools that privilege multimodal experiences of STEM objects, relationships and properties. Our findings indicate how STEM learning involves building from senses of past activities, as the actions, emotions and sensations associated with them are re-enacted. Based on our analyses, we argue that the entanglement of emotion with cognition in sense-making processes makes it critical that discourses and practices that disable rather than empower learners are avoided in inclusive STEM scenarios. Our presentation will bring examples of some of the learning scenarios we have explored, including tactile approaches to engaging with programming, experiencing number as paintings and musical compositions, and the repurposing and recycling of retro-materials into STEM artifacts.

Investigating the communication of mathematics in post primary DEIS schools

Diarmaid Hyland[1], Aoibhinn Ni Shuilleabhain[2], Emma Owens[2]

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A significant amount of a students' time engaged in mathematical conversations occurs in the post primary mathematics classroom. This goes on to be leveraged in other subjects (and outside of school), but the formative experiences occur in this setting.

The research question is as follows: How is mathematics being communicated in post primary mathematics classrooms in Ireland? By focusing on how mathematics is communicated in the post primary setting, the intention is to contribute to the dearth of literature emerging from contemporary Irish classrooms. The additional context of DEIS status highlights an existing inequity which is also under-represented in the academic space.

Seventeen mathematics lessons were observed across four post primary DEIS schools in 2023. In total, over 14 hours of classroom learning was captured in audio format, supplemented by video footage of whiteboard work. The audio data has been transcribed, and is currently being analysed by the research team using a general inductive approach. This approach to qualitative data analysis allows for themes to emerge from raw data, which, in turn, will provide a rich description of classroom discourse in contemporary Irish classrooms.

The preliminary results suggest that teachers leverage multiple effective strategies throughout their lessons, and most of the discourse relates to either student empowerment, assessment, or mathematical content. With respect to mathematical content, it was observed that one teacher's

communication was exemplary, but most teachers had a range of issues of varying significance which speaks to barriers toward numeracy education of students in Ireland.

'I'm a lot more confident than I was' – Examining the influence of rich tasks on students' productive dispositions in mathematics.

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It has been argued that proficiency in mathematics involves more than just skills or understanding and that a productive disposition is a core element in the development of mathematical proficiency (Kilpatrick et al., 2001). However, how students develop a productive disposition in mathematics has received little attention in research literature (Grady, 2016; Graven, 2012). The purpose of this research is to address this gap in research and practice. In this study, a school-based intervention was designed to enhance primary students' learning in mathematics, specifically promoting their productive dispositions in mathematics. This study was conducted over five months, involving 113 sixth-class students (aged 11-12 years) in a primary school in Ireland. Ten rich tasks were designed and implemented to align with the primary mathematics curriculum and support the development of students' productive dispositions in mathematics. The design principles used to develop these rich tasks in mathematics were carried out through an iterative process using an Educational Design Research (EDR) approach. To explore students' experiences of engaging in rich tasks and to examine the influence of these tasks on their dispositions in mathematics, student focus group interviews were conducted at the end of the intervention.

Findings from the analysis of data suggest that primary students' dispositions in mathematics are local and malleable. Factors that may influence productive dispositions in mathematics include students' prior knowledge, familiarity with the context of a task, challenges posed by the task, and the local classroom environment. Further findings indicate that these rich tasks afforded opportunities to develop mathematical thinking, fostered positive student attitudes and enhanced confidence in mathematics. This study has implications for designing and implementing rich tasks in mathematics that can support student learning and foster productive dispositions in mathematics. This presentation will focus on the findings from the analysis of student focus group data and implications will be discussed.

Learning to teach inquiry: a comparison of Queensland and Irish science preservice teachers

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Reforms in science curricula internationally highlight the need to teach science using inquiry based science education. Exploring the extent to which two different cohorts of science preservice teachers (PST) intend on involving learners in active cognitive engagement in their teaching is the focus of this paper. The Quality Teaching Framework developed by the New South Wales Department of Education and Training and based on authentic pedagogy research and the productive pedagogies model was utilised as an analytical framework to map the intellectual qualities of the intent of teaching. This case study includes two regional universities,

one in Australia (UniSC) and a second case in Ireland (UL). In both cases, the PSTs were completing their first science curriculum and pedagogy module. The Australian PSTs were in their third year of a Bachelor of Science or Bachelor of Education (secondary) programme. The Irish PSTs were in their second year of a Bachelor of Science (Education). The study adopted a mixed methods approach using student lesson plans and online student interviews. Lesson plans were coded for intellectual quality under the main categories' of deep knowledge, deep understanding, problematic knowledge, higher-order thinking, substantive communication and student direction using the Quality Teaching Framework rubrics. Science preservice teachers were also interviewed and this data was analysed thematically to identify examples of the Quality Teaching Framework. Some initial analysis reveals Australian preservice teachers planned significantly better for deep knowledge, deep understanding, and substantive conversation whereas Irish preservice teachers planned better for problematic knowledge and student direction. The influence of the preservice science teachers' experience of learning science and science pedagogy modules are discussed. This research raises important questions of how preservice science teachers may be effectively supported during major science curricula reforms.

Beyond Boundaries – teaching Education for Sustainability beyond science: a cross-curricular approach

Karen Kerr and Jennifer Roberts

Queen's University Belfast

This project evaluated the use of a co teaching model of practice (Murphy and Beggs, 2010; Kerr, 2018), to deliver Education for Sustainability (ESD) using a cross-curricular approach in secondary level classrooms. Science and English student co teachers worked together to co-plan, co-deliver and co-evaluate a series of ESD lessons, bringing their own subject expertise.

This project had four overarching aims with regard to teaching and learning for the environment and sustainability in post-primary Science and English:

> *A1. Provide opportunities for Science and English (student) teachers to co-plan, coteach and co-evaluate ESD lessons*
>
> *A2. Promote contact and shared learning experiences between Science and English (student) teachers, to further enhance their competence in cross-curricular teaching.*
>
> *A3. Develop (student) teachers' experience and expertise of using ESD-related tasks and activities with post-primary students.*
>
> *A4. Produce and trial classroom materials to support the wider implementation of teaching ESD in secondary Science and English classrooms.*

Several schools in Northern Ireland were involved, with almost 70 pupils aged 11-14. The outcomes were evaluated using several data collection methods: pre and post online questionnaires with pupils, follow up focus groups with a subsample of pupils, student teacher reflective diaries and follow up interviews, interviews with colleagues in schools and lesson observations. Pupil questionnaires included various scales: Youth leadership and policy control (Peterson et al., 2000) in relation to the environment, attitudes to and understanding of environmental sustainability (Manoli, Johnson and Dunlap, 2007), critical literacy/communication, views on Climate Change (Christensen & Knezek, 2015) and their perspectives on learning through cross-curricular co teaching (adapted from Kerr, 2008).

The effectiveness of this approach was demonstrated through positive outcomes for all participants. The project also provided student teachers with pedagogical approaches for teaching outside a specialist subject area. Based on more recent work by the presenters (McClune, Kerr and Roberts, in press), we will go further to make a link to the teaching and *learning of critical eco-literacy through cross-curricular avenues, with Science and English as the perfect partnership to develop this essential concept among children and young people.*

Delivering a course on spatial thinking in transition year – the teacher experience

Ganjina Khujanazarova

Technological University Dublin

Spatial ability plays a central role in enhancing students' comprehension of STEM-related subjects (Wai, Lubinski & Benbow, 2009). Numerous studies have highlighted the benefits to performance in STEM disciplines across different academic levels following the delivery of an intervention to develop spatial ability (Sorby, Veurink, & Streiner, 2018). However, it is important to understand teachers' views and beliefs when implementing such an intervention (Gagnier, Holochwost, & Fisher, 2022) so any concerns they have can be addressed and any challenges they face can be overcome. In this study, teachers were trained through workshops to deliver the 'Developing Spatial Thinking' course to transition year students (approximately age 15). After the intervention was completed, teachers were invited to attend focus group interviews to learn about their attitudes to the intervention, how the students perceived the course, what skills they believed were developed and how the course could be improved. In total, 34 teachers participated and were divided into several focus groups, with one researcher-interviewer in each group. The questions were the same in all the groups and the responses were recorded, transcribed, analysed, and reported.

The findings reveal that both teachers and students positively received the program, attributing its success to the quality of instructional materials, interactive components, and software applications. Notably, data indicated that teachers delivering the course for the second year reported increased confidence in implementing the activities and addressing learner challenges as they emerged. Several teachers were impressed by how the activities facilitated the integration of engineering and architectural tasks into mathematics classes, fostering tangible connections to real-world contexts (Humphreys & Lubinski, 1996; Gohm, Humphreys, & Yao, 1998). Moreover, the incorporation of animations, real-world applications, manipulatives, videos, and workbooks has been acknowledged as highly successful in capturing the interest of even the students who often find mathematics challenging, leading to a fresh comprehension and enthusiasm.

Despite the few challenges, facilitators in both years found the program and its resources essential for student learning and expressed a desire to continue implementing the activities in the future. Recommendations for improvement include addressing IT infrastructure, fostering a collaborative network among teachers, to facilitate the exchange of experiences and further enhance the effectiveness of the program.

A Design-Based Research Approach to Developing, Evaluating and Modifying Learning Pathways

Mary Kingston, Aisling Twohill, Siún NicMhuirí

DCU Institute of Education

Research suggests that putting learning pathways at the centre of a primary mathematics curriculum helps connect goals, curriculum components, assessment and teaching strategies (Clements et al., 2004). The effectiveness of this approach is evidenced by the growing use of learning pathways as a foundation for many mathematics curricula internationally (Clements & Sarama, 2004; Shiel & Dooley, 2022). For example, the recently revised primary

mathematics curriculum in Ireland that is due to be implemented in schools starting from September 2024 includes a series of learning pathways, described as progression continua.

In this session, we propose a methodological approach for the development of a learning pathway. This proposal is examined in the context of a study that aimed to design and test learning pathways for describing the development of young children's probabilistic thinking. A design-based research approach was taken and data were collected through 96 task-based individual interviews across three phases. A five-step model presented by Anderson and Shattuck (2012) was followed and each phase had a specific focus, as proposed by McKenney and Reeves (2018). Initial drafts of the learning pathways were developed through a synthesis of existing frameworks. Design changes were made following each phase of analysis. We recommend this methodological approach for use in future research studies that aim to develop learning pathways relating to children's understanding of other mathematical concepts.

Supporting Science Teacher Professional Learning through Practitioner Inquiry

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Teacher professional learning (TPL) is an essential component of the life cycle of a teaching practitioner. Professional learning provides a range of opportunities for teachers' to reflect on their practice and to develop and enhance their current practice to impact their pupils' learning (Guskey, 2002). Internationally, there are different approaches regarding how this is offered; in some jurisdictions this is a mandatory requirement for Teacher registration and in others, such as Ireland there are national frameworks which guide this provision. A common criticism of TPL is that it often consists of one-day or short term inputs that do not lead to sustained impact on practice. In this presentation we will discuss the work and outputs of two Erasmus + plus European projects namely, Three Dimensions of Inquiry in Physics Education (3DiPhE) and Remote Inquiries in Science Education (RISE). We will discuss two different methodological approaches to facilitating, one which focused on face to face teacher workshops and another which employed a hybrid approach using both face to face and online workshops. Fundamental to both methodological approaches is the central role that professional learning communities (Vescio et al., 2008) and practitioner inquiry (Cochran-Smith and Lytle, 2009) provide to influence teacher classroom practices and most importantly lead to sustained changes. In this talk we will discuss essential components required for the successful implementation of these two approaches and share key learnings and experiences from science teacher inquiries in their classrooms.

An investigation into first year undergraduate students' thoughts while engaging with procedural and problem-solving questions in mathematics – A Pilot Study

Lauren Matthews, Fiona Faulkner, Paul Robinson, Ciaran O'Sullivan

Technological University Dublin

Like many other countries internationally, the post-primary (12-18 years) mathematics curriculum in Ireland changed from one where rote learning and procedural skills were the focus to a curriculum which placed an emphasis on deep conceptual understanding and problem-solving in real life contexts (Cunningham, Close & Shiel, 2016; Faulkner et al., 2021).

In a recent study, Faulkner et al. (2021) developed a diagnostic test to examine and compare students' procedural and problem-solving skills after the introduction of these curriculum changes. This study found that incoming undergraduate students performed statistically lower when engaging with problem-solving questions when compared with their performance when engaging with procedural questions (Faulkner et al., 2021). This work therefore called for a qualitative investigation into what challenges students may be having, when they engage with both procedural and problem-solving questions in mathematics. This research aims to carry out such an investigation using the Faulkner et. al (2021) diagnostic test combined with a 'think-aloud' protocol. The 'think-aloud' protocol requires students to verbalise their thoughts while engaging with a given task, allowing one to access what is happening in the student's short-term memory (Cowan, 2019; Ericsson, 2003). This paper outlines preliminary quantitative and qualitative data collected in TU Dublin during the academic year 2022/23. The quantitative findings are in line with those found by Faulkner et. al (2021) however additional insights are revealed about the nature of students' challenges via the think-aloud data which focuses on two pilot interviews. An initial analysis from the two pilot interviews which implemented the think-aloud protocol suggests that students felt that the presence of additional text had a negative impact on their performance for the problem-solving questions in comparison to the procedural questions.

Bridging the Boundaries: Practices and perspectives of integrated STEM from the island of Ireland

Beverley McCormick[1], Mairéad Holden[2] and Michelle Fitzpatrick[3]

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Science, Technology, Engineering and Mathematics (STEM) education remains the focus of much attention, as reflected in recent policy discourse in both the Republic of Ireland (ROI) and Northern Ireland (NI), which has highlighted the importance of quality STEM education provision. Given the instrumental role they play in influencing outcomes for young STEM learners (Cotabish et al. 2013; O'Dwyer et al., 2023), primary teachers' perceptions and practices in relation to integrated STEM are important to understand (Shernoff et al., 2017). This paper presents preliminary findings from a cross-border scoping survey, which aimed to capture the views and lived experiences of primary teachers regarding their integrated STEM practices. The survey was administered to a convenience sample of primary teachers in ROI and NI (n=123) who were invited to share their current integrated STEM understandings and practices. Respondents were invited to indicate their level of confidence with enacting integrated STEM practices and to identify any perceived barriers to their implementation of integrated STEM teaching and learning experiences. Where barriers were identified, respondents were asked to provide suggestions for what supports they would need to address these. Despite operating different primary curricula, survey findings revealed similar opportunities and challenges in both jurisdictions in relation to integrated STEM. Respondents reported that they felt relatively confident in their pedagogical practices and positively acknowledged the affordances of integrated STEM to nurture curiosity amongst primary learners and to make connections between separate STEM subjects. While respondents noted a desire to use integrated STEM pedagogical approaches more frequently, other competing curricular and assessment priorities hampered their efforts, with concerns raised around planning, assessment and leadership in STEM. Findings offer important insights for STEM education policymakers and professional development providers, and underline the need for further provisions to be made available for primary teachers in support of their efforts to enact integrated STEM practices.

Trends in Attitudes to Mathematics and Science – Insights from TIMSS & PISA

Gráinne McHugh and Theresa Walsh

Educational Research Centre

Students' attitudes to mathematics and science can influence their choice to continue studying these subjects until and for higher education. Mathematics and science are integral parts of STEM (Science, Technology, Engineering and Mathematics), areas where skills shortages are well documented in Ireland.

The Trends in International Mathematics and Science Study (TIMSS) is an international study assessing mathematics and science skills of students in Fourth Class and Second Year. Ireland has participated in TIMSS in 2011, 2015, 2019, and 2023 (for Fourth Class) and in 2015, 2019 and 2023 (for Second Year). The Programme for International Student Assessment (PISA) is an international study assessing the skills and knowledge of 15-year olds in mathematics, science and reading. Ireland has participated in all previous cycles of PISA with mathematics as the major domain in 2003, 2012, and 2022 and science as the main domain in 2006 and 2015.

This paper aims to explore the trends in attitudes to mathematics and science in Ireland over time at both primary and post-primary levels using data from TIMSS and PISA. It aims to establish whether trends are consistent across both studies. It further aims to explore the gender differences in attitudes to mathematics and science.

Nationally representative data from TIMSS and PISA are used, focusing on data for Ireland. Descriptive statistics are used to examine mean scores on the scales relating to students' attitudes to mathematics and science. For TIMSS, this includes Students Like Learning Mathematics and Science; Students Confident in Mathematics and Science; and Students Value Mathematics and Science. For PISA, this includes Mathematics Anxiety, Mathematics Self-Efficacy and Science Self-Efficacy, Enjoyment of Science, and Motivation in Science. Descriptive statistics are computed using the IDB Analyzer software which accounts for the hierarchical (clustered) structure of the data.

Beyond Numbers- The Textual Challenge Of Junior Cycle Maths for Dyslexic Students

Philippa Mcintosh

Bandon Grammar School

My research aimed to identify and explore barriers that may be faced by dyslexic students, like myself, sitting their Junior Certificate (JC) exams, heavily influenced by my own personal experience, when I sat my JC mathematics paper last year.

The investigation entailed a study of past JC maths papers, through the use of readability formulas. These formulas are highly effective methods of determining the difficulty of readability in a given text[1] essentially, the higher something scores, using these formulas, the more difficult it is to read.[2] After analysis of these papers, it was revealed that since the introduction of 'Project Maths' into the JC curriculum, the readability of the papers has increased significantly, doubling on average compared to previous years, making them significantly more difficult to read. I then compared the JC mathematics papers to the UK state exam equivalent, GSCEs[3] and found that the GCSE mathematics papers were significantly easier to read, producing far lower scores in these readability formulas than the JC papers over the last 5 years on average.

I then decided to create a test of my own, to determine whether or not dyslexic students would struggle with 'high readability' questions. I created three simple maths questions, however the readability of questions mirrored recent JC papers. I then tested 100 students who were selected at random. The findings clearly illustrated that dyslexic students, on average, took far longer to complete the test, approximately 128.23 seconds—compared to their non-dyslexic peers, who averaged 67.74 seconds. Dyslexic students also had a notably lower accuracy.

Statistical tools were additionally employed to further support my findings. They all seemed to point to the same conclusion- that dyslexic students are in fact sitting at a disadvantage.

In light of these findings, some potential recommendations could include simplifying the linguistic complexity of exam questions and extending time allowances.

Influencing pre-service teachers' understanding of STEM Education through immersive learning experiences

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The STEM Teacher Internship (STInt) programme has been established in Ireland as a professional learning programme for pre-service and early career STEM teachers. Teachers are facilitated to complete a 12-week paid internship in a STEM role and gain first-hand experience of careers in industry and the application of STEM in a wide range of workplaces. "Situation-specific" professional learning for teachers has been highlighted as an important model for achieving meaningful teacher learning and stresses the important role played by teachers' working environments in facilitating meaningful learning [1]. Consequently, teacher professional learning "needs to go beyond the acquisition of new skills and knowledge and into allowing them the time to reflect critically on their practice and to fashion new knowledge and beliefs about content, pedagogy and learners [2].

This research examines the influence of participating in the STInt programme on teachers' conceptions and understanding of STEM Education [3,4]. 32 teachers completed STInt internships in 2019 and all teachers were invited to participate in focus group interviews one year later. The data presented represents the reflections of 14 of these teachers that participated in interviews in 2020. Findings from data revealed that teachers identified the importance of making STEM education more relevant to their students through connections to the 'real world' contexts and relating to STEM careers. Teachers reflected on the importance of designing STEM learning opportunities that promote equity and inclusion in classroom practice. This paper will also discuss teacher's considerations for designing and facilitating authentic STEM learning in their classrooms.

The material culture of science education and its relationship with the history of science

Thomas McCloughlin

Dublin City University

Science at primary and secondary education levels lags behind formal science as a process of teaching or as a research activity at tertiary level. This paper outlines the relationship between the material culture of science education and its relationship with the history of science per se as . As part of this examination, and as a lens, the author also examines the Department of

Education & Science [sic] survey of schools in the 1990s coupled with the official government science teaching equipment list of the time — many of which are now considered redundant although even in the 1990s they were already historic in origin — that is of the 19th century (Brenni, 2012).

Historic science teaching items can be mapped in a time-line of when made, and when mainstream usage ceased, and this locates the type of science thought important to the practitioners at that time. Mirroring this evolution is the development of science education in the teacher education establishments, and the collection of DCU Science Archive & Herbarium may be seen as an indication of the pedagogical philosophy under-pinning the purchase of items at specific periods which correspond to curricular changes at the primary level.

A proposed survey of the types of equipment manufactured by teachers, once completed would firstly acknowledge the skills and capabilities teachers have had, and argue to provide new teachers with the skills and resources to continue with this practice. It is suggested that during the economic boom of 1997 – 2007 when extra funding was given for equipment, teacher-manufactured equipment diminished and much historic equipment was disposed of. If science in school is skill-based and content is reduced, it seems peculiar that choices to remove practical work of low cost which promoted a range of scientific and manual skills would be afforded. Finally, there is also the question whether historic science equipment collections have a role in learning science today (Adúriz-Bravo & Izquierdo-Ayermich, 2009; Heering & Wittje, 2011) — the author believes that it does indeed have such a role within the framework of History and Philosophy of Science (HPS) approach to science education and is underpinned by the theoretic framework provided by the cultural historical activity theory (CHAT) of Yrjö Engeström (see for example Engeström et al., 1996).

Investigating the impact of a continuous professional learning programme on the teaching of science by early childhood teachers in Mauritius

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Research reveals that the teaching and learning of science is considered as the weakest point in the education system at early childhood level in Mauritius and that preschool teachers do not have the necessary pedagogical content knowledge to effectively teach science as part of the Mauritius Early Years National Curriculum Framework (NCF) (Kamudu Applasawmy et al., 2016). Numerous initiatives to support teachers via once off workshops have been developed (Naugah et al. 2022). However, these have been unsuccessful as they tended to be viewed as an event rather than a process in the teachers' transformative practice. Furthermore, it is apparent that these workshops did not consider the different contexts of the schools (Hoban, 2002). This study reports on the findings from an intervention that explored the impact engagement with a continuous longer term professional learning programme had on early childhood teachers' experiences and attitudes towards the teaching and learning of science while implementing the NCF. Unlike the more traditional 'once off' workshops that are typical in Mauritius (Kamudu Applasawmy et al., 2016; Naugah et al., 2022), this continuous professional learning (CPL) programme afforded teachers with frequent opportunities to engage in hands-on activities during CPL workshops, implement the different pedagogies in their classrooms in between workshops, reflect on their experiences of implementing the activities, collaborate with peers and share classroom practices and knowledge (Darling-Hammond et al., 2017; Desimone, 2009; Tannehill et al., 2021; Van Driel et al., 2012). A mixed methods approach was adopted, and data gathered via pre- and post- workshop surveys, teachers' reflective journals and post workshop group interviews. This paper will present some *of the initial findings regarding the impact engagement with the programme had on participating early years' teachers' experiences and apparent increased confidence in teaching and learning science. The paper will also discuss how these educators implemented the workshop pedagogies into classroom practice.*

'Themes do not emerge': A reflection on the active role of researchers in doing reflexive thematic analysis in a mathematics education context

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Research on mathematics education has increasingly employed qualitative research methodologies and methods. One family of widely used qualitative methods is thematic analysis. Reflexive thematic analysis (RTA) is one member of this family and is differentiated from other forms of thematic analysis in its focus on the inherently situated and subjective nature of qualitative data analysis and the active role of researchers in the analytic process (Braun & Clarke, 2022). RTA conceptualises theme development as requiring considerable interpretative work on the part of the research team and considers themes as ultimately generated by researchers. The method also emphasises researcher reflexivity (Berger, 2015) as integral to the analytic process. However, due to constraining factors such as journal-imposed word count restrictions, the methodology sections of published RTA studies often consist of short, polished summaries of the method employed and can fail to offer a full account of the interpretative work undertaken by the research team (Braun & Clarke, 2021). Additionally, while the importance of researcher reflexivity is regularly emphasised, there are few illustrations of what this can look like in practice (see Trainor and Bundon (2021) for a notable exception). The goal of this paper is to offer a reflection on what the active role of researchers in interpreting, and maintaining a reflexive attitude towards, qualitative data may entail. We draw on examples from the audit trail we maintained while conducting RTA as part of an interview-based study with ten participants in the context of undergraduate mathematics education. We reflect upon our interpretative work that contributed to the final themes, and our collaborative efforts to try to ensure that our individual, and at times differing, perspectives on the data were combined to ultimately strengthen the quality of analysis. While acknowledging that there are many ways to conduct RTA, we hope this 'behind-the-scenes' account of our analytic process may be of interest to researchers wishing to conduct RTA in similar contexts.

Using Picturebooks in Inquiry-based Climate Change Education

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Picturebooks have been found to support teaching across curriculum areas including in relation to science education (Oberman, 2023; Akerson et al., 2019). Their use has been shown to increase student motivation and cognitive engagement and to facilitate cross-curricular integration Moses et al., 2016; Wendt et al., 2018). Frameworks for climate change education argue the importance of including social, political and ethical learning as well as scientific content (Cantell et al., 2019). This presentation describes design-based research exploring the use of picturebooks in climate change inquiries with senior primary children. The study involved the progressive refinement of a programme of lessons and retrospective analysis of the data collected across iterations of the programme delivery. This presentation proposes a model of cross-curricular inquiry for exploring climate change through picturebooks. The approach incorporates structured teaching of key content, including the science of climate change, picturebook composition and disciplinary methods, within critical and creative open-ended inquiries. The presentation highlights how the use of picturebooks, in these inquiries,

generates positive emotional experiences for children, supporting deeper learning and processing of the climate crisis.

Unveiling Algebra Readiness for Higher Education

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The well documented 'Mathematics Problem' at third level highlights students' inadequate mathematical skills upon entering science and technology-based programs (Hourigan & O'Donoghue, 2007). A 2018 Higher Education Authority (HEA) report emphasises the need for funding for "Maths enabling courses" in all third-level institutes (Liston, Pigott, Frawley & Carroll, 2018). Since then, the pandemic and school closures may have further negatively impacted students' mathematical ability. This quantitative study investigates first-year undergraduate engineering students' baseline knowledge of initial algebra in a Technological University. The aim is to assess proficiency in fundamental algebraic concepts and skills during the transition from post-primary to higher education. Evidence was collected using a standardised criterion-referenced screener (SCRS) adapted from one validated for Irish second-year post-primary students.

Data was collected from two samples (n=159 & n=156) of first-year engineering undergraduate students who were administered the SCRS in the first week of the 2022/2023 and 2023/2024 academic years. Their scores on the SCRS were compared to their leaving certificate mathematics grade, validating the SCRS for use with first-year undergraduate students. Descriptive statistics identified patterns of strengths and weaknesses in initial algebra among the student cohort. Ethical approval was granted by the Technological University where this study was carried out.

The study's findings provide valuable insights into the mathematical readiness of first-year undergraduate engineering students, confirming significant challenges in key prerequisite content areas such as relational fraction knowledge, decimal numbers, order of operations, integers, and exponents. Consequently, many students did not perform well on algebra content items related to variables, expressions, and equations on the screener, consistent with results from previous international studies. This research aims to identify specific challenges that can inform targeted interventions and curriculum enhancements to support third-level mathematics learning.

Current Chemistry Investigators (CCI): Development and Evaluation of a Scientist in a Classroom Electrochemistry Workshop

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[1] Trinity College Dublin and [2] Atlantic Technological University Sligo

Current Chemistry Investigators (CCI) is an informal education and public engagement project led by Trinity College Dublin in partnership with ATU Sligo, Tyndall, UCC and Lifetime Lab. We spark conversations about the science of energy storage and how electrochemistry is used in everyday life. Considerable previous research has found that students at all levels have difficulty understanding electrochemistry and deem it to be a difficult topic.[1-4] Since 2021 we have worked with teachers and students to provide schools with a tailored experience in core laboratory techniques and career discussions.

Our workshops encourage transition year (TY) students to choose a science subject for Leaving Cert and help Leaving Cert chemistry students continue their interest in science, in addition to providing context for the curriculum. All our activities are run by researchers from our partner *institutions, linking schools with cutting edge research and relatable scientific role models. Our researchers also benefit from the experience through practising their teaching and science communication skills, in addition to meeting and working with researchers from other institutions.*

This talk will discuss the development and evaluation of the CCI school workshops to date. It will also chart the journey and the barriers overcome by the CCI project to successfully transition feedback methods to a reliable digital format. Many schools in Ireland now have smartphone policies where use is prohibited during school time. As a result, opportunities to gather digital feedback using modern solutions such as QR codes and apps is no longer possible. Alternative approaches for digital interactivity and feedback have been incorporated into the CCI workshop using previously established technology. Pre- and post-workshop questions have achieved an impressive 81% consent and full completion rate from 1196 students to date. Numerous useful insights have been gained from this data in addition to positive feedback.[5]

Supports and challenges of embedding Education Outside the Classroom practices in four countries

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Focusing on pedagogical approaches that promote a connection with the environment seems to be an obvious strategy to align with the important issues of today's world. Education Outside the Classroom (EOtC) encompasses the process of outdoor learning in the many different contexts of our world today, classrooms in urban settings, classrooms in rural settings, classrooms with few resources, classrooms with learning challenges. This study presents findings to highlight the similarities and differences of implementing Education Outside the Classroom practices in 4 pilot countries (Finland, Hungary, Ireland & Spain) across 4 different age categories (6-8yrs, 9-11yrs, 12-15yrs, 16-18yrs). The research focuses on collecting evidence of nine teachers' perspective of implementing the OTTER Lab intervention (an EOtC initiative), through semi-structured interviews. The intervention was focused on promoting environmental issues related to the sustainable development goals mainly focused on, but not restricted to STEAM subjects. The findings of this study consider the supports needed to embed EOtC practices across diverse contexts. Challenges related to equitable access to resources and infrastructure to facilitate meaningful EOtC are identified within and across borders. This study suggests a stepwise approach to promoting EOtC that is sensitive to context, curriculum, culture and agency.

Biodiversity education or biodiversity loss? Mapping biodiversity within the secondary school curriculum across the North and South of Ireland

Natalie O'Neill[1] and Karen Kerr[2]

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This paper sets out to map biodiversity education within secondary school curricula across the North and South of Ireland. Using Content Analysis (Stevens, 2023), we first examine relevant curricula/specifications to document how biodiversity is represented across the wider national curriculum in Ireland and Northern Ireland. These include lower secondary Science and upper secondary Biology, Agricultural Science, Geography and a new senior cycle subject Climate Action and Sustainable Development in the Republic of Ireland, and we compare this with a similar mapping of relevant GCSE (Agriculture and Land Use, Biology, Geography) and A

level specifications (Biology, Environmental Technology, Geography, Life and Health Science) in Northern Ireland.

According to the Stanford Encyclopaedia (2021), biodiversity is a contraction of the term 'biological diversity' or 'biotic diversity' which refers to the 'idea of living variation from genes to species to ecosystems.' Our second level of analysis therefore examines the representation of biodiversity across three areas: genetic variation, species variation and ecosystem variation within the biology curricula in both jurisdictions. Template analysis is used in combination with NVivo to code the data as it allows for an inductive coding of overarching key themes combined with a deductive coding of categories within larger themes (King, 2012).

Against the backdrop of the biodiversity crisis (Government of Ireland, 2019), we present a critique of how the vague representation of biodiversity as a topic of study across a range of subjects does not adequately support teaching and learning about biodiversity. We argue that presenting biodiversity within curricula as a deficit (i.e. in terms of biodiversity loss) should be preceded by an appropriate understanding of biodiversity itself as a necessary part of life. We draw on the work of Haraway (2016) to support our study with a theoretical frame that rests on the decentralisation of Man from the study of biodiversity.

Exploring Early Mathematics Provision in Early Childhood Degree Programmes in the Republic of Ireland

Sandra O'Neill, Cora Gillic, Nicola O'Reilly, Margaret O'Donoghue, Julie Winget-Power

Dublin City University

This project aimed to investigate the type and amount of mathematics provided in early childhood education and care (ECEC) degree programmes in the Republic of Ireland (ROI) and document the reported self-efficacy of those tasked with its delivery. Research has shown the importance of early mathematics for later achievement (Duncan et al, 2007). Many ECEC educators are unaware of this importance and do not possess the knowledge to identify and plan for mathematical learning (Grimmond et al., 2022). Mathematical pedagogy presents a particular challenge for many ECEC educators (Neilsen-Hewett et al., 2018) as maths content is often excluded from their initial education (O'Neill, Gillic and O'Reilly, 2023).

Using a qualitative interpretive research paradigm, online questionnaires were completed by ECEC lecturers in third level institutions outlining the provision for early mathematics on their degree programmes and reporting on their confidence and self-efficacy in delivering this content.

The findings demonstrate that the quality and quantity of maths content on ECEC degree programmes in ROI varies greatly. Maths is often included as part of a module (example, within a STEM module) limiting the maths content covered. Lecturers report a high level of confidence and self-efficacy in supporting early mathematics. Findings suggest that teacher educators would benefit from and support the provision of additional supports in the sphere of early mathematics.

"Oh, I just had the greatest idea": Engaging child-participants in the co-design of an Augmented Reality app in the primary classroom

James O'Reilly, Aisling Leavy, Edward Corry

Mary Immaculate College, Limerick

Augmented Reality (AR) is an emerging technology that may have applications to primary education, allowing teachers and learners to access, manipulate and interact with shapes and objects for transformative learning (Korozi et al, 2018, Mustafa & Kilic, 2018). AR may have

particular relevance to the Shape and Space Strand of the primary Mathematics curriculum (Lai et al, 2019; Zsila et al, 2018), allowing children to identify, describe and navigate virtual shapes and spaces through the inbuilt affordances for the dynamic manipulation of objects and spaces (DES, 2023; Korozi et al, 2018; Mustafa & Kilic, 2018), developing spatial awareness and geometric understanding (Mustafa & Kilic, 2018, Safadel & White, 2019).

The increasing accessibility of AR for schools and developers motivated this research to investigate applications of AR technologies, considering how an emerging technology can be developed to support aspects of the Irish primary curriculum, emphasising the wants and needs of children and teachers.

We report on the development of a prototype AR application, PopCubes, through the use of participatory methods in partnership with children. After obtaining ethical clearance from the Mary Immaculate Research Ethics Committee, this qualitative research invited a convenience sample of 21 children to use PopCubes and, through visual data collection methods, surveys and focus groups, provide suggestions on how it could be changed and improved. Measures were taken to facilitate the anonymity of participants, including the use of pseudonyms and the anonymisation of the school within which the research took place. Participants' suggestions were subsequently implemented into PopCubes, before the cycle was repeated to evaluate the newly refined technology.

This presentation will share the methods of data collection adopted in this research, sharing the changes made by the child participant researchers with the aim of suggesting how AR for use in primary education may benefit from the findings of this research.

Using a 'What You See Is What You Get' Electronics Circuit Simulator to Improve Student Confidence and Experience

Leah Ridgway

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The session discusses the use of a 'what you see is what you get' (WYSIWYG) electronic circuit simulation tool to build skills and confidence for non-specialists in fundamental practical electronic engineering methods.

Undergraduate students first work with TinkerCAD Circuits building and simulating the behaviour of components and code before physically constructing those systems to evaluate the practical realities. TinkerCAD Circuits also allows the construction of C++ code in a 'code blocks' format, side by side with C++ syntax allowing students to understand the fundamental logic design and removing the cognitive overload associated with traditional methods of teaching the language. Practical work within engineering at university has been described as "a complex interaction between theory and practice" [1]; the laboratory curricula was designed specifically to bring the two modes together in the same space. The practical activities had two phases in the design; first, a skills development phase where learners engaged with new tools and techniques [2]; followed by a problem-based learning phase with less formal instruction and instead a set of functional specifications (as seen in industry) with additional optional scaffolds presented.

In electronics education, some literature exists on running entirely online (virtual) laboratories and experiments, particularly those presented as a retrospective on operational changes required during Covid restrictions. Of particular interest is Rihar et. al. [3] where mixed-method labs were evaluated using a quantitative approach. The study detailed within this session is novel in utilising qualitative and quantitative methods to explore the learning experiences of students who are not engineers, asking about their perceptions of engineering and their confidence after the laboratories.

The qualitative analysis utilises reflexive thematic analysis (RTA) to identify themes across a dataset [4]. While the content of engineering and science is quantitatively focused, learning in the discipline is suited to a qualitative analysis as this is an individual and subjective experience. RTA was selected as it inherently provides flexibility; to explore what the participants would bring up in discussions themselves in response to stub questions on confidence and experiences.

This session is a reflective retrospective of the experience with the pedagogical design presented alongside a series of take-aways that can be used by attendees in their own professional practice. It is of particular interest where learners need to interact with electronics and software but who do not plan to study engineering at third level. This talk provides consideration to how this free simulator tool can be used to support practical work in a virtual space, so that students can spend time exploring without the requirement and expense of physical equipment.

Developing a mathematical eye through photography: a resource to pose and solve challenging tasks

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We are experiencing deep changes in different areas of society, in particular in mathematics education. So, school mathematics requires effective teaching that engages students in meaningful learning through individual and collaborative experiences, giving them opportunities to communicate, reason, be creative, think critically, solve problems, make decisions, and make sense of mathematical ideas (WEF, 2016). In this context, several researchers refer to the importance of photography outside the classroom for the understanding of math contents, allowing them to understand its applicability and its connections (Kenderov et al., 2009; Meier et al., 2018). Students can see elements in the surrounding contexts, captured through a digital camera that can be the context for creating a mathematical task (Bragg & Nicol, 2011). An image of a real situation captured through a digital camera has a fundamental importance in solving and posing problems (Meier et al., 2018). So, it is important that future teachers are aware of the mathematics around them, with all the complexity, beauty and challenge that it encloses, allowing them to pose problems. This paper reports a study, carried out with elementary pre-service teachers (3-12 years old), in an active learning context, that aims to select and construct tasks establishing connections between mathematics and reality, where visualization has an important role. In particular we aim to identify the features of the environment privileged by the pre-service teachers' mathematical eye and their main difficulties in task design. An exploratory qualitative methodology was adopted and was data collected in a holistic and interpretive way, including observations along the whole experience, the set of photos chosen and written documents (report; poster). Data were analyzed through an inductive approach (Erickson, 1986; Miles & Huberman, 1994). Results suggest that the participants privilege buildings as the basis for posing problems; expressed some difficulties in the design of high-level cognitive tasks; and the outdoor photography experience had a positive impact on developing their own "mathematical eye".

Outcomes of a 'fractions as measures' intervention in a school-university collaboration

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In this presentation we describe a school-university co-designed intervention study focused on fractions in the senior primary grades. Traditionally, fraction teaching begins with exploring fractions as parts of an equally divided whole, often represented visually as the sharing of an object. This project explores an alternative 'fraction as measure' starting point, where unit fractions (a fraction whose numerator is one) are always apart from the reference unit and conceptual understanding is developed through iterating (repeating) fractional pieces of a unit to measure lengths (Cortina et al., 2015). International trials of this approach show evidence of improvement in fraction-size comparison tasks (Cortina et al., 2019).

An Irish school-university partnership began in early 2023 with initial focus on improving mathematical talk and reasoning, an area of challenge identified by participating teachers. The first round of co-designed lessons was trialled in 2023 by two teachers with small groups of 3rd and 5th class students. Successes with encouraging mathematical reasoning and talk were noted, but it appeared that students viewed the measure-based activities as separate from traditional fraction tasks, as evidenced in reversions to traditional procedures, sometimes incorrectly remembered, when they worked on fraction equivalence and operations tasks. This prompted the design of an adapted lesson sequence in which the fraction as measure orientation was extended more explicitly into work with fraction comparisons and fraction addition and subtraction, and trialled by expanded teacher teams with 3rd, 5th and 6th class groups in 2024.

In this presentation, we share details of the adapted lesson sequence and the ways in which and language through which the fraction as measure orientation is introduced and linked with fraction comparison, and addition/subtraction. We also share details of pre- and post-test outcomes across the three intervention classes, and reflect on the learning across the research team from the collaboration.

Facilitating the Integration of STEAM in Early Childhood Education Pedagogical Practice

Paula Walsh

Dundalk Institute of Technology

This paper presents findings from stage 3 of an ongoing doctoral research study which engaged early childhood education [ECE] educators in a STEAM (science, technology, engineering, the arts and maths) training workshop aimed at facilitating the integration of STEAM into ECE pedagogical practice.

Although Irish educational policy is placing an increased focus on the inclusion of STEAM in ECE, primary and post-primary settings (Government of Ireland, 2023), there is a recognised dearth of research specifically related to STEAM interventions in ECE pedagogical practice both internationally and in the Irish context (DeJarnette, 2018; Leavy et al., 2022).

Furthermore, existing research has demonstrated the influence of educator knowledge and beliefs, along with their engagement in appropriate training, on their ability and willingness to integrate STEAM into their ECE practice (Jamil, et.al, 2018; Cabello et al., 2021; Çiftçi et al., 2022).

During stage 2 of this research participants who are qualified ECE educators, engaged in surveys (n=245) and focus groups (n=6) to establish baseline data and identify barriers and facilitating factors impacting the integration of STEAM. Findings from stage 2 informed stage 3 and the development and implementation of a STEAM training workshop. Pre- and post-training surveys and a post training focus group were undertaken to evaluate the impact of the workshop on pedagogy. Participants in stage 3 were a new cohort of qualified ECE educators.

Preliminary findings from stage 3 indicate that, of 153 workshop participants, 93% (n=142) reported an increase in their knowledge of STEAM post training. Of that number, 28% (n=40) reported their knowledge increased a lot and 59% (n=84) reported their knowledge increased significantly. Furthermore, 89.5% n=(137) of total participants (n=153) reported feeling more confident to provide STEAM experiences, while 91% (n=139) reported they were more likely to incorporate more STEAM in their ECE practice after the training.

This research utilises a constructivist interpretivist paradigmatic approach based upon constructivist grounded theory (Chamaz, 2006). Ethical approval was obtained from DkIT. Participants were provided with a consent form and information letter and informed of their right to withdraw. No personal or identifying information was gathered, data aggregated and anonymised.

Lightning Talks

Methodological Approach - Engineering Education for Motivation and Student Experience

Jacob Baneham[1&2], Paul Young[1] and Catriona Ledwith[2]

[1] Dublin City University, School of Mechanical and Manufacturing Engineering, [2] Centre for Talented Youth Ireland

Dublin City University offers engineering as multiple undergraduate programs and is also the home to Early University Entrance (EUE), where high ability TY students can take two modules from these programs. This research project focuses on developing a new curriculum in design education for undergraduate engineers emphasising student competency and motivation with the primary research question "Are novel pedagogical approaches and curriculum design methods impactful on student motivation and competency?"

This research takes a mixed-methods approach, using focus groups and questionnaires to analyse students' motivational profiles and competency longitudinally. The research will use two student groups; Transition Year students participating in EUE will sit an updated version of the undergraduate module EM106 – Project and Technical Drawing, and undergraduate engineers will act as a control group.

In this post-COVID world there are pressures from students and society to improve and adapt engineering education. Polyakova describes students born after 2000 as "digital natives"; different from the previous generation [1]. Holik and Sanda show that these students have deficiencies in communication skills [2], with Donnell et al. stating many industry managers consider the communication skills of engineering graduates weak [3]. The project will use Jones' MUSIC Model of Motivation to design interventions to improve the motivational environment in engineering education [4].

Jones' MUSIC Model of Academic Motivation Inventory will be used to study motivation quantitatively [5]. This model forms motivational profiles of students, using a multidimensional approach to capture insight from the varying types of student interaction and their perceptions of course content. The research will use a collection of competencies relevant to engineering graduates based on both academic literature and accrediting bodies like Engineers Ireland [6]. The analysis of the model will be used to understand the acquisition of communication skills, measuring students' perceived ability and their relative importance compared to other skills.

Circular Future- ready with formal and informal learning

Priya Dharshini Augusthian[1], Orla Kelly[1], James Lovatt[1] and Jack McCarthy[2]

[1] Dublin City University and [2] The Rediscovery Centre, Dublin

As a part of the global move towards a green and sustainable future, The European Union has introduced the circular economy action plan in 2020[1]. This shift from a linear take-make-waste model to a circular model promoting resource reuse, repair and regeneration has been adopted by many countries worldwide, including Ireland [2,3].

While formal education is known to play an important role in this transition towards the Circular economy, and current curriculum and curriculum development in Ireland reflect this, it's important to look at a multitude of strategies[3–6]. There is scope to address this transition through informal (non-formal learning)[7–9]. The blend of formal and informal learning can enable children to be "Future-ready" i.e., to be aware of and equipped with the knowledge of global trends and policies, and possess the skills, attitudes and values required to live sustainably.

This study adopts a change theory-based framework in partnership with the education team of the Rediscovery Centre, Ireland's National Centre for the Circular Economy[10]. The developed framework will be used to study and optimise the fusion of formal and informal learning in the context of the Rediscovery Centre's education programmes. The results of this research can thus support students to be "future-ready", looking beyond the boundaries of formal schooling to work towards a sustainable future.

This presentation will discuss a developing theoretical framework, "appreciative inquiry" to explore the interrelationship between formal and non-formal education with the aim of developing an understanding of CE education. Appreciative inquiry is regarded as an alternative to deficit-based approaches to change in organisations[11,12]. It is especially well-suited for current educational research, as it shifts attention from highlighting negative aspects to recognising and improving the positive aspects of teaching and learning[13].

Investigations of students troubleshooting strategies in Physics and Instrumentation

T.J. Kelly

Department of Computer Science and Applied Physics, School of Science and Computing, Atlantic Technological University

Students are often expected to engage in troubleshooting as part of middle and upper division physics and instrumentation courses. In upper division physics, there are often courses that involve engaging in projects or project-based learning, where troubleshooting plays a major role. In this study, pair-wise interviews were used to empirically study students' troubleshooting strategies when repairing a malfunctioning basic control system. Students were presented with an electrical circuit that is typically used in the construction of closed loop control systems: the inverting emitter follower amplifier. Think aloud paired interviews were used whereby students were videoed fixing the circuit and encouraged to express their thoughts as they went along. The circuit was intentionally equipped with three isolated faults for the students to find. Videos were transcribed and split into two-minute episodes for analysis. Grounded theory was initially used to identify emergent themes, after which a deductive coding scheme was used to analyse students' troubleshooting. Two complementary theoretical frameworks were used in the analysis: Social Mediation Framework and Experimental Modelling framework in line with Stetzer et. al (2016). This empirical study aims to recognize the prevalence of interference in students' application of metacognition, and experimental modelling when taking corrective action for a malfunctioning electrical circuit.

Signs in Context: STEM Education and Irish Sign Language

Elizabeth Mathews, Seán Herlihy and Shaun O'Boyle

Dublin City University

Irish Sign Language (ISL) is a full and complex language with its own grammar, syntax and structure. It is the first language of approximately 5,000 people in Ireland, and there are sometimes gaps in the vocabulary for subjects such as science, technology, engineering and maths (STEM).

The ISL STEM Glossary at DCU is an open-source, searchable collection of STEM terms in ISL. Terms are chosen for the glossary based on the requirements and interests of deaf students, their teachers, and members of the deaf community. Signs are researched and developed by ISL experts and deaf community representatives, in collaboration with teachers (primarily deaf teachers) and subject experts. The selected signs are filmed, annotated, and shared online as a living resource, shaped by ongoing input from the Deaf community.

Between 2018 and 2023, our team added almost 1,000 signs to the glossary—spanning physics, mathematics, chemistry, biology, environmental science, and geography. A key aim of the glossary project is to improve the inclusion of deaf and hard of hearing people in STEM learning and engagement in Ireland.

In 2023, we began development of Signs in Context—a collection of fifty engaging videos presented in ISL, each exploring a different scientific topic. In this lightning presentation, we will introduce Signs in Context and summarise the methodology of ISL STEM Glossary, including the parity of esteem between linguistics and scientific accuracy, mechanisms for community feedback, and our use of the science capital framework. We will also present the methods and key findings from our ongoing evaluation process, and discuss them in the context of STEM engagement practice and literature.

Exploring Students' use of Generative AI tools

Diarmuid McCormack and Emma Howard

Trinity College Dublin

Undoubtedly, generative AI tools are a disruptive technology for education, but also enjoy widespread use amongst the student population. For example, two months after ChatGPT's release date, a survey found that over 89% of students had used it to help with homework assignments (Ward, 2023).

Whilst initial academic concerns focus on the use of generative AI tools for plagiarism, other concerns have been raised. Kortemeyer (2023, pp. 1-2) highlights that "Virtually any physics homework problem ever assigned is available online with solutions and more or less helpful explanations". Kortemeyer suggests that the primary concern should not be ChatGPT's potential as a cheating tool, but rather its potential to take away from genuine learning. Therefore, this qualitative study is being undertaken with the intention of learning how third-level students are adapting to and using generative AI in their own studies.

Semi-structured interviews were conducted with nine undergraduate STEM students. The interview questions were structured under three headings:

1. *Understanding and awareness of generative AI Tools*
2. *Students' use of generative AI tools*
3. *Students' perception regarding the role of the university with generative AI tools*

Interviews were transcribed and thematic analysis is currently being undertaken. Initial analysis has highlighted the themes of: Generative AI as an online tutor, generative AI resulting in the enhancement of academic efficiency and students becoming reliant on the tool. This presentation will discuss the results of the interviews.

Posters

The use of imaginative tools to enhance skills development of Junior Cycle Science students in post primary DEIS schools

Evin Devenney

Dublin City University, Institute of Education

Creativity and imagination are considered important educational approaches that can help maximise student learning experiences (Tsai, 2012), and thus help to stimulate effective student learning (Egan & Judson, 2016). Kiern Egan has played a leading role in the field of imagination in education providing teachers with pedagogical approaches. Egan (1992) emphasises that imagination should be incorporated into all subjects, including science based subjects, and should not be categorised into art based subjects alone.

The term "imaginative tools" refers to the implementation of cognitive approaches involving narratives, metaphor and process diagrams (image schemas) as an approach to teaching scientific concepts, specifically concepts relating to energy processes (Corni & Fuchs, 2020). This poster will examine these approaches in detail, and discuss the appropriateness of "imaginative tools" as a pedagogical approach.

A discussion on the key findings from the literature review will be presented. In particular, the implementation of such imaginative tools in an Irish context specifically in relation to the "Energy" building blocks within the Junior Cycle Science Specification (NCCA, 2015). I conclude by suggesting that imaginative approaches could be implemented to aid with student learning and skills development in junior cycle science. Successful implementation also requires adequate and sufficient teacher professional development pertaining to imaginative tools.

How to write a scientific lab report: A short-term intervention for improving chemistry writing skills

Natalia García Doménech[1], Adrián Sanz Arjona[1&2], Nadezda Prochukhan[1], Noelle P. Scully[1], and John O'Donoghue[1]

[1] Trinity College Dublin and [2] University of Copenhagen

Writing a scientific lab report is an important skill that students develop during their undergraduate course.[1] However, first year undergraduate students, in particular, tend to struggle with this task more than others since they usually have little or no prior experience in scientific report writing.[1–4] One of the most common methods identified for developing scientific report writing skills is the "feedback approach" [3,5–11]. Although successful over time, this approach does not tackle the entire complexity of scientific report writing since the feedback provided usually only assesses the application of a student's knowledge in a lab practical setting.[1] Essentially, this approach is primarily focused on "learning by mistake",[12] with no clear guidance to follow. Previous reports have demonstrated success for a number of approaches. However, the majority are designed around the use of a semester or full academic year format, with a stepwise approach to build skills gradually.[1,13–17]

The goal of this study is to evaluate whether developing a short-term intervention through a co-creation process can be effective for improving lab report writing skills and evaluate whether this approach is effective. For this purpose, a tutorial on "How to write a scientific lab report" was prepared and delivered. The tutorial was developed to give tips and explain the structure of a lab report. The material was broad and not specific to chemistry, as we wanted to focus on the general aspects of a lab report such as presenting data in a clear way or discussing results *as a whole as well as understanding possible shortcomings. Attendance at the in-person tutorial was voluntary and the performance of the students that attended the tutorial was compared to those who did not attend Feedback from the students was also obtained to evaluate the effect of the tutorial. Before the intervention, the main problems were identified by carrying out informal interviews with the demonstrators and students. After the intervention, the data was collected by checking the overall grades of the students before and after the intervention and feedback was obtained in the form of interviews with the students at the end of the undergraduate degree.*

Investigating current practice amongst teachers of the Junior Cycle Science specification and the relationships between Junior Science CBAs, Pre-Examinations and Final Assessment results

Patrick Dundon

University of Limerick

This study aims to better understand current practice amongst Irish science teachers that are currently teaching the Junior Cycle Science specification. Six teachers from five different schools were interviewed. The interviews were conducted on a one-to-one basis via Teams. Each teacher was asked a series of twenty semi-structured questions. Teachers were asked to describe how they currently prepare their students for both Classroom-Based Assessments, the Assessment Task and the Final Assessment. Teacher's opinions on the efficacy of Pre-Examinations in Junior Cycle Science were also canvassed. All responses were transcribed and were subject to inductive thematic content analysis.

Assessment data was also collected from the five schools for the 2022-2023 cohort of Junior Cycle Science students. This data included the descriptors and/or results of the following assessment components: CBA 1 (EEI), CBA 2 (SSI), the Final Assessment and the result of the earlier Pre-Examination. The data was subjected to descriptive statistical analyses and Chi-Square tests to determine relationships, if any, that exist between student attainment in the various assessment components.

From Curriculum to Classroom: Understanding Student Attitudes in the Context of the Revised Leaving Certificate Applied Mathematics Syllabus

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Applied Mathematics is an optional subject examined as part of the Irish Leaving Certificate, a high-stakes set of examinations used to determine entry to third-level education. The subject is traditionally sat by a small number of students nationally, and its syllabus underwent a major modernising shift in 2021 after almost a century of consistency. This study aims to analyse changes to the syllabus and examine empirically whether studying Applied Mathematics affects Leaving Certificate students' Attitudes Towards Mathematics, or ATM. This ATM concept is broken into three components, namely an Affective Component, a Behavioural Component, and a Cognitive Component. Data was collected via 150 bilingual questionnaires distributed to students in English- and Irish-speaking post-primary schools. Results were statistically significant across all three components, finding that Higher Level Mathematics students also studying Applied Mathematics exhibited higher ATM scores. The study concludes with an examination of limitations and possible directions for future research, with suggested improvements including the addition of a longitudinal element to isolate how ATM changes over time. In all, this study contributes to a long-existing field of literature examining student ATM, adding a contemporary and contextualised example from the Irish education system.

Further Education Graduates Who Progress to Higher Education STEM Degrees

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This research aims to analyse Further Education graduates who progress to Higher Education STEM degrees, with a particular focus on their level of mathematical preparedness for such a progression. This requires an analysis of the Further Education sector, how mathematics is taught and assessed in the sector, and existing progression pathways from the sector into HE STEM degrees. To that end, data is to be collected from Further Education students aiming to progress to Higher Education, as is data from students aiming to make similar progressions from the secondary school sector, thereby allowing analysis of the academic performance of FE graduates relative to other entrants to HE STEM degrees.

With that in mind, the author has devised a student survey consisting of three main parts. The first part aims to collect demographic information for the purposes of profile-building. Secondly, the survey will contain the Indiana Belief Scales Instrument (Stage & Kloosterman, 1992), a questionnaire which has been used in Mathematics Education research internationally to assess students' 'beliefs' around mathematics. Lastly, the survey will contain a short diagnostic test of key mathematical skills, designed for the specific purpose of this research.

This poster will detail the design of this survey, situate it in the relevant international literature, and set out the plan for the data collection and analysis phases of the research.

Collective creativity in solving authentic problems with the engineering design cycle

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Teachers play a fundamental role in students' mathematical development, using tasks as the starting point for developing different skills that are essential for social integration, such as problem-solving and creativity (WEF, 2016). In particular, tasks that challenge students to solve problems, lead to understanding concepts and encourage fluency, flexibility and originality as components of creative thinking (Leikin, 2013). Besides, STEAM education and disciplinary integration can provide students to deal with society's challenges (English & King, 2019). One possible way is solving authentic problems through the engineering design (ED) process, which enables the mobilization of STEAM areas (Hester & Cunningham, 2007). This paper reports part of a study carried out with 45 elementary pre-service teachers (3-12 years old) that attended a curricular unit of Didactics of Mathematics. We aim to analyze the performance and difficulties underlying the use of ED when solving challenging hands-on problems, as well as to understand whether the tasks and ED promote the participants' collective creativity. The experience was implemented during four classes in a total of 8 hours, where the participants worked in groups of 3/4 elements. We adopted an exploratory qualitative and interpretative approach methodology (Creswell, 2009) and data was collected in a holistic, descriptive and interpretative way through participant observation, observational notes of the future teachers' conversations, reactions, and interactions, group posters, artefacts and photos. We used an inductive approach to analyze the data (Miles & Huberman, 1994). Preliminary results show: a positive reaction from the participants to the experience and persistence and motivation were identified in the collective creation of different prototypes. Difficulties were evident in the identification of some of the concepts underlying the construction of the artefacts,

with representation from Math and Science. The ED cycle proved to be useful in solving problems, despite some of the different stages being grouped together. The participants' productions allowed us to identify the dimensions of creativity, where originality stood out, through the various stages of the ED cycle.