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Introduction: Growing back better to regenerate STEM Education

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On the 24th and 25th of June 2022 educators, researchers, teachers, students, and other members of the STEM education learning ecosystem from Ireland and beyond gathered in Dublin City University for CASTeL's 9th STEM Education research conference (SMEC). Taking a cue from what has been posited as an affective turn in social science research (Dukes et al, 2022), the conference was convened under the broad thematic banner of "growing back better" in the service of "regenerating STEM education". This growth alludes to the personal flourishing of students but importantly also their teachers. As we collectively but cautiously emerged from lock-downed learning, we sought to include under the conference call a cognisance of the role of emotion and well-being for education. The verb "grow" was deliberately chosen as an alternative to build. We cannot "build back" brains, bodies or battered spirits - these things must grow. Growth also reminds us that we share this planet with a vast range of other organic beings. As the focus turns towards grave planetary issues, of climate change and ecological collapse, we will need constant reminders as to the ultimate effects of human activities, including those in the domains of education and industry (Facer 2020; MacGilChrist 2021; Selwyn 2021).

Affective models of human behavior focus on emotions, feelings, motivations, moods. The affective construct of belonging came through strongly in the conference such as a predictor of persistence and success in STEM education and research as highlighted by the research of our keynote speaker Associate Professor Mica Estrada in her work on integration in scientific communities. The environmental element was captured by Associate Professor Maria Evagouru in her wide-ranging talk on research into socio-scientific issues through vivid depictions of her students learning in and about the environments of saltwater swamps. Affective education does not supersede behavioral or cognitive models however, rather it only incoproate or builds on them. Fittingly then our opening keynote Professor Mieke De Cock gave a tour de force of her work in the fascinating area of representations in STEM and how students may work with abstractions to build types of representational fluency to better solve mathematical and scientific problems. You can read the abstracts of these talks and many more in these proceedings but we also have a selection of full papers which we next briefly introduce.

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The area of problem solving is explored in several of the papers in these proceedings. Fitzsimons and Ní Fhloinn (2022) give an account of a doctoral study that developed a purpose-built mathematics intervention in the form of a classroom programme for highly-able mathematics students in "Transition Year" of the Irish school system. This intervention centered on group work based problem solving. An insightful paper by Neururer and Ni Shuilleabhain (2022) report on timely research investigating post-primary mathematics teachers' concerns and feedback around problem-solving and associated classroom-based assessment in the context of curriculum change. The paper reports on interview data suggesting that teachers feel constrained in attempting change to traditional practice, lacking both confidence and resources under the added pressure of a packed curriculum. But these teachers also give testimony to a desire to collaborate, develop and deepen their practice with each other. Further issues with teachers and problem-solving pedagogies are highlighted by Owens and Nolan (2022) whose findings from work with a cohort of in-service mathematics post-primary teachers showing how they often fall back on computational skills and previously learned routines and procedures rather than on developing problem solving skills.

Critical junctures representing the transition between educational levels and settings for learners were explored in two papers (Howard, Nic Mhuirí, & O Reilly, 2022; Kaur, McLoughlin & Grimes; 2022). Howard, Nic Mhuirí, and O Reilly (2022), using a methodology of narrative enquiry, report on a study that suggests that participants' mathematical understanding could be deepened by varying the forms of assessment for both formative and summative work. Kaur, McLoughlin & Grimes (2022) give a clear account of ongoing research using Practitioner Inquiry. Findings reported here show much encouragement for this approach and for enabling teachers to develop their practice to better guide students in problem solving.

Given the almost perennial issue of Mathematics teacher shortages, the issue of teacher identity, explored here in the work of Quirke (2022) makes a very useful contribution to our understanding of teachers who teach mathematics "out-of-field". Representations of identity, comprised of the "self-understandings" or stories, told by teachers about themselves as reported in this research may have implications for mathematics professional education programmes and for informing conversations around teacher certification. The theme of identity for women in STEM careers is explored by Slattery, Prendergast and Ní Ríordáin (2022) whose paper offers insights into encouraging younger girls to feel they belong in STEM fields and to have confidence in essential skills they can bring to bear in associated careers. Lastly, in another of the set of papers focused on Mathematics published here, Howard and Ní Fhloinn (2022) report on lessons learned from providing online mathematics support during lockdown and give insight into which elements could be retained as students increasingly seek digital-first supports.

Although a preponderance of the papers here focused on Mathematics, two final papers deal with the holistic conception of STEM more broadly. A paper by McLoughlin and Chadwick (2022) outlines an approach adopted to design a Framework for STEAM Education for the Youthreach initiative. This framework was developed via stakeholder perspectives and by drawing on relevant literature. It is to be used in alternative education provision to reach learners who need it most. Lastly, a very insightful and wide-ranging scholarly piece by Mooney Simmie (2022), critically weaves together studies from STEM and wider education literature from a policy perspective. The author makes a compelling case for STEM Education as "a human and relational endeavour, a sociological project that needs to be understood as an open and dynamic system - for assuring human emancipation as well as living well in a vibrant dynamic democracy - rather than a static and predictable system" (Mooney Simmie 2022, p 74). This is a very fitting sentiment on which to conclude this short introductory note from the conference chair and thus make way for the published proceedings proper.

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"We've just lost six weeks of teaching": Mathematics teachers' feedback on CBAs in problem-solving – Investigating the implementation

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ABSTRACT

This research investigates post-primary mathematics teachers' concerns and feedback around problem-solving and the associated classroom-based assessment (CBA), following significant curriculum reform. Based on a framework of concerns (Hall et al., 1977), semi-structured interviews were conducted with 16 mathematics teachers from across Ireland, representing a range of teaching experiences and school contexts. Initial findings suggest that many teachers feel constrained in attempting any change to their traditional classroom practice due to a lack of confidence and resources in implementing problem-solving in the classroom. Furthermore, teachers directly associate the concentrated nature of the curriculum content and the associated time pressures to a lack of meaningful engagement with the CBA. Teachers' feedback also emphasises the desire to collaborate with other teachers, both in considering approaches and materials but also in building confidence in their own practice.

KEYWORDS

Problem-solving, teacher concerns, teacher professional development, curriculum reform, classroom-based assessments

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Introduction

Problem-solving has been increasingly emphasised in recent waves of mathematical curriculum reform, both nationally and internationally. In Ireland this is particularly identifiable in the new Junior Cycle mathematics specification, where one of the two compulsory classroom-based assessments (CBAs) focuses on problem-solving. However, despite the focus on problem-solving in the curriculum documents, a number of studies suggest this is not being effectively translated into classroom practice (Byrne & Prendergast, 2020; Jeffes et al., 2013). Moreover, it seems teachers are experiencing high levels of concern and uncertainty around enacting problem-solving in their classroom. Therefore, despite the curricular emphasis, students may not be experiencing the types of learning environments and activities that build their confidence, knowledge, and skills as problem-solvers.

This research aims to understand post-primary mathematics teachers' perceptions of problem-solving and the associated CBA, and to investigate the nature of their concerns in the context of significant curriculum reform. It asks the question:

> What is the nature of Irish post-primary mathematics teachers concerns with regards to problem-solving and the associated classroom-based assessment following recent curriculum reforms?

Following some background to the research, the theoretical framework underpinning the research is outlined and the methodology and initial findings are presented.

Background to the Research

In recent years significant reforms of the post-primary mathematics curriculum have taken place in Ireland. In line with international trends there has been a greater focus on problem-solving and mathematical literacy. Project Maths, introduced nationally in 2010, aimed to encourage teachers to incorporate a problem-solving approach into their classroom practice. Problem-solving was further emphasised in the revisions to the curriculum at Junior Cycle in 2017. In addition, two classroom-based assessments (CBAs) were introduced. The first of these (CBA1) is a problem-solving task where students must pose their own problem and attempt to solve it. As well explicitly incorporating problem-solving into assessment at Junior Cycle, the CBAs represent a change in students' typical experience of mathematics work and in teachers' roles assessing their students' learning.

To support teachers with enacting these reforms professional development workshops were provided by the PDST (Professional Development Service for Teachers), the public body tasked with the provision of teacher professional development. Following the introduction of Project Maths there were 10 optional day-long workshops offered to all Mathematics teachers over the five-year period from 2010 to 2015. These were organised around the five topic strands and focused on classroom practice. One of these workshops was focused explicitly on problem-solving. Following the revisions at Junior Cycle, teachers were provided with subject specific professional development one day each year, with some of the time focusing on the CBAs. However, the dominant model of professional development in Ireland, usually consisting of "one-off" workshops, does not seem to align with the characteristics of effective professional development (Darling-Hammond et al., 2017) or meet teachers' professional needs with regards to the most-recent reforms (White et al., 2021). There is little evidence that classroom practices, and consequently students' learning experiences, have significantly changed and research indicates that direct instruction remains the dominant mode of teaching (Byrne &

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Prendergast, 2020; Jeffes et al., 2013). A recent study conducted by Berry et al. (2021) suggests that teachers are not comfortable incorporating the problem-solving approaches encouraged by Project Maths in their classrooms and remain unconvinced of their effectiveness when compared to traditional teaching approaches (Berry et al., 2021).
Given that twelve years have passed since Project Maths was introduced into all schools, it is of significant concern that teachers still feel unable to implement many of the promoted teaching approaches. This points to a need to further investigate the nature of teachers' concerns regarding the reform and in order to better support them to enact the principles of Project Maths and support their students with CBA1.

Theoretical Framework – Stages of Concern

The successful enactment of curriculum reform depends on the teachers who will interpret and implement it (Spillane, 1999). However, educational reforms often impose new demands on teachers, aggravating their concerns about their own practice and about their students' learning (Charalambous & Philippou, 2010). These concerns can have a powerful influence on the implementation of reforms (Christou et al., 2004).

Hall et al. (1977) proposed seven "Stages of Concern" (SoC), outlined in Table 1, which teachers experience as they implement a reform.

Table 1. *Stages of concern proposed by Hall et al. (1977)*

	Stages	Teachers…	
0	Awareness	Express little concern about, or involvement with, the reform	Self
1	Informational	Gradually become interested in the reform and seek to learn more about it.	
2	Personal	Focus on their role in enacting the reform, their personal capabilities to implement the reform, as well as on how the change will affect them	
3	Management	Consider the practicalities of implementing the reform.	Task
4	Consequence	Focus their attention on the impact on student learning	Impact
5	Collaboration	Seek to share their experiences and work with colleagues	
6	Refocusing	Begin to consider improvements, or even alternatives, to the reform	

Although distinct, the seven Stages of Concern are not mutually exclusive. It is likely that an individual will hold some degree of concern in several stages at any given time. However, the intensity of these concerns will vary as the implementations of the reform progresses (Hord et al., 2006). These seven stages were later grouped into self, task, and impact concerns. This three-stage framework is widely used in research examining teacher concerns in curriculum reform (see Byrne & Prendergast, 2020; Charalambous & Philippou, 2010; Christou et al., 2004; Conway & Clark, 2003; Johnson et al., 2020).

Studies have indicated a pattern where teachers move through these stages as a reform is introduced, implemented, and becomes established (Tunks & Weller, 2009; van den Berg & Ros, 1999). Tunks and Weller (2009) found that this shift from self, to task, to impact concerns is associated with effective implementation of the reform and is facilitated when teachers are continuously and substantially supported. To support the successful enactment of curriculum reform, it is therefore important to identify and attend to the concerns of teachers.

Recent research found high levels of self and task concerns among mathematics teachers in Ireland following the introduction of Project Maths (Byrne & Prendergast, 2020). The introduction of CBAs, and the change they represent in a teachers' role, is likely to further aggravate teacher concerns. While there is a role for professional development to play in alleviating these concerns, we must first gain a deeper understanding of the nature of these concerns and the factors that contribute to them.

Methodology

Since the focus of this research is on understanding teachers' perspectives on and experiences of problem-solving and CBA1, it demanded a qualitative approach. A key feature of qualitative research is that any attempts to understand the phenomena of study are, as much as possible, based on the participants' own perspectives and frame of reference (Elliott et al., 1999; Yin, 2015). Semi-structured interviews with teachers were therefore chosen as the primary data generation tool.

Participants

To ensure a range of perspectives were included, it was necessary to recruit teachers representing a variety of teaching experiences (gender, mathematical background, years of experience) and school contexts (DEIS[1]/non-DEIS, co-educational/single sex, small/large pupil population). To address this issue, a short online survey for potential participants was designed to obtain demographic information about them and their school context. Information about the research, along with a link to the online survey, was shared through emails to mathematics teacher email groups and to teacher organisations (Irish Mathematics Teacher Association groups), as well as posts on social media (Twitter). Teachers interested in taking part were asked to fill out the short online survey. In total, 32 teachers completed the survey. From these, teachers who had not provided contact details, had not carried out CBA1 with their classes, or were unavailable to participate in an interview were removed from consideration for inclusion. The remaining 25 teachers were contacted by email and invited to take part in an interview. 15 teachers agreed to participate in the research and a further participant was recruited through personal contacts to increase the representation of teachers working in DEIS schools.

In total, 16 teachers from 15 different schools were interviewed. Relevant demographic information is outlined in Table 2. Ethical approval was provided through UCD and all teacher names used are pseudonyms. All participants had conducted the CBA1 at least once.

Table 2. *Participant demographics*

Participant	Gender	Years teaching	School Size	Cohort	DEIS	Out-of-field
Kate	F	< 4 years	Large	Co-ed	N	N
Mary	F	> 12 years	Large	Girls	N	Y
Bríd	F	< 4 years	Large	Boys	N	N
Éabha	F	> 12 years	Small	Boys	Y	Y
Aoife	F	> 12 years	Large	Boys	N	N
Dara	M	4 - 7 years	Medium	Co-ed	N	N
Emer	F	< 4 years	Large	Co-ed	N	N
Cian	M	< 4 years	Large	Co-ed	N	N
Ben	M	> 12 years	Medium	Co-ed	N	N
Lucy	F	4 - 7 years	Large	Girls	N	Y

[1] Delivering Equality of opportunity in Schools (DEIS), is a government initiative focused on addressing the educational needs of children and young people from socio-economically disadvantaged communities.

Cillian	M	< 4 years	Small*	Co-ed	N	N
Ciara	F	> 12 years	Large	Boys	N	N
Liam	M	>12 years	Large	Co-ed	N	Y
Rory	M	7 - 12 years	Large	Boys	N	N
Billy	M	>12 years	Large	Co-ed	Y	N
Deirdre	F	7 - 12 years	Small	Girls**	Y	N

*Cillian's school was only recently established and at present has students up to fourth year. **Deirdre's school is becoming co-educational and currently has both boys and girls in first year.

Data Generation & Analysis

The SoC framework informed the development of the interview schedule, with opportunities provided for teachers to potentially address and elaborate on their concerns in each of the seven stages. In line with the qualitative approach adopted, questions were open-ended allowing participants to use their own words and take any direction they wanted with their response (Yin, 2015).

The interviews were conducted online via Zoom, lasted on average 55 minutes, and were audio-recorded. The interviews were auto transcribed using the integrated Zoom transcription function. These were then checked for accuracy against the recordings and edited accordingly. Any identifying information was removed, with pseudonyms used for all teacher and school names, before being imported into NVivo12 for analysis.

Once all interviews were transcribed and anonymised, they were read through a number of times to develop familiarity with the data. The initial phase of analysis involved coding instances of teachers expressing concerns relating to the SoC framework. Data was coded by both authors to ensure agreement in the assignment of codes and to provide further insights into teachers' responses with regards to their enactment of the curriculum reform.

Initial Findings

Although data analysis is ongoing, there are several preliminary findings emerging from this initial phase of analysis.

Management concerns were ubiquitous for participating teachers. All participants expressed concerns regarding the practicalities of implementing the reforms. Most of these were related to time pressures and constraints felt with regards to the curriculum. A number of teachers felt unable to devote the necessary amount of time to problem-solving in their classroom, due to the volume of content in the curriculum and the limited amount of time they had to teach it.

> "It's just being able to facilitate [problem-solving] in the classroom under the time constraints seems to be a serious challenge to me." (Mary)
>
> "I just find the curriculum is so busy there's so much to cover that you, I just feel that I don't, particularly with a higher-level group, that I don't have the time and the space." (Aoife)

In addition, some teachers were concerned about the six weeks assigned to the two CBAs and viewed this as six weeks taken from their classroom teaching time.

> "It's six, seven weeks overall with the assessment task (…) that's a lot of time given up to is when they still are preparing for an exam that's 90%...There's still the exact same stuff to be done, but we've even less time now, because of the seven weeks" (Cillian)

Other management concerns related to the difficulty in sourcing appropriate resources for both CBA1 and problem-solving in general. Teachers did not feel that resources provided to them in professional development were of use in the implementation of the CBA in the classroom.

> "Finding the resources takes time. Examining them, making sure they are applicable to your class, how do you integrate them into lessons, that all takes up an enormous amount of time." (Dara)

Collaboration was a dominant theme across the interviews. Many teachers cited collaboration with colleagues as a key source of support in enacting these reforms. In addition, there was an explicit desire for more collaboration. Teachers spoke about wanting to know what other teachers were doing in their classrooms and expressed a desire to share practice with colleagues across schools.

> "I'd love… yeah to know what other teachers are doing that's working well" (Éabha)
> "I would love […] more collegiate discussion" (Aoife)

A number of teachers' wishes for increased collaboration was rooted in a desire to build assurance in their own practice. This was especially noticeable in Deirdre's and Cillian's interviews. Both of these teachers come from small schools with only one other teacher in their department.

> "I think [what would support me is] more opportunities to work with schools around, because I think the biggest thing schools are struggling with is we're so confined to our own school, you know we think we're doing a great job but there could be something we could be doing even better". (Cillian)

Regarding CBA1 and students' experiences, a number of teachers felt that it did not impact greatly on their students' mathematical learning.

> "I have concerns that some of the students wouldn't have learned a whole lot from it" (Mary)

Other teachers felt that, if not handled correctly, undertaking CBA1 could have a negative effect on students' engagement with and attitudes towards the subject.

> "I'd be afraid that if it wasn't done in a way that kind of supports the students while they're doing it, that they'll actually be really disengaged with the maths and say, well, I can't even do an easy, a seemingly easy project" (Cian)

This contrasted with other teachers' views that the CBA had the potential to positively impact on students' affective disposition with regards to mathematics.

> "[The students] reacted very positively and, and I suppose just the fact that they can see the relevance of maths in their everyday lives, has been huge." (Rory)

> "It helps them as well, in the course, they come back with a slightly more positive attitude, changed attitude towards maths because they've made something of it themselves" (Billy)

Within this research, there is limited evidence of refocusing concerns and very few teachers expressed what changes they would like to see with regards to the reform. Of the refocusing concerns articulated, they related to superficial elements such as the timing of CBA1.

Discussion and Conclusion

This research investigated the experiences of post-primary Mathematics teachers in engaging with and enacting problem-solving, and the associated CBA, in their classrooms. The prevalence of task, or management, concerns reported by teachers is consistent with previous

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research on post-primary mathematics teachers following recent curriculum reform. Byrne and Prendergast (2020) found high levels of task concerns among the teachers they surveyed while Berry et al. (2021) found that time was a key factor in many teachers' low uptake of the problem-solving approaches promoted by Project Maths. The initial findings from this research suggest that time remains a key factor hindering the enactment of problem-solving in the classroom and that this may have been further exacerbated by the introduction of CBAs. Among the teachers participating in this research, there is a perception that problem-solving is time-consuming in comparison to more traditional, direct instruction approaches and that spending time on such activities is not warranted given the nature of the final formal post-primary examinations, i.e. the Leaving Certificate, that students will take. These concerns around the limited amount of time available to deliver an overcrowded curriculum is contributing to the gap between intended and implemented curriculum. Interestingly, teachers did not express concerns about their role in assessing students' work but did express concern regarding the rigid nature of the provided assessment guide and lack of opportunities to compare these with other schools.

In addition to the management concerns outlined above, the recent reforms require significant changes in teachers' daily practice and consequently demand significant time in planning. This is particularly the case as teachers feel unsure of how to meaningfully practice problem-solving in the classroom. Teachers struggled to find appropriate resources to support their enactment of problem-solving and CBA1. Professional development aiming to support teachers in enacting problem-solving in their classroom has not alleviated these efforts and teachers highlighted the lack of a broad range of examples and assessments on which to base their own classroom practice. In order to alleviate these task concerns and support teacher learning, professional development that is grounded in classroom practice and focused on teaching strategies, linked with specifically designed and accessible resources, may be useful in assisting teachers to enact these reforms (Borko, 2004; Darling-Hammond et al., 2017; Desimone, 2009).

The dominance of collaboration concerns among the teachers who participated, and the explicit requests for more opportunities to share and discuss their practice with colleagues suggests that such collaborative professional development opportunities should be provided to teachers. This may be a surprising finding, given the traditionally isolated nature of teaching in Ireland (Gleeson, 2012). At present, teacher professional development in Ireland does not seem to provide adequate opportunities for teachers to work collaboratively and meaningfully discuss their classroom practice. This has likely been exacerbated due to the Covid-19 pandemic, as professional development moved to an online format and the possibility of informal collegiate discussion has been reduced. Given that providing teachers with opportunity to share ideas and reflect together on pedagogy can be such a powerful form of teacher learning (Darling-Hammond et al., 2017; Desimone, 2009) and can contribute to successful enactment of curriculum reform (Ni Shuilleabhain & Seery, 2019), the findings of this research should be taken into consideration in the provision of support for teachers in their incorporation of problem-solving and CBAs.

The lack of refocusing concerns is worthy of note, particularly considering that the reform has been in place for 12 years. This may point to a lack of teacher efficacy in considering the enactment of the reform and requires further research.

The research is limited by the small number of participating teachers and the fact that few of the participating teachers were out-of-field, thereby potentially unrepresentative of the population of mathematics teachers in Ireland (Ni Riordain & Hannigan, 2011). Nonetheless, we hope it contributes to the literature on the mathematics reforms in Ireland.

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Career Aspirations of Female STEM Students

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ABSTRACT

The STEM gender gap is caused by the interaction of several complex and nuanced factors, all of which need to be considered when designing effective interventions. Providing students, parents and teachers with information about the broad range of career opportunities that STEM can offer is one of the factors frequently discussed in the literature. Addressing this information deficit is also identified as a specific action amongst the Recommendations on Gender Balance in STEM Education. The perception that STEM careers are not compatible with students' desire to work with people or on areas of societal benefit is a commonly held misconception that deters female students from considering STEM pathways. Dispelling this stereotype should form a key emphasis for STEM promotion and information campaigns; particularly those targeted at younger teenagers. This paper presents an account of the career aspirations of undergraduate and postgraduate female STEM students. The research forms part of an ongoing PhD study focussing on the key factors influencing women who do choose STEM careers. The students interviewed (n = 21) are nearing the end of their programme of study in STEM and are considering future career paths. Many have undertaken work placements or internships and have experienced varied career opportunities. Thus, they offer a unique perspective on the interests, motivations and career goals of young women in STEM. This perspective is largely unheard in current discourse, and it is anticipated that their insights will be useful in designing promotion campaigns aimed at encouraging more female students to consider STEM as a personally fulfilling, rewarding, and exciting career.

KEYWORDS

Gender gap, female student perspectives, key influences, career aspirations, interventions.

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Introduction

> I always had people telling me that it (*engineering*) would be something that I would be good at and I think I didn't have an interest in it because I didn't know what it was to be completely honest…. I was never really educated on what it was and what I would be doing if I was doing it, you know?

This quote from Sophie (pseudonym), an engineering undergraduate interviewed as part of this study, highlights one of the many challenges underpinning the Science, Technology, Engineering and Mathematics (STEM) gender gap, namely a lack of awareness of STEM career opportunities. A survey of teenage girls in Ireland found that 87% of respondents stated a lack of information about STEM jobs as a barrier to a STEM career (iWish, 2021). Therefore, providing students, teacher and parents with information about the vast range of opportunities offered by STEM is an essential tool for addressing the imbalance.

The *Recommendations on Gender Balance in STEM Education* (Department of Education, 2022) considers STEM education from early childhood through to higher education. It discusses a STEM ecosystem where "families, early years settings, schools, policy, industry and society" (p.5) each have crucial roles to play in creating more gender balance. Four key areas for action, encompassing this ecosystem, are identified and this paper focuses on the fourth action; "Support a societal and cultural shift to address current barriers to gender balance in STEM" (p.6) which includes engagement campaigns to raise awareness of STEM careers.

This paper presents preliminary findings relating to career aspirations from an ongoing PhD research study exploring the commonalities, if any, amongst female STEM students. Career aspirations are one of the aspects being studied as it is anticipated that student insights will be beneficial in informing engagement campaigns.

Key Considerations for STEM Career Awareness Campaigns

Information campaigns aimed at raising awareness of STEM careers need also to address the main barriers deterring girls from choosing STEM. These include; gender stereotypes, confidence and interest. Multiple theories exploring these barriers are presented in research literature. No single theory uniquely captures the problem since the issues involved are complex and layered. The gender gap is best understood by considering the culmination of a range of interacting factors, at play from early childhood and intertwining at all stages and levels of girls' lives and experiences.

Barriers to STEM Entry

From an early age, girls are subjected to gender stereotypes. Parents with strong gender stereotypes around male/female roles, interests and abilities project these onto their children (Wang & Degol, 2017). Media portrayals of scientists and engineers as predominantly male, socially isolated and technology focussed (Cheryan et al., 2017) reinforce STEM stereotypes whilst a lack of female role models (Diekman et al., 2017) and little information about what STEM professionals actually do and why (Boucher et al., 2017) further exacerbates the issues. Within the wider environment, girls receive less encouragements from parents, teachers and peers to study STEM subjects such as physics (Francis et al., 2016). Thus, girls' perceptions of their place in STEM is framed from childhood and they begin to associate STEM with being a masculine domain in which they neither belong nor have the ability to succeed in.

Confidence and self-efficacy are significant factors in the STEM gender gap. Cheryan et al., (2017) highlight that female students of computer science, engineering, physics and maths report less confidence in their ability to succeed and note that even amongst students who

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perform equally well in mathematics assessments, boys are more likely to rate their mathematics abilities as high compared with girls. Furthermore, girls are more likely to believe that innate intelligence is needed to succeed in STEM and are less confident in their own natural abilities (Wang & Degol, 2017). This attitude is replicated by teachers who tend to perceive girls' achievements in physics as being attributed to hard work whereas boys' achievements are attributed to natural ability (Francis et al., 2016). Thus, girls believe that they need to put more effort and work harder than their male peers in order to achieve the same result

To wish to pursue a career in STEM, students need to feel that they have the ability required but also an interest and motivation in the area. Having an interest is as important an indicator of career preference as aptitude (Wang & Degol, 2017). Interest and ability are related since lower confidence and self-efficacy results in lower interest in STEM and less motivation to pursue a STEM career. Interest is also heavily linked with a sense of belonging (Cheryan et al., 2017).

Boucher et al. (2017) discuss the STEM gender gap through the lens of communal goals – the desire to collaborate and help others. As noted by Boucher et al.'s (2017) findings girls highly favour communal goals and their underrepresentation in STEM can be viewed as being attributed to a misperception that STEM careers are not compatible with communal goals. They suggest that girls with communal goals are less likely to feel a sense of belonging in STEM and, thus, have less interest and motivation in pursuing STEM careers. This also seems to be borne out by a recent survey of teenagers' career aspirations. Results from the 2018 Programme for International Student Assessment (PISA) survey found 15 year-olds' career aspirations to be narrowly focussed on a small range of career options. In Ireland, 60% of girls and 49% of boys expressed a desire to work in one of 10 jobs. Despite a rapidly changing sociocultural and socioeconomic landscape, teenagers' career aspirations were also found to have changed little in the last 20 years (Mann et al., 2020). Career expectations were found to differ significantly by gender, even amongst boys and girls who achieved similar learning outcomes in PISA. The top two occupations favoured by girls were medicine and teaching – aligning with communal goals theory - whereas engineering and business management were top for boys.

Focus Areas for Interventions

Thus, interventions addressing the STEM gender gap need to be multi-faceted and appeal to girls on many different levels. Francis et al. (2016) discuss the need to dispel the image of STEM subjects such as physics as being a masculine and hard domain and of the importance of presenting STEM as a welcoming and accessible option for women. They highlight the negative impact of the lack of women in subjects such as physics and stress the responsibility of the media to portray positive representations of women in STEM. Wang and Degol (2017) also present the case for more female role models and for breaking down stereotypes. They recommend the need to communicate the relevance of STEM qualifications in real world applications and emphasise actions enhancing girls' interests as well as abilities. Efforts that encourage girls' sense of belonging in STEM are proposed by Cheryan et al. (2017). The need for role models whose communal goals are being satisfied by a career in STEM is discussed by Boucher et al. (2017) who also present the case for increased awareness of the relevance of STEM applications in addressing such communal goals. Diekman et al., (2017) outline how female role models perpetuate a sense of belonging while Cowgill et al. (2021) propose that interventions should demonstrate how women belong and are welcomed within STEM.

This research study is focussed on actions aimed at female students in second level education. It seeks to build on the recommendations in the existing body of literature by demonstrating, for example, how female STEM students are finding coherence between communal goals and career aspirations. The research participants provide rich insights into skillsets needed for successful STEM careers and it is proposed that emphasising such skillsets may be of benefit in fostering female students' sense of belonging and interest in STEM.

Research Method

A qualitative research design, involving one-to-one interviews with female undergraduate and postgraduate students studying mathematics-intensive STEM programmes in University College Cork (UCC) or Munster Technological University (MTU), was implemented. Interviews were semi-structured with questions partially guided by theories exploring barriers to STEM entry as outlined in the previous section. Participants were asked about experiences in secondary school; career choices; college experience; hobbies and interests, and perspectives on the STEM gender gap. At the end of the interview participants were given an overview of theories being explored in the research study and invited to comment. Reflexive thematic analysis (Braun & Clarke, 2022) was used to explore factors influencing students' choice to study STEM in University and to identify what commonalities, if any, the students share besides their gender

To recruit participants, invitation to participate emails were sent to female students by lecturers in their departments. This email included a brief description of the rationale for the study and of how the research would be conducted. Interested students were asked to contact the student researcher for further details. Prior to interview, once the students had provided consent to participate, they were asked to complete a preliminary survey during which data on programme of study, secondary school and Leaving Certificate (LC) subjects were collated. This data is shown in the interviewee profile in Table 1 with the participants being identified by pseudonyms.

Table 1: *Research Participant Profile*

Student (Pseudonym)	STEM Programme of Study	University	Year of Study	Leaving Certificate STEM Subjects (Higher Level)
Alex	S	UCC	PhD	N/a
Alice	S	UCC	4th	Maths, Physics, Chemistry
Anne	SE	UCC	PhD	Maths, Biology
Caoimhe	E	MTU	3rd	Maths, Chemistry
Caroline	M	UCC	4th	Maths, Physics, Chemistry, Applied Maths. Design and Communication Graphics (DCG)
Clodagh	E	MTU	4th	Maths, Physics, Chemistry, Applied Maths
Emily	E	MTU	4th	Maths, Physics, Chemistry, Applied Maths
Jade	M	UCC	4th	Maths, Chemistry, Applied Maths, Biology
Jennifer	E	UCC	4th	Maths, Physics, Chemistry, Applied Maths, Biology
Kathryn	E	UCC	5th	Maths, Physics, Chemistry
Leah	E	MTU	4th	Maths, Physics, Applied Maths
Lola	S	UCC	4th	Maths, Physics, Chemistry
Madeline	S	UCC	3rd	Maths, Physics, Chemistry, Biology
Molly	E	MTU	4th	Maths, Physics, Chemistry
Natalie	SM	UCC	3rd	Maths, Physics, Chemistry, Applied Maths
Niamh	SM	UCC	4th	Maths, Physics, Chemistry
Roisín	S	UCC	PhD	Maths, Physics, Chemistry, Biology
Sonia	SM	UCC	3rd	Maths, Physics, Applied Maths, Engineering
Sophie	E	UCC	4th	Maths, Physics, Chemistry, Applied Maths, Biology
Úna	S	MTU & UCC (Joint)	Undergrad	Maths, Physics, Chemistry, Biology
Zoe	E	UCC	5th	Maths, Physics, DCG

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The interviewees programmes of study include: E (engineering, *n*=10); S (physics or computer science, *n*=10) or M (mathematics, *n*=5). Where students are studying e.g. mathematics and physics, they are included in both the science (S) and mathematics (M) categories shown in Column 2 of Table 1. As some of the students interviewed may be the only female in their class, it's not possible to breakdown the categorisation of students further as this may make the students identifiable and contravene ethical requirements to preserve anonymity of research participants.
Interviews were conducted online via Microsoft® Teams and were typically 50 minutes in duration. Students self-selected to participate and 21 third and fourth year undergraduate and postgraduate students were interviewed between January and May 2022. The interviews were recorded and once an anonymised transcription of the interview was created, the recordings were deleted.
The preliminary findings presented in this paper are drawn from thematically analysing student responses to questions asking them to describe their dream jobs, what attributes they felt were required to be a successful professional in their chosen field as well as insights students shared from experiences in a workplace environment.

Preliminary Findings

Three themes describing career aspirations were generated from the data. These are categorised as:

- Field; encompassing what type of workplace environment students would like to work in and why – including specific application areas,
- Skillsets; encompassing what attributes the students feel professionals need to work in the field and,
- Lifestyle, encompassing desirable features students are looking for as part of their career.

Table 2 shows a summary of these themes and lists the subthemes within each category.

Table 2: *Categorisation of themes relating to Career Aspirations*

	Career Aspirations	
Field	**Skillsets/Attributes**	**Lifestyle**
Healthcare Applications	Problem Solving	Variety
Lecturing/Teaching	Teamwork	Travel
Industry/R&D	Communication	Autonomy
Humanitarian	Thirst for Knowledge	Work-life Balance
	Patience/Perseverance	Job Security
	Hard Working	

Field

18 of the students expressed a desire to work within one of fields shown in Table 2. The other three students described their dream jobs in terms of specific lifestyle aspects they sought from a career in STEM. Six students wished to work in the healthcare space, four hoped to pursue careers in lecturing/teaching, six intended to work in industry or research and development organisations and two had aspirations to work in the humanitarian sector.
Students who aspire to a career in lecturing highlighted the lack of female lecturers in their programmes of study. Jennifer, who is excited to be a female engineer and help break stereotypes, takes inspiration from this as;

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I've always found that I'm quite good at explaining things to people and helping them. So I wouldn't mind being a lecturer…. I have that fantasy in my head 'cause like I've never had a female lecturer

The desire to "make a difference" was expressed by many students, Kathryn sees this as;

……..something that has a real life application….my project that I'm doing this year is looking at heart rate and seeing how that could help diagnose brain injury in neonatal intensive care units. I love that project.…..I kind of like that application part

For some of the students, their dream to work in a particular field was informed by college work placement or relevant job opportunities they availed of during college. For others it was from their experiences during their programme of study. Caroline, for example, describes how a visiting lecturer came to speak with her mathematics class about opportunities in computational neuroscience. She tells of her dream to work in this field as it would satisfy her interests in both mathematics and the human brain. She describes how studying mathematics has taught her that "maths is just so practical and applicable to any kind of field."

Skillsets/Attributes

As well as the career fields they would like to enter, the interviewees were asked what they believe are the main attributes needed to work in STEM. It's unsurprising that problem solving and analytical skills were most frequently cited by the students as these are core skills needed by STEM professionals.

However, the students equally highlighted communication and teamwork skills as key attributes. Alice believes she has good communication skills and she described how valuable this has been to her throughout her undergraduate years. For Alice the attributes of a good physicist are:

...self-belief, problem solving skills and good communication skills, which often doesn't go hand in hand with people who are really good at physics. Definitely communication is huge because, like, that's what science is built on basically - learning things off other people and new discoveries are found that way, you know…..I think it's just as important as being super intelligent is being able to communicate

Emily did work placement in industry where she was part of a maintenance team. She describes the importance of being able to communicate to everybody within the organisation when trying to troubleshoot;

Communication! It's a huge thing.........You don't think about this when you're going into engineering, but like Oh my God!, it's just all talking to teams and to people and different offices and stuff

Clodagh highlighted having good people skills as being essential throughout college, particularly when working in group situations. She says;

I think being able to work with people, definitely. Like in all the group projects I've had, the people I found the best are those who are good at interacting with people and just willing to help

Emphasising the necessity of such skillsets would be useful in fostering girls' sense of belonging in STEM, as discussed in the next section.

Lifestyle

Lifestyle factors were identified as a third subtheme within career aspirations. Financial security is frequently mentioned as one of the benefits of a career in STEM. Of all the participants in this research study, only three mentioned finance when discussing career aspirations. Only one student valued the financial security of a STEM career in and of itself. The other two students spoke of the benefits of STEM being financially lucrative in that it would enable them to finance hobbies or a desire to do humanitarian work.

A career providing variety and not "being in an office all day" (Caoimhe) were also valued by the students. Úna spoke of how, on her current work placement in a medical devices company, she saw that staff had the freedom to decide to structure their working day between laboratory and office activities and she valued this flexibility and autonomy.

Implications for Promoting STEM Careers and Lifepaths to Girls

Engagement campaigns to raise girls' awareness of the diversity of career opportunities offered by STEM need to tackle all the barriers of entry faced by female students. The students interviewed for this research study have overcome several challenges in breaking down these barriers and are now positioned to see how STEM careers offer the opportunity to fulfil personal goals in richly diverse fields.

Fostering a sense of belonging needs to dispel stereotypical images of STEM professionals as males working in isolation. In contrast to this, the participants in this research study highlighted the importance of people skills, including teamwork and communication, as being essential attributes for STEM professionals. Emphasising these attributes, more commonly associated with women, would not only help girls feel a greater sense of belonging in STEM but may foster girls' confidence in believing that they bring valued and necessary skills needed to optimise the use of STEM applications across the entire range of fields. As well as promoting the diversity of STEM career opportunities, it's worthwhile to also promote the people skills needed for STEM jobs to reinforce to girls that they do fit within a STEM environment.

While the career aspirations of the research participants lay in several different fields, common amongst all the students was the vision of how their STEM qualifications could be applied in any area of their choice, in a manner satisfying their personal goals. The perception that STEM careers provide less fulfilling pathways for people with communal goals who wish to work in collaboration with and helping other is one of the most significant deterrents that needs to be addressed. In this research study, students who expressed communal goals found no incongruity between goals and STEM careers. Instead, they had identified clear pathways of how their STEM qualifications could be applied in diverse fields including healthcare applications, teaching, environmental challenges and futureproofing electronics systems. Not only did they recognise communal goals opportunities in STEM, they also saw how their identities could bring a significant contribution in their chosen fields.

Conclusions

The importance of female role models is widely cited in the literature. Greater collaborations between schools and universities, including opportunities for students – particularly in Junior Cycle (JC) – to collaborate with undergraduate and postgraduate female STEM students may encourage more girls to remain in STEM for Senior Cycle. Mentoring programmes where JC students can meet with and learn from the experiences of current university students may have significant benefit in fostering interest, motivation and belonging. As young professionals, female STEM students share ideals and values with teenage girls and are well positioned to highlight how they are finding personal fulfilment and rewarding opportunities as they plan the next stages of their careers. Not only would this provide JC students with an opportunity to see what's involved in different programmes of study, it would help reinforce the real life applications of STEM. Parents and teachers also need be addressed by STEM information campaigns with different messages targeted at different groups; e.g. parents may place more value on the job security and financial benefits of STEM careers.

The insights and perspectives of female STEM undergraduate and postgraduate students offer many exciting opportunities in the development of interventions addressing the gender gap.

These insights are valuable in encouraging younger girls that not only do they belong in STEM but that they bring skills essential to ensure that STEM knowledge and applications are best utilised in a manner that benefits all of society.

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Getting to Grips with Online Mathematics Education During the COVID-19 Pandemic

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ABSTRACT

The COVID-19 pandemic necessitated a move to emergency remote teaching in many universities across the globe, beginning in the early months of 2020. As a result, lecturers and students had to transition to an online form of education at very short notice. Due to the symbolic nature of the subject, online education in mathematics presented additional challenges, in terms of representing mathematical notation and communicating effectively with students online. In May 2020 and again in May 2021, we undertook an anonymous online survey of mathematics lecturers in higher education, aiming to investigate their experience of emergency remote teaching and any changes to their practice as a result. We received 257 and 190 responses respectively, and respondents were based in 30 countries, primarily in Europe. They reported on the types of hardware and software they used; whether they opted for live sessions or pre-recorded; the main challenges they and their students faced; and the changes to assessment necessitated by the move online. In this paper, we report upon their reflections of their journeys in online teaching, as they compare their initial experiences of emergency remote teaching with their approaches one year on.

KEYWORDS

COVID-19, mathematics education, higher education, online teaching

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Introduction

From around March 2020, the COVID-19 pandemic necessitated a move to emergency remote teaching (Hodges et al., 2020) in higher education across the globe. This meant that students and educators had to pivot to online teaching at very short notice, with little to no time to prepare or source the necessary hardware or software. Teaching mathematics online presents particular challenges in this regard, due to the symbolic nature of the subject and the difficulty in representing mathematical notation in many commonly-used software systems (Engelbrecht & Harding, 2005).

In May 2020, and again in May 2021, we undertook an anonymous online survey of mathematics lecturers in higher education, aiming to investigate their experience of emergency remote teaching and any changes to their practice as a result. We received 257 and 190 responses respectively, from 30 countries. The results of the earlier survey have been reported in a number of journal articles (Fitzmaurice & Ní Fhloinn, 2021; Ní Fhloinn & Fitzmaurice, 2021b, 2021c, 2021a) and explored issues such as the types of technology used; whether sessions were conducted live or pre-recorded; the main challenges faced; and the changes lecturers made to their assessments in order to conduct them remotely. Extensive literature reviews of the corresponding areas can be found in each of the above papers, along with detailed discussions of the results. While these reported on a snapshot in time, in which lecturers had about three months' experience of emergency remote teaching (often in lockdown conditions), it was of interest to explore their experiences in further detail one year on, as many were still teaching remotely. During the academic year of 2020/2021, many mathematics lecturers were engaged in what would be more accurately termed blended (Graham, 2006), hybrid (Snart, 2010) or distance learning (Moore et al., 2011), but for clarity for the respondents of the survey, we called this "online learning" and will use this term throughout.

Although we cannot accurately measure the overlap between the samples in the two anonymous surveys, we can make some overall observations about trends in their responses. Therefore, in this paper, we consider the following research questions:

- How do mathematics lecturers describe their experience of online teaching by May 2021?
- Is there any evidence of a shift in their reported experience between May 2020 and May 2021?

Methodology

Survey design and analysis

The surveys used in this study were purpose-designed, as nothing similar existed at the time. They were piloted with a group of experienced mathematics lecturers prior to distribution, and changes were made based on their feedback. The second survey, undertaken a year after the first one, made use of many of the same questions, amended to reflect the passage of time. Ethical approval was granted by the first author's university.

The anonymous online survey reported on here was issued using Google Forms in May – June 2021. It was distributed via a number of mailing lists for mathematicians, as well as highlighted at relevant online mathematics education conferences and workshops. The quantitative data was analysed using Excel and general inductive analysis (Thomas, 2006) was used for the qualitative data.

Survey sample

The profile of survey respondents is shown in Table 1. The age profile is as might be expected, with over a quarter in each of the 30 – 39, 40 – 49 and 50 – 59 brackets, and smaller numbers in the 20 – 29 and 60+ brackets. The vast majority of respondents are on permanent contracts and have over 10 years of teaching experience. Unusually, the proportion of female respondents is higher than that of male, which is not reflective of the population of mathematics lecturers. This is likely due to the fact that the survey was shared on a mailing list of female mathematicians. While it is meaningful to have included the voice of so many female mathematicians here, it must be acknowledged that the results may not be entirely reflective of the full population, given the sample size and the gender skew therein.

Table 1. *Profile of survey respondents (n=190)*

Gender	*n*	*%*
Male	87	46%
Female	99	52%
(Blank)	4	2%
Age	*n*	*%*
20 – 29	8	4%
30 – 39	52	27%
40 – 49	60	32%
50 – 59	50	26%
60+	19	10%
(Blank)	1	1%
Experience teaching maths in higher education	*n*	*%*
0 – 1 year	2	1%
2 – 3 years	11	6%
3 – 5 years	18	10%
5 – 10 years	28	15%
10 – 15 years	39	21%
15 – 20 years	17	9%
20+ years	75	40%
Employment Status	*n*	*%*
PhD / Teaching Assistant	2	1%
Short-term contract (<=1 yr)	4	2%
Long-term contract (>1 yr)	22	12%
Permanent	162	85%

The country in which respondents were working at the time of the survey is shown in Table 2. Over a third of respondents were based in Ireland, as are the authors of this work, with all but a tiny proportion of the others based in Europe. Again, while this provides an interesting insight into the spread of experiences across the continent, it cannot be presumed that the results would necessarily generalise beyond that.

Three-fifths of respondents were teaching students who were undertaking a mathematics major, while half of respondents lectured students taking non-specialist (service) mathematics. In terms of class size, 58% had small classes of less than 30 students; 57% had medium-sized classes of between 30 and 100 students; and 37% had large classes of over 100 students.

Table 2. *Country in which respondents (n=190) were working at time of survey*

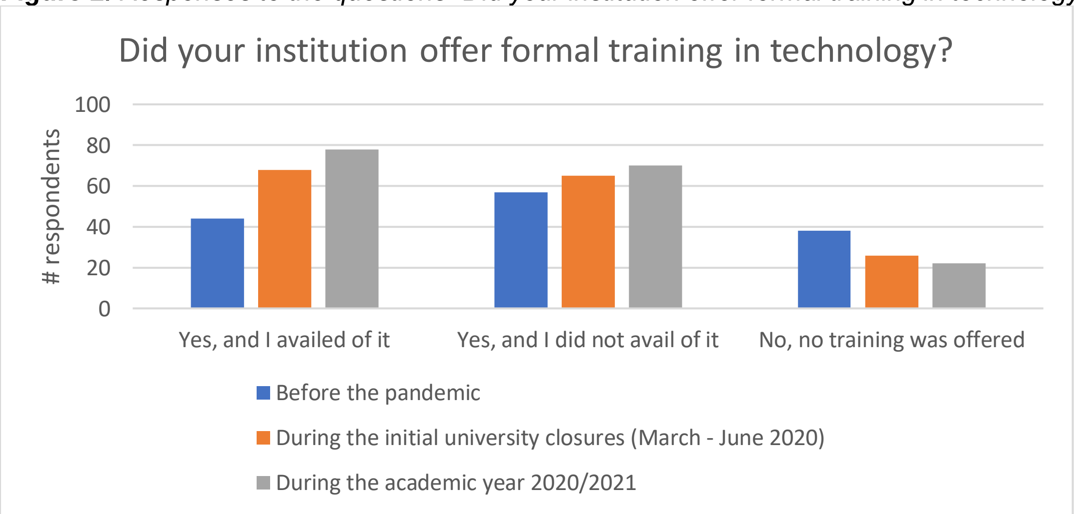
Country	*N*	*%*
Ireland	69	36.3%
UK	20	10.5%
France	16	8.4%
Italy	12	6.3%
Germany	9	4.7%
USA	6	3.2%
England / Iceland / The Netherlands	5	2.6%
Scotland	4	2.1%
Croatia / Romania / Switzerland	3	1.6%
Portugal / Sweden / Wales	2	1.1%
Argentina / Austria / Australia / Denmark / Finland / Kuwait / Macedonia / Malta / Nigeria / Poland / Spain / UAE / Unknown	1	0.5%

In the academic year 2020/2021, almost three-quarters of respondents did all of their teaching online, with a further 17% stating it was almost all online. 85% of respondents worked always or mostly from home during that time period. Prior to the pandemic, 75% of respondents had done no online teaching of any kind, with a further 13% having done only a little.

Reflections on Online Teaching

Before delving into respondents' experiences of online teaching, we first explored the training they had received in their university, to ascertain the extent and effectiveness of this. Unless stated otherwise, the data refer to the May 2021 survey data only. We therefore asked if respondents had received formal training in technology, and if so, when this was available. The results are shown in Figure 1 below. The vast majority of respondents were offered some kind of formal training by their universities, both during the initial university closures and during the academic year 2020/2021.

Figure 1. *Responses to the questions "Did your institution offer formal training in technology?" (n=190)*



The most common feedback overall about the training on offer was that it was too general and not specific to the teaching of mathematics online (e.g. *"Training tends to ignore specialist software for maths teaching and the focus for other application tends to be not applicable for maths*"). The most common theme from those who availed of training was that it was of use to them (e.g. *"generally helpful, with support for subsequent questions / problems"*). Those who

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did not avail of training mostly commented that they either did not need it (e.g. *"I really didn't need it as am fairly computer savvy"*), were too busy to avail of it (e.g. *"We were getting so many emails about online courses in IT training, it was overwhelming to be honest. I was so busy I just didn't have time.*") or that they preferred to ask colleagues for help instead (e.g. *"It was of no interest to me - talking to colleagues was a lot more useful"*).

To explore mathematics lecturers' experiences of online teaching, we asked a series of questions, where respondents had to rank various reactions to online teaching on a 5-point Likert scale. We first did this in May 2020, and the results are reported in Authors A&B (2021b). We repeated the same series of questions in our May 2021 survey, and the results are shown below.

Figure 2. *Responses to the questions "How did you find online teaching when you first began?" (n=190) and "How do you find online teaching now?" (n=190)*

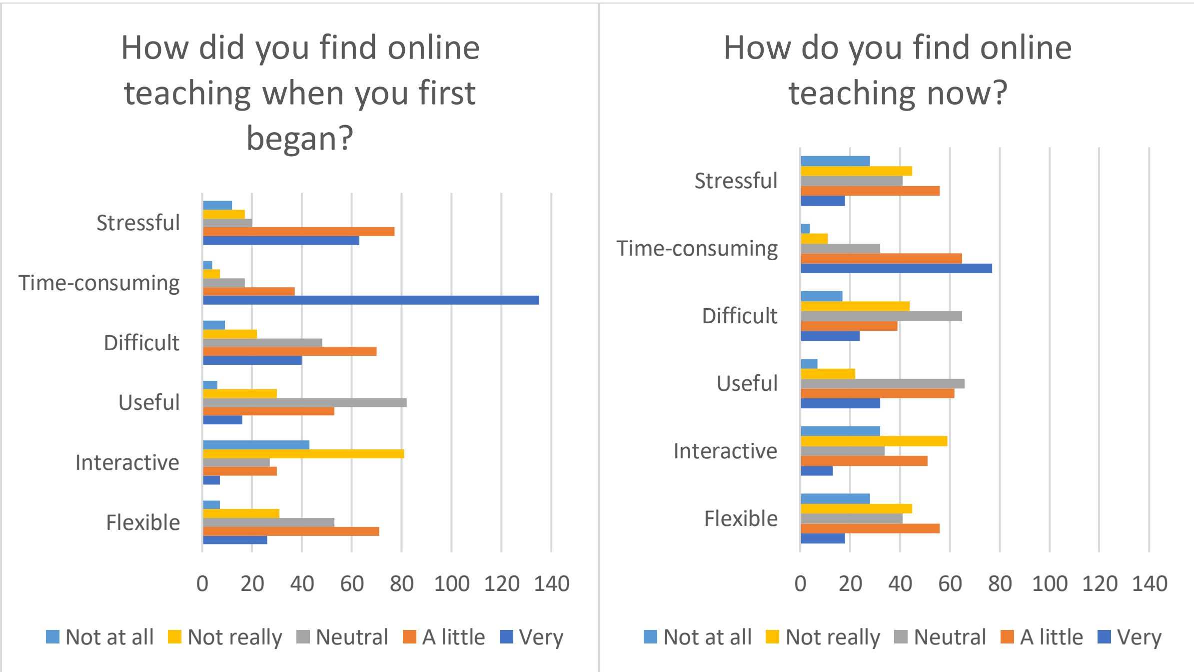
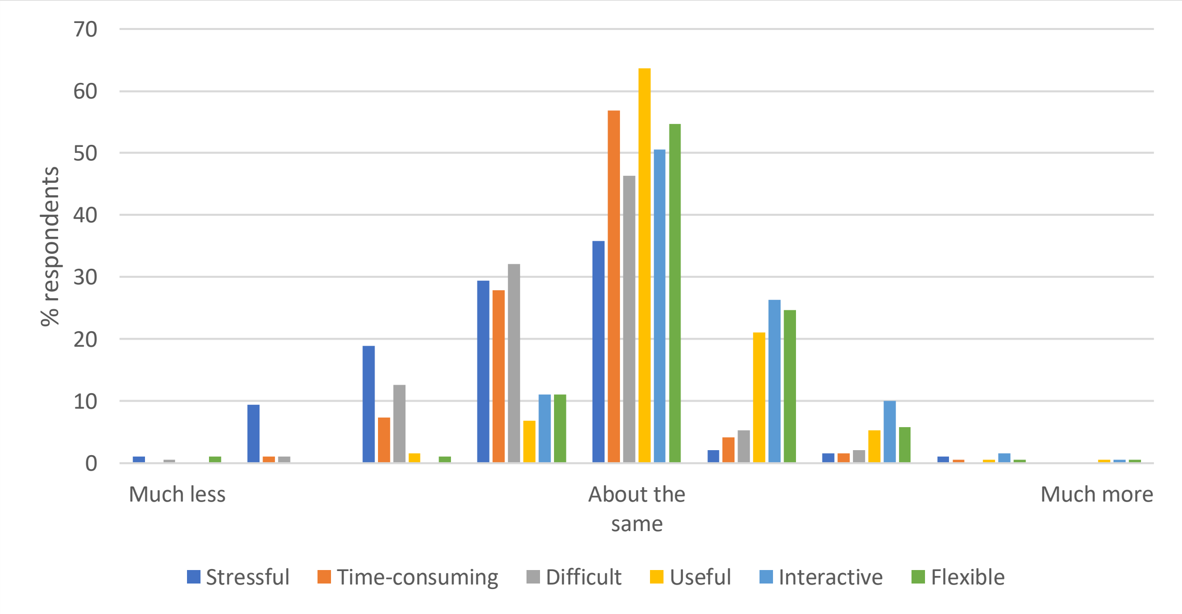


Figure 2 shows how respondents ranked online teaching, both when they first began and in May 2021. The time-consuming nature of online teaching was the most striking element to emerge, with 85% of respondents ranking it "very" or "a little" time-consuming; and although this had reduced after more than a year, it was still the most prominent response with three-quarters ranking it "very" or "a little" time-consuming at this point. 85% of respondents also found online teaching "very" or "a little" stressful when they first began, and similarly, this had only reduced to 75% by May 2021. In our previous survey in May 2020, the corresponding figures were 88% dropping to 79%. The two samples cannot be directly compared as we cannot identify the respondents in each, but the general trend can be observed, whereby there was some small reduction in the perception of the time-consuming and stressful nature of online teaching, but not a lot. It would appear that lecturers found it easier to teach online as their experience grew, as 58% found it "a little" or "very" difficult initially, which dropped to 33% by the end of the academic year. On a more positive note, lecturers' perceptions of the flexibility of online teaching increased from 51% finding it "a little" or "very" flexible initially to 62% by May 2021. Similarly, their reporting of the usefulness of online teaching increased from 36% initially in the "a little" or "very" categories to 49% a year later. Despite less than a fifth (19%) of respondents finding online teaching interactive initially, this increased to a third of respondents in the end.

We then investigated the changes in each category for each individual respondent, by comparing their responses to each of the "initial" and "now" questions. The results are shown in Figure 3. We see that the majority of respondents did not change their opinions as time went on, particularly in relation to the usefulness and time-consuming nature of online teaching. However, the stress and difficulty levels are seen to decrease. These responses mirror those of respondents in May 2020 (Authors A&B, 2021b) where a similar pattern was observed. Most respondents, if they did change their opinion, moved only one position in the Likert scale, so very few dramatic changes in their reactions to online teaching were reported.

Figure 3. *Differences between individual respondents' initial experiences of online teaching versus their experiences more than one year on (n=190)*



In order to establish how the respondents found online teaching in comparison to their regular in-person teaching, we asked the same series of questions as before (shown in Figure 4), and it emerged that online teaching was considered to be much less interactive but a little more flexible than in-person teaching. If we again compare these results with those of the survey conducted one year earlier (Authors A&B, 2021b), we see that 9% of respondents in 2021 scored online teaching as a little or much more interactive than in-person, compared with 6% in 2020, suggesting little real change. Similarly, 61% of respondents in 2021 thought online teaching was a little or much more flexible than in-person, whereas 57% reported this in 2020.

Figure 4. *Responses to the question "Comparing your experience of online teaching with your regular in-person teaching, online teaching is:" (n=190)*

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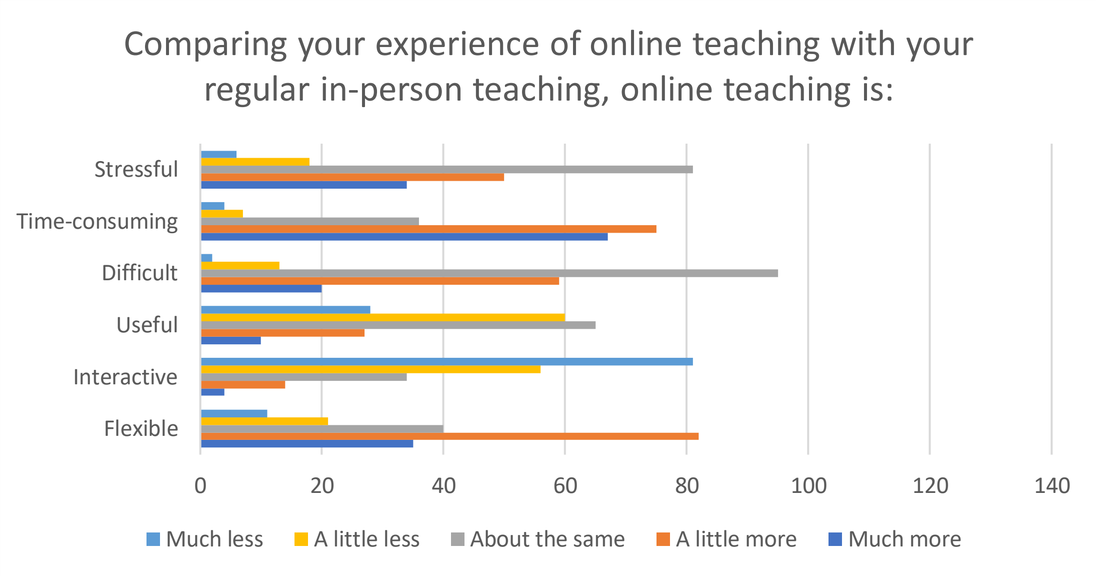
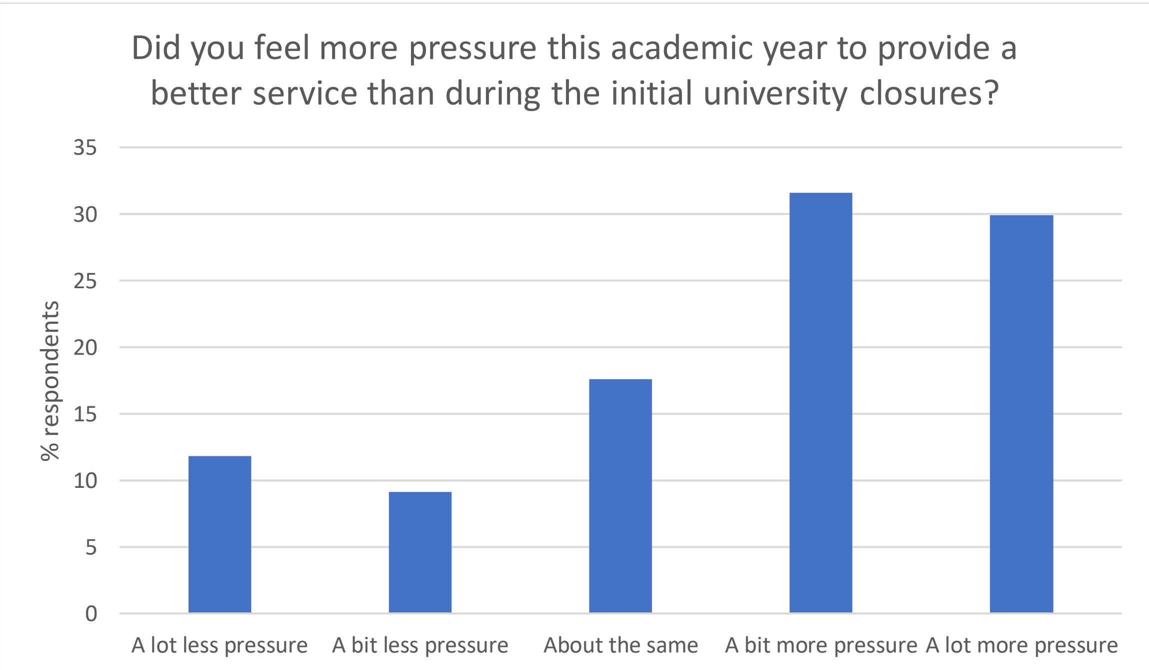


When asked if they shared teaching tips and support with colleagues more than usual during the academic year 2020/2021, 64% of respondents said that they did a bit or a lot more – just one percentage point less than the previous year's survey. So although lecturers were further into their journey of remote teaching, the increased engagement with colleagues in terms of discussing teaching approaches and techniques seems to have remained constant.

Figure 5. *Responses to the question "Did you feel more pressure this academic year to provide a better service than during the initial university closures?" (n=187)*



Respondents were then asked if they felt more pressure during the academic year 2020/2021 to provide a better service than during the initial university closures of March 2020, and over 60% of respondents agreed that they did, as shown in Figure 5. When asked for the source of this pressure, three main themes emerged with almost equal frequency: themselves, students and their university. Many respondents in the first category referenced their desire to do their very best (e.g. *"Myself most likely - I like to do the best job I can always and I really want my students to enjoy maths"*) and also their recognition that this was going to be for a longer time

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period (e.g. *"During the initial closures, what we provided felt very 'scrambled together at the last minute' -- it was very much emergency online teaching. I did put pressure on myself to ensure that if online teaching was going to last for a longer period of time, the quality should be at a standard comparable to in-person teaching*"). Those who mentioned students as a source of pressure referred to a range of factors, such as the impact of fees (e.g. *"Students even more vociferous about value for money"*), higher expectations (e.g. *"Students might expect more since we had more time to prepare*") and retention/engagement issues (e.g. *"The fear of losing the disgruntled/disinterested student*"). Finally, those who felt pressure from their university to provide a better service largely felt that decisions were made without consultation (e.g. *"Frankly unrealistic decisions made without consultation by the University management."*).

Discussion and Conclusions

The first research question we wished to address was in relation to how mathematics lecturers described their experience of online teaching by May 2021. Although lecturers had somewhat more time to prepare for this academic year of online teaching, it has been observed that advice about teaching mathematics online is still somewhat limited (Quinn et al., 2015). This was reinforced by many of our respondents reporting that there was no discipline-specific training provided by their university for teaching mathematics online. This is disappointing, given that effective training and support is vital in order to ensure proper engagement from lecturing staff when moving to fully online teaching (Jääskelä et al., 2017). Teaching mathematics online has been recognised as having a particularly steep learning curve due to the need for discipline-specific software to handle mathematical symbols (Smith et al., 2008). Lecturers also reported finding online teaching to be time-consuming and stressful, even by the end of the academic year 2020/2021, although they felt the difficulty levels had decreased as they became more used to the techniques involved. However, it should also be remembered that, in most cases, lecturers were faced with having to create online content for a full academic year, having only previously produced material for the final weeks of the year in early 2020, and the time-consuming nature of moving teaching online has long been established (Youngblood et al., 2001).

Our second research question involved exploring any possible evidence of a shift in lecturers' reported experiences of online teaching between May 2020 and May 2021, based on the two surveys issued one year apart. Overall, the results were strikingly similar between the two surveys, with lecturers still reporting similar reactions to and experiences of online teaching, despite the passage of time. As noted above, this could be due to the fact that this was still the first full academic year of online teaching, so there was a considerable workload attached to this, and many were trialling new approaches to keep students engaged with material. One area where they reported a difference was in feeling increased pressure to provide an improved service in the academic year of 2020/2021. This echoes the findings of Plummer et al. (2021), who found that lecturers in physical therapy who were*"accustomed to serving as high-functioning classroom authorities, now felt pressure to advance their novice skills as online educators to expert levels in a short period."* Given the reported levels of stress relating to online teaching, and this increased pressure to perform at a higher level, there is an obvious danger of burnout among academics in this position, as identified also by VanLeeuwen et al. (2021), who suggested a range of measures to counteract this. However, it was promising to observe that the reported increase in engagement with colleagues on teaching matters has also not changed one year on, suggesting a real opportunity for increased open discussion on pedagogy matters in mathematics in higher education among faculty members who might not have done so prior to the pandemic. It would be advisable to universities to capitalise on this by providing discipline-specific pedagogical training in mathematics, both for online and in-person teaching, in order to enhance the teaching and learning of mathematics in higher education by building upon the lessons learned through emergency remote and online teaching during the pandemic.

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OPEN ACCESS

Towards a Framework for STEAM Education in Youthreach in Ireland: Building on stakeholder perspectives

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ABSTRACT

STEAM education is a pedagogical approach that merges science, technology, engineering, arts and mathematics and aims to develop learner knowledge, skills/life skills and attitudes, while promoting engagement. It can be particularly relevant in alternative education provision settings, such as the Youthreach programme for early school leavers, in Ireland. This research is based on the implementation of a two-year project "Full STEAM ahead: A partnership approach to STEAM in Youthreach". This paper presents the approach adopted to design a Framework for STEAM Education in Youthreach, developed in light of current literature and through co-creation between researchers and stakeholders, over the first year of the project. Stakeholder viewpoints were gathered through interviews, then analysed through qualitative content analysis. This involved comparing interview transcripts to a pre-determined coding frame based on the Framework for STEAM Education in Youthreach. The Framework identifies STEAM; STEAM learning outcomes; STEAM session supports; and STEAM assessment. The proposed Framework is informed by the innovative and emerging field of literature in STEAM education and the important role that STEAM education can play within Youthreach alternative education provision in Ireland.

KEYWORDS

STEAM, alternative education, Youthreach, framework, competences

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Introduction

STEAM education

STEAM education is a pedagogical approach that merges science, technology, engineering, arts and mathematics, and has a wide range of definitions within literature. One main purpose of STEAM education is to develop students' creativity and problem-solving skills in real-world settings (Herro & Quigley, 2017; OECD, 2019; Perignat & Katz-Buonincontro, 2019). Real-world contexts situate the problem within the STEAM disciplines, allowing the integration of STEM disciplines and Arts, and exploration of STEAM in disciplinary or interdisciplinary ways (Darian-Smith & McCarty, 2016; Herro & Quigley, 2017; Perignat & Katz-Buonincontro, 2019). The level of integration of the STEAM disciplines may vary as some approaches view STEAM as "adding the Arts to STEM" (Perignat & Katz-Buonincontro, 2019, p.38), where Arts (as a synonym for creativity) plays a supporting role to STEM disciplines. Other approaches characterise STEAM education as a fully integrated approach, merging the five disciplines in a transdisciplinary, multidisciplinary or interdisciplinary way (Darian-Smith & McCarty, 2016; Perignat & Katz-Buonincontro, 2019). Learners are encouraged to view the practical applications of their developing STEAM knowledge, skills and attitudes in more relevant, realistic and familiar scenarios, with the aim of engaging and motivating learners (Darian-Smith & McCarty, 2016; Herro & Quigley, 2017). STEAM education often incorporates digital learning, through technology-based activities, digital literacy enhancing activities and creative arts involving digital tools. Alongside this focus on digital learning is the focus on design-based activities in STEAM, often utilising technology in the process (Perignat & Katz-Buonincontro, 2019). STEAM education theory is put into practice through the use of a wide range of context specific teaching approaches (Herro & Quigley, 2017).

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 provides education for young people who leave mainstream education before Leaving Certificate level, sometimes without having completed the Junior Cycle (Smyth et al., 2019). Learners may describe Youthreach as a "last chance" and the Youthreach programme offers them opportunities that were not available in mainstream schooling (McHugh, 2014, p6). Youthreach currently has 112 centres in Ireland serving around 11,000 learners (Smyth et al., 2019). The overall aim of Youthreach is to prepare young people for further education, training and employment (Smyth et al., 2019). To do so, 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). Youthreach centres are afforded a degree of autonomy to choose which courses they offer based on local contexts and learner needs (Smyth et al., 2019).

Youthreach aims to develop young people's knowledge and skills, promote engagement and positive attitudes towards education, improve personal and social skills, increase self-esteem, sense of belonging and purpose in life (Department of Further and Higher Education, Research, Innovation and Science, 2022; Smyth et al., 2019). Youthreach provision benefits from small class sizes and individualised learner support. Teaching and learning in Youthreach aims to use a variety of teaching methods where learners work at their own pace. These aspects are key to re-engaging learners in education and promoting positive attitudes towards education (Smyth et al., 2019). However, within Youthreach there are issues around learner non-attendance, which can often be due to difficult home or community circumstances. There are also concerns around high rates of non-completion of accredited programmes (McHugh, 2014; Smyth et al., 2019). Youthreach education emphasises the importance of building positive relationships between staff and learners, and learners note that their positive learning experiences stem from building these relationships with staff. Staff working in Youthreach centres have a range of experience and backgrounds, including industry, craft, mainstream education and youth work (McHugh, 2014; Smyth et al., 2019).

Research aims

Alternative educational provision in Ireland is not clearly defined in literature and policy. In addition, there is a lack of evidence-based research into alternative educational provision in Ireland upon which to make recommendations (Cahill et al., 2020; Smyth et al., 2019). The research presented in this paper is from the implementation of *Full STEAM ahead: A partnership approach to STEAM in Youthreach.* The project aims to support Youthreach staff to implement STEAM education by developing a Framework for STEAM Education in Youthreach. This Framework draws on the perspectives of stakeholders, including professionals with an interest in and working within alternative educational provision in Ireland, and on current literature in the field of STEAM education. The Framework for STEAM Education in Youthreach will be developed through co-creation between researchers and stakeholders over the pilot year of the project. The Framework aims to support the professional learning of Youthreach staff to design and implement STEAM activities with Youthreach learners.

Methods

A qualitative methodology was used to gather and analyse data. Semi-structured interviews were conducted with ten individuals, identified as key stakeholders with an interest or involvement in STEAM education in Youthreach. This included four representatives of national organisations, three Youthreach centre coordinators and three Youthreach educators involved in the pilot project. The participants were asked to discuss their experiences and understanding of STEAM education in Youthreach at the beginning of their involvement in the project. These interviews were conducted by one of the researchers using online meeting software, audio-recorded and transcribed.

Deductive qualitative content analysis was used to analyse interview. Deductive content analysis uses a coding frame (also called a categorisation matrix) to code data according to pre-determined categories (Elo & Kyngas, 2008). The coding frames (Figures 1 and 2) aimed to gather data relating to the proposed Framework for STEAM Education in Youthreach, which focused on four domains:

- STEAM characteristics: The features of STEAM education;
- STEAM learning outcomes: The development of learners' knowledge, skills/life skills and attitudes and values;
- STEAM sessions: The practical aspects of facilitating STEAM in Youthreach
- STEAM Assessment: Assessment and feedback of learning in STEAM.

The characteristics of STEAM can be summarise as: real-world contexts; disciplinary and interdisciplinary learning; problem solving; creativity; design thinking; digital literacy; and appropriate teaching approaches.

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The specific domain is indicated in square brackets after the coding category in Figures 1 and 2

Awareness of STEAM education [characteristics of STEAM]
Awareness of the value of STEAM education
Understanding of STEAM Education in Youthreach
Commitment to maintain STEAM in Youthreach
Changes made as a result of involvement in STEAM in Youthreach
Future plans and intentions regarding STEAM in Youthreach
Challenges to STEAM in Youthreach

Figure 1: *Coding frame for analysis of interviews with national stakeholders*

Plans for STEAM education in Youthreach
Skills, knowledge, attitudes of STEAM [STEAM learning outcomes & STEAM assessment]
Accreditation for courses (LCA/QQI) [STEAM sessions]
Teaching and learning approaches [STEAM characteristics]
Life skills [STEAM learning outcomes]
Inclusion of underrepresented groups [STEAM learning outcomes]
Confidence and concerns for designing, planning, teaching and delivering STEAM education in Youthreach [Educators only]
Concerns for designing/planning [STEAM sessions]
Confident about designing/planning [STEAM sessions]
Concerns for teaching/delivering [STEAM sessions]
Confident about teaching/delivering [STEAM sessions]
Planned links to STEAM industry
Learning and awareness of STEAM industry and alternative career pathways [STEAM learning outcomes]
Links with STEAM industries and role models [STEAM learning outcomes]
Plans for sharing learning
Sharing learning within the Youthreach centre
Sharing learning with other Youthreach centres
Sharing learning beyond Youthreach

Figure 2: *Coding frame for analysis of interviews with Youthreach coordinators and educators*

Findings and discussion

The Framework for STEAM Education in Youthreach was informed by analysis of interviews with participants who have an interest and knowledge of STEAM education in Youthreach contexts, alongside current literature. The participants' first-hand knowledge of alternative education provision in Ireland (Youthreach) supported the development of a more appropriate Framework for designing and implementing STEAM activities in the Youthreach context.

The Framework for STEAM Education in Youthreach identifies STEAM characteristics, STEAM learning outcomes, STEAM session planning, STEAM assessment and feedback.

These aspects were reported in literature (e.g. Herro & Quigley, 2017; Perignat & Katz-Buonincontro, 2019) and observed in interviews with stakeholders.

STEAM Characteristics

STEAM Education in Youthreach is described with seven characteristics (Table 1).

Table 1: *STEAM characteristics and relevant stakeholder quotes*

STEAM characteristic	Quote from stakeholder
a) Real-World Contexts	"We're going to take it locally and very much aim it at a world that they're familiar with." P3.1 Youthreach educator
b) Disciplinary and Interdisciplinary Learning	"There would be a cross with Craft and Design. There will be a cross with health and fitness, there will be a cross with hotel and catering, and there definitely will be a cross with maths, and with technical drawing." P3.1 Youthreach educator
c) Problem Solving	"Taking problems and coming up with solutions and relate them to the real world." National stakeholder (NC-AYRC)
d) Creativity	"Value and recognise the development of skills (problem solving, creativity, digital literacy)" National stakeholder (NC-AYRC)
e) Design Thinking	"Bring in little projects and little kits they can make and do." P3.1 Youthreach educator
f) Digital Literacy	"We're very conscious of the developing digital divide, really, for our young people in the area and beyond." P1.2 Youthreach coordinator
g) Appropriate Teaching Approaches	"Practical, hands-on, collaborative … very specific to the group of learners that I'm working with." P1.1 Youthreach educator

a) Real-world contexts

Learners develop skills and life skills, knowledge and positive attitudes towards STEAM through exploring contemporary, familiar and relevant real-life situations. This approach aims to appeal to learners' interests and motivations (Herro & Quigley, 2017). Learning within real-life and culturally relevant contexts encourages young people to identify the connections between themselves, their communities and society more widely, and connect new and existing knowledge (Caudle et al., 2021). Contexts may be drawn from the United Nations' 17 Sustainable Development Goals (SDGs) which aim to improve the lives of people everywhere (https://sdgs.un.org/goals).

b) Disciplinary and Interdisciplinary Learning

Learners explore new ways of thinking about and organising their knowledge from the STEAM areas. Disciplinary learning focuses on learning about the discrete disciplines of Science, Technology, Engineering, Arts and Mathematics. These disciplines may be combined with increasing complexity from multi-disciplinary to transdisciplinary learning (Darian-Smith & McCarty, 2016). Exploring multiple STEAM disciplines aims to strengthen learning within the disciplines and between disciplines, making explicit connections between them. This can lead to increased interest and engagement with the STEAM disciplines that learners were not previously exposed to (Herro & Quigley, 2017). STEAM Education in Youthreach aims to

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promote learning through exploring contexts with links to at least three of the STEAM disciplines.

c) Problem solving

Problem solving in STEAM education is a collaborative process where learners work together to develop and use their STEAM knowledge, skills/life skills, and attitudes and values to solve a problem set in a real-world context. Learners are encouraged to seek out and identify problems, and work together to find solutions. The emphasis is on the process, rather than the final outcome or product (Perignat & Katz-Buonincontro, 2019).

d) Creativity

Creativity is often associated with the "A"/arts within STEAM (Perignat & Katz-Buonincontro, 2019). The Framework for STEAM Education in Youthreach emphasises that creativity is inherent within and adds value to all disciplines of STEAM. The focus is on developing creative habits of mind: Collaborative, inquisitive, persistent, imaginative, disciplined (Thomas Tallis School, undated).

e) Design thinking

Design thinking is when learners use their creativity to solve real-world problems, following a five step process where learners empathise, define, ideate, prototype, and test their designs (Henriksen, Mehta & Mehta, 2019). Similarly to collaborative problem solving, the focus is on the process and skills development rather than the final outcome or design.

f) Digital literacy

In STEAM Education in Youthreach, digital tools are used to support teaching and learning and to encourage active involvement in the learning process. Learners use technology to engage in learner-centred inquiry and design processes to explore real-world problems. The aim is for learners to develop a range of digital literacy skills to support their learning, life and future careers (Department of Education, 2022). These skills relate to: proficiency in use of digital technology, communication tools and the internet; creating digital content and file management; communication and collaboration; and awareness of safety and environmental impact of digital technology (Vuorikari et al., 2016).

g) Appropriate teaching approaches

Appropriate teaching approaches for alternative education settings are a key characteristic of STEAM Education in Youthreach. The aim is to promote the empowerment of young people in relation to their learning and positive experiences for young people whose needs may not have been met by the mainstream learning environment (Cahill et al., 2020; Gutherson et al., 2011). At the centre of STEAM education in Youthreach is a learner-led approach which promotes young people having the space to express a view (space), be supported to express their views (voice), have their views listened to (audience) and have their views acted upon (influence) (Lundy, 2020). Teaching and learning approaches are broad ranging to suit the needs of learners and include inquiry-based learning, problem-based learning, project-based learning, designing and making (with focus on process and product), direct instruction/ teaching, collaboration and teamwork, authentic learning activities (field trips, visits from experts/industry) and work experience (Smyth et al., 2019).

STEAM learning outcomes

STEAM learning outcomes refer to the knowledge, skills/life skills, and attitudes and values that learners in Youthreach develop through their involvement in STEAM education. STEAM learning outcomes is the term preferred by Youthreach staff due to its use in the specification documents for the courses they teach. The term is used in the Framework synonymously for learning goals, learning objectives, learning intentions, goals or aims (Allan, 1996). Allan (1996) describes learning outcomes as "broad overarching consequences of learning" in terms of "what a learner knows or can do" (p.99).

The Framework for STEAM Education in Youthreach promotes the development of knowledge, skills/life skills, and attitudes and values of STEAM. These are developed interdependently, through the mobilisation of knowledge, skills, attitudes and values within specific real-world contexts as competences/competencies (OECD, 2019). Knowledge, skills, and attitudes and values include foundational learning on which further learning depends, such as literacy and numeracy, health/wellbeing literacy, and social, ethical and emotional literacy (OECD, 2019).

Table 2: *STEAM learning outcomes and relevant stakeholder quotes*

STEAM learning outcomes	**Quote from stakeholder**
a) Knowledge	"Teaching them the history of photography." P2.1 Youthreach educator
b) Skills	"All the life skills that go around working collaboratively … teamwork and group cohesion. But then also linking the 3D print stuff to industry and considering further employment opportunities and skills for on the job." P1.1 Youthreach educator
c) Attitudes and values	"Maybe change their attitudes towards STEAM that they may hold from traditional schooling. Most think they don't understand math … to really see that they actually have those skills." P2.2 Youthreach coordinator

a) Knowledge

In the Framework for STEAM Education in Youthreach, knowledge is defined as the established concepts, facts and figures, ideas and theories about the world (OECD, 2019). Knowledge is mobilised by learners alongside skills and attitudes and values in the performance of competencies to meet complex demands (OECD, 2019). There are different types of STEAM knowledge: content knowledge, and procedural knowledge (OECD, 2019). Content knowledge is theoretical knowledge which includes understanding of concepts and ideas of STEAM. In STEAM education in Youthreach, knowledge may be disciplinary, relating to one of the STEAM subjects, or span multiple disciplines (Darian-Smith & McCarty, 2016). Disciplinary knowledge includes subject-specific concepts and content. Interdisciplinary/multidisciplinary knowledge encourages learners to relate the concepts and content of one STEAM discipline to the concepts and content of another (OECD, 2019). Procedural knowledge, sometimes known as practical knowledge, is based on learners' experience and practice of activities and is the understanding of how something is done. This knowledge type can also be discipline specific or interdisciplinary (OECD, 2019).

b) Skills

STEAM Education in Youthreach aims to support learners to develop a range of skills, which are the ability and capacity to responsibly carry out processes and use knowledge to achieve a goal. Skills are mobilised alongside knowledge and attitudes and values as competencies (OECD, 2019). STEAM skills include cognitive and metacognitive (learning about learning) skills, social and emotional skills, and physical and practical skills. These different types of skills work together to allow learners to be successful in their education, future learning, careers and life (OECD, 2019). In STEAM education in Youthreach learners develop discipline specific skills relating to one aspect of STEAM. Learners may then apply these skills in interdisciplinary STEAM contexts spanning multiple STEAM disciplines. STEAM education in Youthreach also encourages learners to develop transdisciplinary skills such as those related to creativity and problem solving (Herro & Quigley, 2017; Perignat & Katz-Buonincontro, 2019). These are often referred to as life skills or life skills within the Youthreach context.

c) *Attitudes and values*

STEAM Education in Youthreach aims to positively influence learners' attitudes and values, which are the principles and beliefs that influence the learner's choices, judgements, behaviours and actions (OECD, 2019). Combining the various disciplines of STEAM learning and focusing on real-world contexts increases learner interest, engagement and motivation towards STEAM (Herro & Quigley, 2017). The following actions aim to promote the development of positive attitudes and values towards STEAM within the Youthreach context:

1. Facilitating learners to engage in diverse and inclusive STEAM learning experiences through a range of pedagogical approaches;
2. Encouraging learners to recognise and understand their existing attitudes and values, known as dispositions, and understand the context in which these were formed;
3. Promoting learners' STEAM identities including feeling a positive connection with STEAM and that STEAM is 'for me';
4. Fostering positive attitudes towards the different aspects of STEAM by highlighting their use and relevance in everyday life and potential careers;
5. Enable learners to use their STEAM learning to benefit themselves and their communities;
6. Enable learners to appreciate ethical aspects of STEAM.

(Cahill et al., 2020; Gutherson et al., 2011; Lundy, 2020; OECD, 2019)

STEAM sessions

This aspect of the Framework provides practical resources for planning STEAM education activities in Youthreach. It includes scheme and session plan templates to guide Youthreach staff. The templates were based on the Framework and the needs of Youthreach staff as expressed during piloting of this project.

STEAM assessment

Assessment approaches for STEAM Education in Youthreach aim to assess the development of knowledge, skills/life skills, and attitudes and values STEAM learning outcomes. Assessment approaches aim to gather evidence of learning and provide opportunities for effective feedback to support learning (Black & Wiliam, 2010). However, skills and attitudes and values are often harder to measure than content knowledge. Determining the impact of learning activities in STEAM on the learners' skills, life skills, and attitudes and values in STEAM education in Youthreach can be challenging (Perignat & Katz-Buonincontro, 2019; Smyth et al., 2019). The methods of assessment aim to reflect the purpose, principles and values of Youthreach, which emphasises personal development and core skills (Department of Further and Higher Education, Research, Innovation and Science, 2022). Assessment in STEAM

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education in Youthreach may be summative or formative. Summative assessment is a judgement of achievement, usually for the purpose of reporting. It is often conducted at the end of the learning, such as a final exam, portfolio or other format (Black & Wiliam, 2010). In Youthreach, summative assessments such as tests or exams are conducted "occasionally" (Smyth et al., 2019).

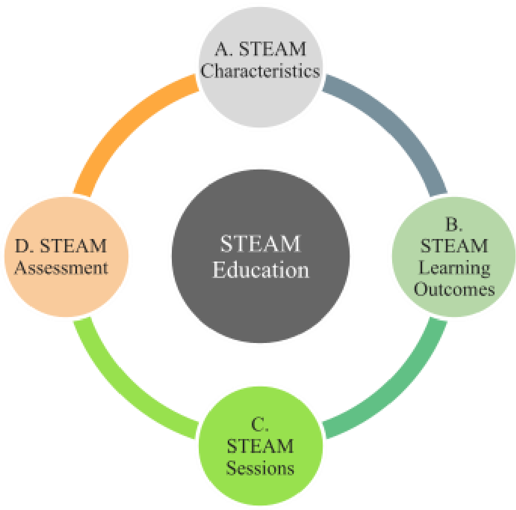
Formative assessment is assessment for the purpose of supporting learning. Formative assessment aims to make learning visible to the educator and to the learner, and gives the learner opportunities to improve (Black & Wiliam, 2010). There are various ways that formative assessment may be carried out in STEAM education in Youthreach. Examples of evidence gathered may include practical work and project work, written work, classroom dialogue, interviews, observations, learning portfolios, product designs, multimedia presentations, peer and self-assessment feedback (Smyth et al., 2019). Once evidence of learning has been gathered, it is important that learners receive formative feedback about their learning and how to improve further. Feedback is critical to improving learning as it increases learners' motivation and their ability to learn and may come from the educator, peers or the learner themselves (Black & Wiliam, 2001). STEAM education in Youthreach promotes the practice of regular feedback to promote the development of knowledge, skills/life skills and attitudes and values of youthreach learners.

Conclusions & Implications

This study presents the approach adopted to design a Framework for STEAM Education in Youthreach, developed from the implementation of the project *Full STEAM ahead: A partnership approach to STEAM in Youthreach.* The Framework builds upon the perspectives of stakeholders and current literature to propose an appropriate Framework for implementing STEAM education in the Youthreach context in Ireland.

The Framework (shown in Figure 3) 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 implementation of STEAM education in alternative education provision in Ireland. This will work towards promoting the engagement of learners who are often excluded from STEAM learning and careers, by developing their knowledge, skills/life skills, and attitudes and values of STEAM.

Figure 3: *Towards a Framework for STEAM Education in Youthreach*



The Framework will be further developed in the next phase of this project and informed by follow-up interviews with the participants in this study and other key stakeholders (e.g., Youthreach learners, project partners). Participants' experiences of designing and implementing STEAM activities will be discussed in relation to the Framework for STEAM Education in Youthreach. This will allow continued development of the Framework to align closely with the innovative and emerging field of literature regarding STEAM education and the implementation of STEAM education within Youthreach alternative education provision in Ireland.

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The journey or the destination? An investigation into the beliefs of pre-service post-primary mathematics teachers regarding problem-solving

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ABSTRACT

It has been widely reported that the affective domain is an important contributor to problem-solving behaviour among students. Cognitive resources available to students are related to the students' beliefs around what they consider useful in learning maths (Schoenfeld, 1983). Problem-solving holds a key position in both Junior Cycle and Senior Cycle curricula in Ireland. Given that much research has shown that the teachers' beliefs about problem-solving play an integral role in building positive attitudes to problem solving among their students, it is essential to investigate the beliefs of prospective mathematics teachers. The aim of this study was to investigate the affective domain of pre-service post-primary mathematics teachers in Ireland. This study was conducted in a university setting and involved the implementation of both quantitative and qualitative measures; the existing Indiana Mathematical Belief Scale (IMB), and open-ended questionnaires. Participants in the survey were enrolled in a module on mathematical problem solving. The open-ended questionnaire asked participants to describe how they felt at different stages during their attempt to solve a mathematical problem. This was then analysed using an inductive approach. A statistical analysis of the IMB (n=151) showed that students strongly believed that an increase in effort can have a positive influence on mathematical ability. However, it was concerning to find that students believe that problem-solving involves learning step-by-step procedures. Another positive finding of the IMB was that students strongly value the understanding of mathematical concepts over memorization of procedures. In contradiction to this, it was found through the analysis of the open-ended questionnaire that students had a greater focus on achieving an answer rather than on the problem-solving process. We discuss the implications for the design of the module, which seeks to support the development of the capacities required for the successful teaching of mathematical problem solving.

KEYWORDS

Mathematical problem-solving, affective domain, prospective post-primary teachers

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Background

Problem-solving has always been a part of mathematics, but the formal study of problem-solving has a shorter history with a prominent role in the earliest stages taken by Polya (1945). Schoenfeld (1985, p. 69) states that Polya's work on problem-solving "is held in high regard by both mathematicians and mathematics educators". Schoenfeld (1992) attests that there is a wide variety of meanings for the terms "problems" and "problem solving": this has been highlighted more recently by Lester (2013). It has been highlighted that with the focus on developing problem solving, there is confusion regarding the actual definition of problem-solving (Stanic & Kilpatrick, 1989). Acknowledging the lack of clarity on the definition of problem-solving but recognising the need for clarity, from a review of the literature there appears to be consensus on the following aspects of problem-solving (Chamberlin, 2008; Lester & Kehle, 2003):

1. Problem-solving includes a goal;
2. It is not immediately clear how to achieve the goal;
3. The problem-solver must organize prior knowledge to generate reasoning towards achieving the goal.

Throughout this paper, we will refer to these as the Three Key Characteristics of problem solving.

The lack of agreement described above must be set against the widespread acknowledgement of the importance of problem solving in the mathematics curriculum both nationally and internationally (Conway & Sloane, 2006). In Ireland, problem-solving is one of the six elements of the Unifying Strand of the Junior Cycle specifications and is specifically mentioned in each strand of the Senior Cycle mathematics syllabus. Similarly, this privileged position that problem-solving holds is evident internationally (Cheng, 2001; DfE, 2013; Mullins et al., 2016).

The role of the affective domain on problem-solving

Lester (2013) notes that it is widely agreed that the development of students' problem-solving capabilities is a main goal of mathematics instruction. The realisation of this goal involves multiple factors such as metacognition and beliefs along with factors associated with the teacher (Schoenfeld, 1992). It has been widely reported that the affective domain is an important contributor to problem solving behaviour (Lester & Kroll, 1993). McLeod (1988) set out to provide a theoretical framework for investigating the affective factors that are associated with problem solving. McLeod (1988) defines *affect* as a term used to represent "all of the feelings that seem to be related to mathematics learning" (p.135). He highlights that a variety of emotions can be expressed while a person is trying to solve a non-routine mathematical problem. When failure to reach a solution occurs, he states that the emotions can include frustration and panic (McLeod 1988). These emotions can become increasingly intense over a prolonged period of time, particularly for novice problem solvers with little experience of problem solving.

As stated in the Three Key Characteristics of mathematical problem-solving, it is not immediately clear to the problem solver on how to achieve the goal that the problem sets out . McLeod (1988) highlights that this ambiguity in how to approach a non-routine mathematical problem is precisely the situation that can lead to emotions arising. McLeod (1988) explains that the reaction to problem-solving can be different in every person with both negative and positive emotions being possible results of a variety of stimuli or experiences while working

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on the problem, for example interruptions (as discussed in detail by Mandler (1984)). McLeod (1988) explains that when the majority of a students' mathematical experience involves doing routine exercises then the inevitable consequences to interruptions during problem-solving are intense emotional reactions.

The beliefs of teachers have a direct influence on the beliefs of their students because when many students are confronted with a mathematics problem, they may have low intrinsic motivation to work through the problem and depend on extrinsic motivation (Marcou & Philippou, 2005) which primarily comes from the teacher. Schoenfeld (1983) highlighted that beliefs influence behaviours when attempting mathematical problems. Furthermore, he claims that if students do not value understanding as a goal of mathematical learning, then they may not be able to access stored information that would otherwise be of use to them in carrying out mathematical work.

When entering teacher education programmes, future teachers possess ideologies on what being a teacher entails based on previous experiences (Taguchi, 2007). Kayi-Aydar (2015) highlights that prospective teachers' identity is not based on the attributes they desire to possess when teaching once qualified. However, a teacher's identity is greatly influenced by the teacher education they have undergone and is reflected in their teaching (Chapman, 2014). Teacher education programmes are viewed as a critical stage in teachers' development (Teaching Council of Ireland, 2017). During teacher education programmes, prospective teachers' beliefs regarding teaching and learning should be considered and challenged as they will bring these beliefs forward into their professional practice (Teaching Council of Ireland, 2017). Philipp (2007) suggests that teacher education programmes must promote positive beliefs in prospective teachers in order to develop mathematical proficiency and ultimately help equip graduates of the programme to create positive mathematical learning environments for their students.

The Study

This study aims to present findings about the affective domain of pre-service mathematics teachers (PSMTs) relating to problem-solving, motivated by the capacities outlined by Chapman (2015) as being a key to effectively teaching problem-solving.
The participants in this study are PSMTs undertaking a concurrent initial teacher education programme. The participants are students of two different programmes of study. Students of both programmes were taking a module that includes the study (and practice) of mathematical problem-solving. Graduates of the relevant programmes are qualified to teach mathematics to Leaving Certificate level in Ireland, and typically go on to do so, and so preparing the PSMTs for the task of teaching problem-solving is a key concern of the programme team. All the participants completed their second-level education in the Irish system, and thereby completed the Leaving Certificate curriculum.

Methodology

The methodology for this study is a mixed methods approach. Creswell & Garrett (2008, p. 2) describe mixed methods as an approach to inquiry that involves the researcher connecting quantitative and qualitative data in some way in order to make a 'unified understanding of a research problem'.

The quantitative element of this study was done through the implementation of a survey, the *Indiana Mathematics Belief Scale (*IMB), developed by Kloosterman and Stage (1992).

Kloosterman and Stage created an instrument to measure the beliefs of secondary school and college students which they extensively analysed and reviewed to ensure validity using statistical software. The IMB has since been used by researchers to test the mathematical beliefs of students (Mason, 2003; Prendergast et al., 2018).
This instrument consisted of five scales with six items in each scale totalling in thirty items. Of these thirty items, twelve questions were with a negative valence and eighteen with a positive valence. Each item was graded in a Likert- scale fashion whereby the following numbers indicated the respondents' level of agreement or disagreement with each item; 1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly. In tabulating the results below, the scales are reversed (where necessary) so that in every case, a higher mark corresponds to a more positive disposition. Each of the scales are described below as defined by Kloosterman and Stage (1992):

1) I can solve time-consuming mathematics problems [Difficult Problems]
The first scale involved investigating the persons' perceived ability to solve time-consuming mathematics problems. According to Schoenfeld (1985), students who give up on any problem which cannot be completed in five minutes or less believe that problems must be solvable in five minutes or less.

2) There are word problems that cannot be solved with simple step-by-step procedures [Steps]
This scale involves the use of procedural skills and formulae to solve problems. Given that the definition of a mathematical problem involves having no clear path or procedure readily available, it is evident that a problem solver must be motivated to solve problems for which there are no memorized procedures to employ (Lester & Charles, 1992).

3) Understanding concepts is important in mathematics [Understanding]
This scale measures the degree to which the respondent believes in the importance of understanding the concept. This involves understanding why an answer is correct, and how the solution was obtained. High scores on this scale are associated with motivation to learn and solve mathematical problems.

4) Word problems are important in mathematics [Word problems]
This scale involves investigating the respondents' beliefs about the importance of word problems compared to computational or procedural skills. It has been shown that those who believe that computational skills are more important than word problems will be less motivated to solve problems.

5) Effort can increase mathematical ability [Effort]
Like the other scales, belief that effort can increase mathematical ability is associated with motivation in problem-solving. This scale is used to provide an insight into the respondents' attitude towards their ability to improve their mathematical skills by putting in effort.

These beliefs were chosen specifically for secondary school and college level students in relation to their motivation to learn to solve mathematical problems (Kloosterman & Stage, 1992). Scales 1, 3 and 5 measure the beliefs of the respondent as a learner of mathematics while scales 2 and 4 measure the beliefs about mathematics.

The qualitative element of this research involved participants completing an open-ended question after attempting a mathematical problem. The participants were asked to describe how they felt at three different stages of their problem-solving attempt, namely; the start of the problem, the middle of the problem, and the end of the problem. The students were prompted to refer to how they felt if they were stuck and if they were making progress. This was done at three different points during the module while participants worked on three different mathematical problems. The first problem involved the topic of area, the second problem involved number and algebra, and the third problem involved the topic of trigonometry.

The responses were analyzed using a general inductive approach (Thomas, 2006). This involved the coding and identification of categories from iterative reading of the raw data by the researcher. The data was analysed to categorise the statements made by the respondents at the start, middle and end of each problem attempt. The themes were identified and the number of statements in each category was counted. The data was then analysed to convert the counting of statements into the counting of participants' perspective.

Results

Table 1 below shows the mean result for each of the five scales of the IMB as described above. Each mean score is out of a maximum of 30. The mean for each cohort and the overall mean is shown below.

Table 1. *Table 1 shows the results of the IMB of each of the four cohorts of participants*

	Cohort 1 (n=30)	Cohort 2 (n=44)	Cohort 3 (n=30)	Cohort 4 (n=47)	Total (n=151)	Overall mean
Difficult Problems	22.9	22.7	17.1	13.4	76.1	19.025
Steps	17.2	16.6	16.8	16.0	66.6	16.65
Understanding	20.9	21.5	19.4	20.7	82.5	20.625
Word Problems	19.2	19.3	14.3	20.5	73.3	18.325
Effort	26.7	27.0	25.5	19.9	99.1	24.775

From the general inductive analysis of the qualitative data the following categories were identified. These were; neutral, negative, positive, both positive and negative, answer positive, answer negative, process positive, process negative, negative answer but positive process, both answer and process positive, and both answer and process negative. The term 'positive' refers to statements of a positive disposition, the term 'negative' refers to statements of a negative disposition, and the term 'neutral' refers to statements which are neither positive nor negative. The analysis of the data from the end of each problem produced the categories involving the problem-solving process and the positive or negative answer categories. Space precludes provision of representative quotes in this paper.

Table 2 shows the number of respondents who were classified in the previously mentioned categories at the start, middle and end of each problem. SP1 indicates the start of problem one, MP1 indicates the middle of problem one, and EP1 indicates the end of problem one. This notation is also used for problem two and problem three.

Table 2. *Table 2 indicates the number of participants in the appropriate classification across start, middle and end of each of the three problems.*

Classification	SP 1	MP 1	EP 1	SP 2	MP 2	EP 2	SP 3	MP 3	EP 3	Total
Neutral	10	4	2	6	3	3	4	11	1	44
Negative	16	12	4	14	15	2	11	14	2	90
Positive	16	16	3	11	8	1	20	9	0	84
Both Positive and Negative	1	9	1	1	6	1	5	6	0	30
Answer positive	0	0	5	0	0	6	0	0	7	18
Answer negative	0	0	9	0	0	10	0	0	12	31
Process positive	0	0	8	0	0	3	0	0	1	12
Process negative	0	0	1	0	0	0	0	0	1	2
Negative answer but positive process	0	0	6	0	0	3	0	0	2	11
Both answer and process positive	0	0	4	0	0	1	0	0	8	13
Both answer and process negative	0	0	0	0	0	0	0	0	2	2
Missing values	7	9	7	18	18	20	10	10	14	113
Total	50	50	50	50	50	50	50	50	50	

Discussion

The IMB has been used by researchers to investigate beliefs about mathematical problem-solving. One such study was conducted by Mason (2003) which involved implementing the IMB with Italian high school students (n=599). Similarly, Prendergast et al. (2018) conducted the IMB with post-primary students but in Ireland. The IMB was distributed to nine secondary schools with a total of 975 questionnaires completed and returned. The participants in this study are PSMTs who all completed post-primary education in Ireland and the focus of this study is to investigate their beliefs using the IMB through the perspective of prospective teachers rather than students.

The analysis of the results of the IMB from the four cohorts of participants is discussed below. The combined results of the four cohorts of the IMB showed that the scale with the highest mean score was *Effort* with a score of 24.85/30. This scale had the highest mean score in Cohorts 1, 2, and 4 and was second highest in Cohort 3. This shows that participants positively agree that effort and working hard can have a positive impact on mathematical ability (Kloosterman & Stage, 1992). This finding is in line with the findings of a study conducted by Prendergast et al., (2018). It is interesting to note that the results of the study conducted by Prendergast et al. (2018) could be seen to be representative of the same group of participants that were involved in this study since participants in this study all completed post-primary education in Ireland. This is a positive finding as there is an implication that participants demonstrate aspects of a growth mindset. Dweck (2008) states that students who have a growth mindset are at a significant advantage to students who are of a fixed mindset. In research conducted by Dweck, it was found that students with a growth mindset cared more about learning and also demonstrated a greater belief in the influence of effort on their grades than

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students with a fixed mindset. Similarly, it was found that those having a growth mindset reacted in a more positive manner to setbacks than those with a fixed mindset.
The scale which had the lowest overall mean was *Steps* with a score of 16.645/30. This scale had the lowest mean score in each cohort of participants. This result is of concern as it is indicative of the belief that rote learning and procedures are adequate to solve mathematical problems. This lowest mean aligns with the lowest mean other studies (Kloosterman & Stage, 1992; Mason, 2003; Prendergast et al., 2018).

The analysis of the qualitative data showed that there was a strong focus on achieving an answer in each of the problems. From the 150 responses regarding the end of each of the three problems, 84/150 referred to achieving or not achieving an answer. This showed that there was a greater focus on finding an answer rather than on the problem-solving process. Of these 84 answer-focused responses, 31 consisted of negative comments in relation to not being able to achieve an answer; 18 participants provided positive comments.

Forty out of the 150 respondents referred to the problem-solving process, with four of these responses reported negative feelings towards their problem-solving process while 44 out of 150 responses reported negative feelings toward achieving an answer. This shows that there may be a stronger negative association with not achieving an answer than on the problem-solving process. We also note that the number of participants that referred to the problem-solving process declined between each of the problems. Simultaneously, there was an increase in the number of participants who referred to achieving or not achieving an answer.

From the results of the IMB the scale, *Understanding,* had the second highest overall mean with a score of 20.61/30. A high score in this scale demonstrates that there is a greater value on understanding a mathematical concept rather than achieving a correct answer. This involves the understanding of why an answer is correct and how a procedure works. One negatively worded question in this scale is; *It doesn't really matter if you understand a maths problem if you can get the right answer*. This suggests that the PSMTs place a greater importance on understanding rather than achieving an answer. This is in contrast to the results of the qualitative data which showed that there was a greater focus on achieving an answer than on the process. A potential reason for this is participants reporting what they believe they should say rather than their actual behaviours.

From the analysis of the scale; *Understanding*, Prendergast et al., (2018) found that Junior Cycle students demonstrated stronger levels of agreement than Senior Cycle students. The authors hypothesize that this could be due to an increased focus on obtaining a correct answer in examinations. This hypothesis could explain the strong focus placed on achieving an answer by the PSMTs.

Conclusion

From benchmarking against other studies, the results of the IMB showed that; the *Effort* scale was higher in this study, the *Understanding* scale was lower in this study, and the *Steps* scale was consistent with other results. This is indicative that the PSMTs have a positive disposition towards effort influencing mathematical ability. The results of the *Word Problem* scale and the *Steps* scale are relatively low given that the maximum score is 30. This suggests that PSMTs place a high value on the role of computational skills and previously learned procedures rather than on problem solving skills.

The qualitative data indicates that there appears to be a greater focus on achieving an answer than focusing on the problem-solving process. This is contrary to the results of the *Understanding* scale of the IMB. Comparing the quantitative and qualitative results, there appears to be a discrepancy between what PSMTs report and how they behave while problem-solving. This is something that will be taken into consideration in the development of the module that the PSMTs undertake.

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Using a narrative approach to study the transition to higher-level education

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ABSTRACT

This paper presents the results of a longitudinal study into the mathematical identity of science and engineering students (MISE) in Dublin City University. The goal of the research was to expand on previous mathematical identity research in Ireland by including science and engineering students since they study a significant amount of mathematics at university level.

Mathematical identity is considered to be one's relationship with mathematics, including knowledge of the subject and perception of oneself and others (Eaton & OReilly, 2009, p. 228). This qualitative study was conducted over four years using a narrative approach to mathematical identity (Radovic, Black, Williams & Salas, 2018, p. 29). The study involved 32 participants from science and engineering courses in DCU, including several students of science education who have since qualified as teachers. All participants completed an online open-ended questionnaire on mathematical identity in their first year of university. A further five participants contributed to focus groups and six participants took part in narrative interviews at the final stage of data collection. The conclusions are derived from participants' mathematical identity narratives which were developed through several stages of data collection involving both thematic and narrative analysis.

The findings highlight several issues that affected multiple participants and may affect a broader cohort of students than were included in the study. We also present some unique features of mathematical identity that arose in this context as students transitioned to higher-level education.

KEYWORDS

Mathematical identity, narrative inquiry, narrative analysis, transition, thematic analysis

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Introduction

While competing definitions of mathematical identity exist (Darragh, 2016) research on this topic has grown in prominence in recent years and it is widely recognised as an important concept for explaining why people may disengage from, or persist with, the learning of mathematics (Graven & Heyd-Metzuyanim, 2019). This paper is drawn from a larger PhD study, the title of which is *Mathematical Identity of Science and Engineering students* (MISE). Its purpose is to explore science and engineering students' relationship with mathematics and the contexts that inform this relationship as they transition to higher-level education. Researching mathematical identity in this context is important for a number of reasons. The primary purpose of this research is to explore learners' mathematical identities (Radovic et al., 2018). Existing research in the Irish context has tended to focus on the mathematical identity of teachers or student teachers engaging in teacher education (cf. Eaton et al., 2014). Moreover, exploration of mathematical identity as students transition to higher education may give insight into the policies and practices universities might put in place to support students' successful transition.

The MISE study, a study conducted in the narrative paradigm, will report on the longitudinal change in mathematical identity that was observed over several stages of data collection spanning four years in total. In this paper, reflexive thematic analysis (Braun & Clarke, 2022) was used to unpack how a particular theme, *Ways of Learning Mathematics*, developed over the course of the study. The importance of this theme has long been established in the literature (cf. Skemp, 1976) and has been a recurring theme in research on mathematical identity (Eaton & OReilly, 2009; Machalow et al., 2020). Furthermore, focusing on this one dimension of the MISE research, allows us to illustrate the methods of the larger study, and to explore self-identified differences in ways of learning mathematics across the different cohorts (Science and Engineering students), and across time.

Literature Review

Darragh's (2016) comprehensive review of identity research in mathematics education traces both sociological and psychological framings of identity, where identity can be seen, respectively, as an action or as an acquisition. Recent research on mathematical identity largely draws on socio-cultural theories of learning (Graven & Heyd-Metzuyanim, 2019). While a common critique of (mathematical) identity research is the lack of attention to clear definitions of identity (Darragh, 2016; Sfard & Prusak, 2005), narrative is sometimes theorised to contribute to identity and has been identified as one of four theoretical approaches to the study of identity, the others being poststructural theory, positioning theory and psychoanalytic theory (Langer-Osuna & Esmonde, 2017). In some cases, identity is considered to equate with narrative. Sfard and Prusak (2005) operationalise identity as significant, reified, and endorsable stories about a person, or "the product of collective story-telling" (Graven & Heyd-Metzuyanim, 2019, p. 363). While this view of identity as narrative is widely cited within mathematics education research, the full implications for methodology are not often realised (Graven & Heyd-Metzuyanim, 2019).

In this paper, mathematical identity is conceptualised as the multi-faceted relationship that an individual has with mathematics, including knowledge, experiences and perceptions of oneself and others (Eaton & OReilly, 2009). This definition was inspired by Grootenboer and Zevenbergen (2008) who proposed that identity incorporates students' "knowledge, abilities, skills, beliefs, dispositions, attitudes and emotions" (p. 244). We adopt a narrative approach to the study of identity as outlined by Langer-Osuna and Esmonde (2017). In particular, we

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maintain that the creation of narratives or stories is a key means of making sense of experience, and that mathematical identities develop as people make sense of their experiences.

In this paper, we consider higher-education students' mathematical identities in terms of how they discuss ways of learning mathematics. Conceptions of the nature of mathematics itself often underpin assumptions about how mathematics should be taught and learned. Ernest (1989) compares the instrumentalist view of mathematics, where mathematics is seen as a set of unrelated, utilitarian rules and facts; the Platonist view of mathematics, where mathematics is seen as a static but unified body of knowledge; and the view of mathematics as a cultural product, dynamic and continually expanding. He draws connections between these views of mathematics and associated views of teachers and learners. Models of teaching and learning can foreground the role of teacher as instructor (focus on skills mastery and students' compliant behaviour and reception of knowledge); explainer (focus on conceptual understanding and students' active construction of understanding); or facilitator (focus on problem posing/solving and students' autonomous exploration and learning). Arising from Skemp (1976), the contrast between relational or connected, conceptual understanding of mathematical ideas, and instrumental understanding, where disconnected rules and procedures are understood, has long been a focus in mathematics education research. Previous research on mathematics identity in Ireland has drawn attention to pre-service teachers' "broadly Platonist conceptions" of the nature of mathematics, but recognised the preference for instrumentalist or problem-solving views among some participants (Eaton et al., 2011, p. 40). It is argued that the instrumentalist view of mathematics is one that prioritises doing over understanding and results in students who struggle to "make connections between mathematical topics across different contexts or in unfamiliar problems" (p. 31). When it comes to affect, Machalow et al. (2020) showed that relational learning opportunities lead to positive narratives among pre-service teachers (PSTs) while instrumental learning opportunities lead to fragile or negative narratives.

Methods

The sample for the study consisted of 32 participants from science and engineering courses in DCU, including several students of science education who have since qualified as teachers. A series of previous studies in Ireland developed an online open-ended questionnaire for exploring mathematical identity of PSTs (Eaton & OReilly, 2009) which was adapted for this new context. The questionnaire consists of a broad opening question, a follow-up question which includes some prompts and a final evaluative question. All participants (in this study) completed the online questionnaire in their first year of university. In their third year, a further five participants contributed to focus groups. In their fourth year, six participants took part in narrative interviews for the final stage of data collection. These stages are shown in Table 1 below.

Table 1. *MISE Data Collection Timeline*

Data Collection Stage	Year	Semester
Questionnaire	1	II
Focus groups	3	I
Interviews	4	II

Narrative interviewing is a method of data collection that facilitates co-construction of meaning between interviewer and participant (Mishler, 1991, p. 52). We were drawn to

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narrative interviewing because “[t]he goal of the narrative interview is to get the interviewee to tell stories about things that are important to him or her” (Kaasila, 2007, p. 207). Although the interviews were semi-structured (there were some pre-prepared questions), participants were afforded the opportunity to direct the course of the interview rather than confining control to the interviewer (Cohen et al., 2007). To empower participants to do this, one must change the traditional interviewer-interviewee relationship to one of listener-narrator (Mishler, 1991, p. 117). In narrative interviews, participants are allowed time and space to “hold the floor"' (Coffey & Atkinson, 1996, p. 56) more than usual and organise their responses into stories. This is not prioritised in traditional semi-structured interviews where “there is usually not enough scope for recounting narratives” (Kaasila, 2007, p. 207).

The questionnaire and focus group data were analysed using thematic analysis to establish themes one of which, *Ways of Learning Mathematics*, was applied to the interview data for the purposes of this paper. The latter step involved identifying instances of the existing theme in the interview data.

Braun and Clarke have indicated that the underlying assumptions or philosophy (ontology, epistemology and theoretical perspective) influence one’s approach to thematic analysis (Braun & Clarke, 2022, p. 157). They have recently introduced the term reflexive thematic analysis to clarify some of the misconceptions regarding the flexibility of the method, as they see it. Qualitative epistemologies can be thought of as a continuum, with constructionism and subjectivism at its extremes (Crotty, 1998). This study was conducted under a narrative paradigm which is informed by a constructionist epistemology. According to this viewpoint, researcher and participant are “partners in the generation of meaning” (Crotty, 1998, p. 9) and knowledge of mathematical identity is co-constructed. This is relevant because the co-construction of meaning in reflexive thematic analysis necessitates a constructionist approach (Byrne, 2021, p. 5)

While recurrence of themes is a basic requirement in any form of thematic analysis, in reflexive thematic analysis the subjectivity and reflexivity of the researcher is vital in selecting which codes and themes are meaningful. For instance, a theme which is reported by only a few participants may be considered meaningful in the light of the research questions or the conviction of the participants’ responses (Byrne, 2021, p. 5). Thus, the conclusions presented in this paper should be seen as situated in context and, consistent with the approach outlined by Braun and Clarke (2022, p. 145), we do not seek to make claims about the generalisability of the results beyond this context. In addition, Eaton et al. (2014, p. 370) have previously demonstrated that the relevance of a theme (or ‘aspect’ to use their terminology for sub-themes) related to mathematical identity can vary for different cohorts of students.

Analytic Narratives

First year

At this early stage of their higher-level education, participants tended to focus on their mathematical experience at post-primary level. They made a distinction between two types of learning: doing mathematics and understanding mathematics. In contrast to the instrumentalist view of mathematics discussed earlier, MISE participants had experienced, and disliked, doing tasks without any element of understanding, what Skemp called “rules without reasons” (1976, p. 20). They celebrated the benefits of combining both forms of learning:

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> *Once I started to actually understand maths, rather than just do it, I began to really enjoy it. (ID066)*

> *Understanding the maths we were studying instead of just learning off an equation. This definitely helps me … now. (ID054)*

Other participants decried being "told to do questions in the book with no explanation" (ID076), or learning without hearing the "reasoning behind what [they] were doing" (ID118). Classroom experiences that lacked these elements were viewed as hollow, frustrating and lacking purpose since "we just learned it for the sake of learning" (ID118).

MISE participants contended that understanding mathematics frequently involves a higher level of thinking, one where students are familiar with the "underlying concepts" (ID015) and, almost exactly quoting the definition given by Skemp (1976, p. 20), understand "what to do, and why to do it" (ID086). This approach has been shown to induce a positive affective response through students feelings and motivations (cf. Machalow et al., 2020).

Participants placed great value on their teachers' ability to explain mathematics to their students since "grades are also highly dependent on the teacher/lecturer … simply the teacher is bad at explaining" (ID021). One participant chose to move into the higher-level mathematics class and thrived there because they identified that their new teacher had this skill:

> *I found that teacher very bad in terms of her ability to explain maths. I moved myself to higher mathematics. … That teacher was very professional and talented at explaining maths, for me it became easier to understand maths. (ID086)*

Combined, these two participants link good explanations to both results and understanding. This emerged as an early hint at a characterisation of understanding which will be made clearer in the next section: you understand it if you can explain it to someone else.

Overall, while reflecting on the teaching they experienced participants' emphasised that doing should be balanced with understanding in the classroom but that "[t]he importance of learning through concepts rather than through questions should be stressed a lot more" (ID066). It was surprising that participants presented no evidence of working collaboratively in mathematics at this point of their studies. Since this has featured prominently in other research on mathematical identity (Eaton & OReilly, 2009), it was important to be alert to the possibility that this would change as they transitioned to higher-level education.

Third year

In the focus groups, participants still saw the distinction between the two types of learning described above: "Do this, do that instead of actually understanding … the how and the why get lost" (ID083). Three PSTs were clear that in the post-primary classroom, understanding mathematics is manifestly separate to being able to answer questions, and they may need to balance the two when teaching:

> *If you can do a question, it doesn't necessarily mean you understand it. (ID046)*

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> *Well and good to be able to do … a question but once it's applied to a real-world situation, you being able to know which formula or whatever to use. (ID083)*

> *Like, you don't necessarily teach for your students to have an understanding, you teach that they have an ability to answer questions. (ID084)*

While learning mathematics at university level, participants continued to reject the instrumentalist view described earlier, and emphasised that understanding means going further than being able to answer questions and pass your university exams:

> *Understanding it means going deeper, understanding how things work from the fundamentals. … then you're going to apply the theorems or specific rules, or algorithms to solve a wider range of problems. (ID122)*

For this engineering student, this philosophy was reinforced by the format of their end-of-year exams. Unlike in tutorials or assignments, "they give us unseen problems that we have to try to solve using the theory that we've been taught … We have to find our own way of solving them" (ID122). Not only this but they "regularly apply the same [mathematical] tools in other modules" (ID122).

One PST agrees that being able to "take something from another section and use it here" (ID083) means their students understand the mathematics they have learned: they can see the connections between different topics (cf. Skemp, 1976, p. 8). A science student similarly noted that "you really had to pull maths from like a bunch of different areas" (ID125), and confirmed that the concepts and methods from their mathematics modules arise "outside of actual maths itself" (ID125). The same participant provided this plain-language characterisation of understanding: "I feel like you definitely understand it if you're able to fully explain it to someone else and they get it" (ID125).

Fourth year

In fourth year, narrative interviews were used to draw-out participants' interpretations of their experiences in university, and how their mathematical identity had changed over that time. The distinction between understanding and doing persisted but despite the enthusiasm with which MISE participants seek out both types of learning, there were examples of modules where they had to forego this approach:

> *I learned off that this is what I have to, do you get me? But I never knew why I was doing it. I didn't understand it. I just kind of had it drilled into my head ... Whereas with maths with [a different lecturer] I'd understand say 90% of things as [they were] teaching them. (ID112)*

> *I found myself out of my comfort zone … I kind of approached it differently than I did the other modules. … I could answer the question fairly adequately but if the second part of the question was 'explain why it works,' I was just totally out.(ID084)*

This suggests that students may feel they have to rote learn mathematics due to the complexity of a module. However, the teaching style of the lecturer can have an influence

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also . One participant insisted that in one module they were pressured into replicating exact solutions in work submitted for assessment:

> *There's one way to do it, you do it any other way, no matter if it's right, you're not getting marks. I didn't like that. (ID031)*

In the previous section, a PST noted that in the classroom, teachers may forego teaching for understanding in favour of ensuring their students can answer questions. This pressure may influence lecturers at university level also.

This dataset revealed some insights into the ways that MISE participants began to collaborate with their classmates over time. However, a science student describes how they were "pretty much just working on [their] own" and that this may actually have benefitted them when it came to progressing through university:

> *But in terms of like my own development in my own course, I think working alone definitely suits me better, yeah. (ID125)*

Another engineering student shares the view that working alone can be better: "I wouldn't say that I'm a team player. Like a lot of things, I like doing it on my own or I like it being done my way" (ID112).

Although their final year project allowed them the space to work this way, they describe "other modules where you have to work as part of a team and people don't pull their own weight," (ID112) which suggests that engineering students don't have the option to "do it on their own." Engineering students also collaborated on assignments where they would "kind of compare answers, just to see if we were getting them right .… Then, it would turn into a big argument if someone thought they were right over someone else (ID112)"

In contrast with their working patterns in first year, PSTs "did the assignments together" (ID031) as well as exam papers, and even "just general, kind of keeping up with content of ehm modules and stuff" (ID046). Unsurprisingly, this change is seen as entirely positive by MISE participants: "I like the support network, I like bouncing off … my friends first. … it was nice having that small network" (ID046).

Discussion

This paper presents Science and Engineering student's views on the distinction between doing questions/exams (instrumental understanding) and understanding mathematics (relational understanding).

For MISE students, understanding means being able to explain, recognising useful concepts and methods in other contexts and knowing what to do, and why. Engineering students describe how their final exams feature unseen problems, for which these skills are useful. However, most participants are seldom given the opportunity to demonstrate these skills in final exams and still resort to instrumental learning when they feel it is required.

In first year, participants found common ground in rejecting instrumentalist mathematics, based on their experiences at post-primary level. Although most participants appeared to describe mathematics as an individual pursuit in first year, by final year a support-network of collaboration was more common. Participants' views on what it means to understand mathematics appeared to become more precise and clearer over time, as demonstrated in the analytic narratives for the second and third stages of data collection. This is particularly the case for PSTs whose mathematical identity was influenced by their teaching experiences and their evolving views of teaching and learners.

The results of this study demonstrate the power of using narrative methods to collect rich data about students' mathematical identities as they transition to third level. We suggest that participants' desire to understand mathematics beyond answering exam questions could be nourished by using different forms of assessment (individual and group work, continuous assessment and exam conditions) for both formative and summative work.

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OPEN ACCESS

What we can learn from attendance data at a mathematics support centre during and after campus closures due to COVID-19

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ABSTRACT

In this paper, we consider the impact of campus closures on the Mathematics Learning Centre (MLC) in Dublin City University (DCU) in the wake of COVID-19 restrictions which required online teaching. Up to March 2020, the MLC operated as an in-person drop-in service in the university's main library. Any DCU student who needed additional mathematics support could "drop in" without making a booking in advance and get help from a tutor. There was no online provision on offer, although plans had been evolving to offer a skeleton online service in the evenings. From March 2020, and throughout the academic year 2020-21, the majority of university teaching in DCU took place completely online, as did the service offered by the MLC. By necessity, mathematics support took a different format to the previous in-person drop-in centre. Students could pre-book a 25-minute session online via Zoom with a tutor, and they could attend alone or as part of a small group as per their preference. There were no restrictions on how many sessions a student booked or how often they attended, although they were encouraged to book no more than one per day, to allow themselves time to work on the material covered in the session. Several papers have explored the practices implemented by Irish universities during the initial move to online learning in March 2020 (Hodds, 2020; Mac an Bhaird et al., 2021). Previous papers have reported on the in-person MLC attendance in DCU, and analysed trends in engagement and success rates of students who use the service (Jacob & Ní Fhloinn, 2019). However, no such analysis has been undertaken to date of engagement with the online support provision. Here, we will consider attendance patterns, with a particular focus on first year students compared to older year groups, to investigate any emerging trends. We will also discuss the knowledge gained by mathematics support providers following a full year of online provision and how this might impact future practice.

KEYWORDS

Mathematics support, attendance, COVID-19 restrictions, engagement, online learning

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Introduction

In DCU, the Mathematics Learning Centre (MLC) provides free, additional support with mathematics to DCU students studying any kind of mathematics (Jacob & Ní Fhloinn, 2019). The support acts in tandem with timetabled lectures and tutorials to allow students to address any mathematical difficulties they might have. The MLC generally operates as a drop-in service located in the main library on the Glasnevin campus. Students can avail of one-to-one help from a tutor or can attend in a small group. Students record their attendance upon arrival on a tablet, in order to track usage of the centre and help with planning staffing levels and so on. The room can hold up to 40 students at the same time and is generally staffed with two tutors, although this increases to three at busy times.

In March 2020, the COVID-19 pandemic resulted in an abrupt move to emergency remote teaching in higher education, and for the first time, the MLC provided support via an online medium. With only five weeks left in semester, the MLC offered students drop-in sessions via Zoom, but uptake was extremely low. Research by Gilbert et al. (2021) showed that teaching practitioners were uncertain as to how best to manage online support, especially in the early months of COVID-19 restrictions. For the academic year 2020/2021, there was more time to plan and collaborate across the mathematics support practitioner networks, learning from what had happened up until that point.

This paper reports on attendance data gathered from September 2020 until June 2021, during which time, teaching for the academic year 2020-21 was conducted online. The MLC operated online via Loop, the university's virtual learning environment (VLE), which is based on Moodle. This online system included some significantly different characteristics than the in-person support. Students now had to pre-book a time slot; each slot was limited to 25 minutes; and the number of slots was reduced compared to the in-person hours that had been available. The online sessions took place via Zoom, for which the university had a licence and so all staff and students had access via their institutional logins. Although a group option was provided when booking a slot, most students attended on their own. The tutor's camera was always turned on during the session, but students frequently preferred to remain off-camera and, on rare occasions, preferred to type rather than speak through the microphone.

In addition to the above, "support tutorials" were also available for some service-mathematics modules, as well as those taking mathematics degree programmes, and were conducted by the tutor for the module. These consisted of one hour per week where the tutor was available to answer any questions from students via Zoom, but without any prescribed material to be covered. Attendance at these sessions varied hugely depending on the module, with some regularly attended by most of the class, and others seeing just a handful of students. In addition, many students attended these sessions without any questions to ask, but simply to see if other students asked questions that might be important for them to understand. Tutors offered students the option of emailing questions in advance or using the private chat option in Zoom to send questions directly to the tutor so that students could pose questions anonymously, and this proved a far more popular approach than asking questions via a microphone.

Given the difficulty of gauging engagement from students who attended online support tutorials, we chose instead to focus on those who booked online support sessions and aim to address the research question "What were the levels of engagement with bookable online mathematics support sessions during the academic year 2020/2021?". It is of particular interest to establish any discernible patterns in this engagement in order to optimise the online support offering in the future.

Literature review

Several publications have focussed on the initial change to online learning in Ireland in March 2020 and the months that followed (Mac and Bhaird et al., 2021; Ní Fhloinn & Fitzmaurice, 2021a; Ní Fhloinn & Fitzmaurice, 2021b). To date, the number of publications focused on mathematics in higher-level institutions during the pandemic is still relatively small (Ní Fhloinn & Fitzmaurice, 2021a, p. 2), although this number is ever-increasing, as might be expected, with some of the leading journals devoting special issues to the topic. Some of these publications have dealt with the student perspective (Hyland & O'Shea, 2021); others with the practitioners' experience (Ní Fhloinn & Fitzmaurice, 2021b).

Anecdotal evidence from the mathematics support community via the Teaching and Learning Mathematics Online (TALMO) events (www.talmo.uk) held early in the pandemic reported that engagement with mathematics support during the early months of the pandemic was greatly reduced across universities throughout Ireland and the UK. Hodds (2020) subsequently undertook a survey of mathematics support practitioners to investigate the changes to practices in mathematics support at this time. He found that 74% of UK institutions, 82% of Irish institutions and 63% of those elsewhere in the world reported lower numbers than in usual times, and in many cases, there were dramatically lower, with some institutions seeing the same number of students between March and May 2020 as they would normally see in a week, or even a day. This was certainly true of DCU; in the four days leading up to the campus closure (9th- 12th March 2020), there were 256 visits to the MLC, but between 19th March and 5th May 2020, there were only 98 online visits in total. The mathematics support centre in UCD reported a 79% drop in usage compared to the same period in the previous year (Mullen et al., 2021, p. 6).

Several studies have looked at the effectiveness of their approach to online support during the academic year 2020/2021, as this paper also does. Mac an Bhaird et al. (2021) explored the student perspective of the combination of online study groups and drop-in online mathematics support, as undertaken in Maynooth University. Students opted in to being placed in a study group of 4-5 students, with one tutor responsible for up to 3 groups per hour-long session. Students were generally positive about the experience, although they did note the difficulties that arose when others in their group did not engage or attend sessions. However, they appreciated the help from tutors and the structure provided by the study group environment, even if it was online.

O'Sullivan et al. (2021) considered the situation in Cork Institute of Technology (CIT). They investigated student engagement with their online asynchronous mathematics support page hosted on the university's virtual learning environment. First and second year non-mathematics specialty students, who were studying a mathematics module or statistics module provided by CIT mathematics department, were enrolled automatically. The analysis revealed that 73% of students had engaged with the service between January 2019 and May 2020. However, many students disengaged with the service. Overall, 83% of students spent thirty minutes or less engaging with the online system. They inferred that support systems should include as much relevant support as possible and clearly signpost it so that students can easily, and quickly, locate the resources they need.

Mullen et al. (2021) compared the experience of mathematics support of students and tutors in Ireland and Australia during this time period. They found that both groups spoke of the difficulties of learning and communicating with mathematics online as opposed to other subjects. Lower usage of mathematics support services emerged as an issue in Mullen et al. (2021) also.

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Methods

The attendance data were collected via Loop, the university's virtual learning environment (VLE), which is based on Moodle. The online maths support was offered through this platform using its appointment scheduling feature. This allows the user to schedule bookable appointment slots which are attached to a particular tutor.

The attendance data for 2020-21 were exported to include each student's date and time of attendance. The schedule for the semester was also included to determine the total number of sessions that were available and thus, how many slots were not booked. There was no need to validate student names, emails or numbers because these are extracted from their profile on Loop. The data were analysed using Google sheets (the equivalent of Microsoft Excel) with extensive use of pivot tables and charts.

Results

Although there was more time to plan for September 2020, compared to the initial move online in March 2020, it had initially been hoped that it would be possible to provide a skeleton in-person service as well as an online presence; in the end, the university decided that teaching would be online only, which removed the first possibility. As a result, there was uncertainty in determining how many hours of maths support should be provided online, and when they should be available. The analysis showed that, even in the busiest weeks, there were empty slots available to book.

There were four slots available before 2pm every weekday and a further four slots in the evening from Monday to Thursday during the semester. Mathematics support online was also provided for three exam periods: Semester 1 exams in January, Semester 2 exams in May and supplementary exams in August. For the week before examinations in January, 60 booking slots were provided over the course of one week. For Semester 2 exams, there were 40 slots per week available for four weeks, and for supplementary exams, there were 28 slots per week available for four weeks.

Overall, most slots were booked with 66% (242/368) booked in Semester 1, falling to 54% (229/424) in Semester 2. Over the academic year, 61% (736/1208) of the available slots were booked. This suggests that a sufficient level of support was provided, given the times of day selected for the slots, and the fact that students were encouraged to email the MLC if they needed a slot and a suitable one was not available to them.

Of the 736 total bookings, 471 were during term time: 242 in Semester 1 and 229 in Semester 2. The remaining bookings took place during one of the exam study periods. As noted in the introduction, group bookings were uncommon, accounting for only 3% (22/736) over the year. The majority of group bookings were made by first-year students (12/22), with half of all group bookings made by Actuarial Maths students from any year. Group bookings became less popular as the year progressed, with only six taking place after February 2021 in Semester 2.

The analysis showed that the majority of bookings over the year for online maths support were made by first-year students (summarised in Table 1). These attendees had never experienced the in-person mathematics support offered prior to March 2020.

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Table 1. *Number of slots booked by year for the academic year 2020-21*

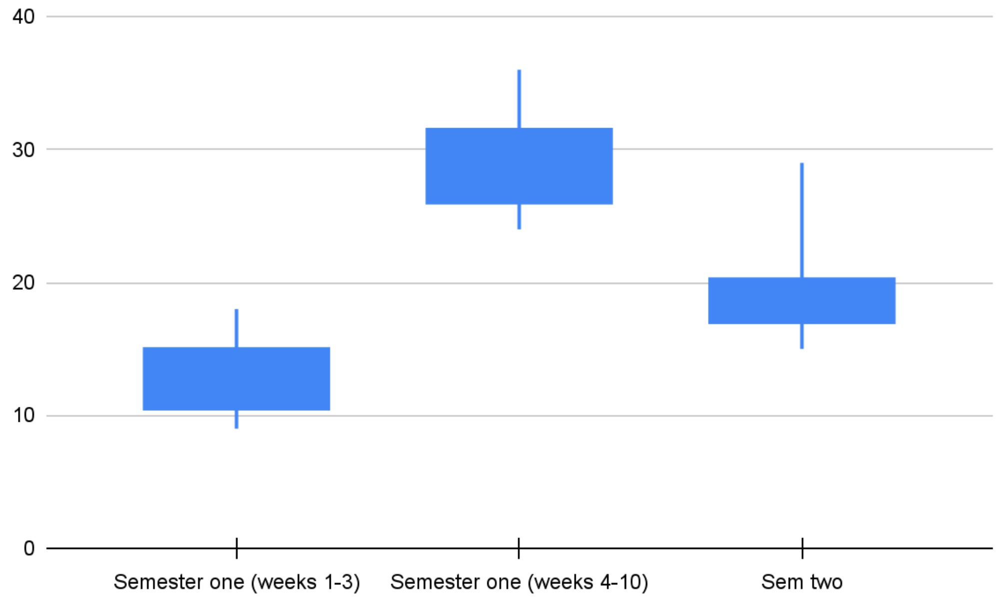
Year	1	2	3	4	Other	Total
Number of bookings	456	150	77	41	12	736
%	62.0%	20.4%	10.5%	5.6%	1.6%	

Three programmes made up 40% of the first-year bookings: Actuarial Mathematics (69), Accounting and Finance (50), and Common Entry into Actuarial and Financial Mathematics (66). The first and last of these programmes exclusively contain mathematics modules, while the middle one has a strong mathematics component throughout.

Trends over the semester

The first semester began with three weeks of lower numbers of bookings (9, 12 and 18), whereafter a median of 28 bookings per week persisted in weeks 4-10 with little variation (see Figure 1). Semester 2 saw a median of 18 bookings per week with a low variation (see Figure 1).

Figure 1. *Box plots of the range and interquartile range of the number of bookings made per week in semester 1 and semester 2*



While the number of bookings remained quite consistent for each of the periods shown in Figure 3, small spikes around continuous assessments were noted, driven by the groups who attended the MLC most (namely Actuarial Mathematics, Common Entry into Actuarial and Financial Mathematics, and Physical Education with Mathematics). The overall trends for both semesters are shown in Figure 2.

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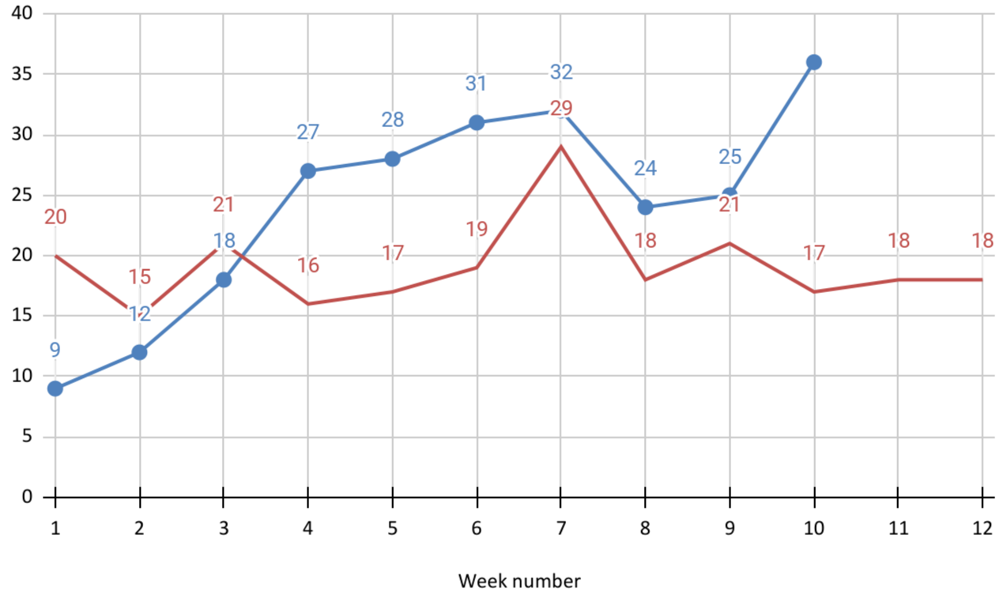
Figure 2. *Line chart of the number of bookings for each week of semester 1 (in blue) and semester 2 (in red)*



A peak in week 7 of both semesters and in the final week of semester 1 were observed. Note that in semester 2, MLC support continued for four weeks after the end of the semester in preparation for exams. It was expected that there would be increased demand for online support in the lead-up to examinations. In fact, this depended very much on the amount of time available for study and support. Because the examinations took place after Christmas in Semester 1, there was only a single week of pre-exam revision time. In this one week before the January exams, there were 54 bookings, almost twice the median number for semester 1 bookings. However, there was considerably more time for study before the semester 2 exams, and in the four study weeks before and during the summer exams, the average number of bookings was only 20.75 per week. Finally, for the six weeks before August supplementary exams, the average number of bookings was 21.5 per week. It should however be noted that a large number of students take a mathematics module in Semester 1 that do not take one in Semester 2 (up to 600 first-year students in Business programmes, for example), and this is also likely to have skewed the booking pattern here.

How many students availed of mathematics support?

Overall, for the academic year 2020-21, 240 distinct students availed of our online support sessions, most of whom were first year students (62% = 148/240). Of course, many students returned several times throughout the year. Overall, 53% (127/240) of attendees (including the same percentage of first years) returned for at least one more session. This figure is close to the average of the in-person figures from previous years in the university (Jacob & Ní Fhloinn, 2019, Figure 8). A similar trend was observed for student numbers as that for the number of bookings. In semester 1, weeks 5, 6, 7 and 10 saw the highest number of attendees in one week (25, 26, 25, 25). In semester 2, every week had between 12 and 17 attendees, with a high of 17 in week 7 noted alongside three other weeks which had the same number of attendees.

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Discussion and Conclusions

This paper reports on the engagement levels with online mathematics support in the academic year 2020-21 in DCU, where teaching took place entirely online. Overall, there were 736 bookings for online support made by 240 students. By contrast, for the academic year 2018-2019, there were 4813 visits to the in-person drop-in service by 964 students. This shows the substantial drop in engagement with mathematics support when the offering was online only, in common with what was reported in Hodds (2020) across a wide range of universities. It should be noted that in reality, the situation may not have been as stark as it appears there, as some students may have opted to engage with the support tutorials that were offered instead of booking their own support session. However, these are not really comparable to the in-person drop-in service, and also it is difficult to gauge engagement in such tutorials, as mentioned earlier, so attendance at these has not been included in the above analysis.

Despite the greatly reduced numbers attending online mathematics support, it would seem that this was not due to insufficient provision, given that 39% of the available slots remained unbooked over the course of the year. In addition, students were encouraged to email and request a slot at a different time if needed (and indeed, a small number did so and were accommodated).

Overall, the pattern of attendance mimicked that observed in the in-person drop-in centre usually, where the overall attendance numbers dropped between first and second semester (due to the smaller numbers of students with a mathematics module in semester 2). Similarly, attendance peaks are generally experienced whenever there are assignments due, and this was also observed in the online provision.

Anecdotal reports from the tutors involved in the provision of online support was that those students who used the service seem to both value it and benefit from it, and this would seem to be borne out by the percentage of students who used the service repeatedly. Interestingly, the more experienced tutors who had spent several years working in the in-person service prior to teaching online were taken aback at how well-prepared many students were for their online session: students seem to have invested time and effort into planning what questions they had and what material they wanted to cover in a way that was far less common in the in-person service. This was particularly the case in the exam revision weeks. Although students generally focus on practicing exam questions towards the end of each semester, many attendees to the online service had attempted such questions and identified specific parts of the solutions that they were unsure about. Perhaps the 25-minute time limit motivated them to make the most of their time with the tutor, in contrast to the in-person service where there are no such time restrictions. We intend to encourage students to use online support in this manner in future.

For the reasons above, we expect the demand for online mathematics support to continue alongside that for traditional in-person support. The strongest benefits of maintaining online support include its accessibility for distance learners and that students can remain anonymous rather than attend a location with other students present (Gilbert, Hodds & Lawson, 2021, p. 303). Additionally, it has been reported by some practitioners that “less confident students seemed more likely to engage with online support than they were with physical support” (Gilbert, Hodds & Lawson, 2021, p. 298). Given the continued rate of COVID-19 infections, it is also of use to students to be able to access support remotely if they are contagious but not overly unwell.

The data under discussion helped us decide how to balance these priorities in heading into the academic year 2021-22. In-person learning returned and DCU opted to retain some online support in tandem. The data from this year is currently being investigated with a view to seeing how first-year students responded to the joint offering of in-person and online support, and how second-year students (who spent their first year learning remotely) would choose to avail of support when they were back on campus. It is hoped that this information will give further insights into the future of online mathematics support provision in higher education.

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How can the philosophy of education inform STEM Education Policy in schooling and higher education in a post-Covid pluralist and democratic Ireland: Growing back better

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ABSTRACT

In this paper I make the case to open for critical scrutiny the purpose of STEM education policy in schooling and higher educaton in a post-Covid pluralist and democratic Ireland. Until now the policy (political) framing (representation) of STEM education policy in Ireland and elsewhere draws from a postpositivist stance of techné that is advocated by the state and industry and connected to transdisciplinarity, nature of science, science-in-context, skills sets and evidence-based inquiry scaffolded through one engineering model of STEM Pedagogy. The SMART (*Self-regulated, Motivated, Adaptible, Responsible and Technologically competent*) STEM student and teacher learns to fit in with a consensus view of the ideal human and demonstrate their comparative performance as measureable outputs ('what works best'). The critical scrutiny of STEM literature conducted here shows that we live in a fast globalising and digitising world where UNESCO (2021) asks us reimagine a new social contract for education. It is a timely question given that children and young people are nowadays growing up in a highly scientific and technological society where questions of the good life and STEM literacies need to be freshly interrogated. Here I share insights gleaned from a select literature review revealing the dilemmas of our time and offering new signposts forward. STEM education that balances science, philosophy and practical wisdom and underscores the limits of scientific reason in order to prepare students on one hand to combat populist anti-science attitudes and on the other to prevent falling into a narrow 'scientism'.

KEYWORDS

STEM education policy, Ireland, postpositivist, techné, STEM pedagogy. SMART student, critical scrutiny, select literature review, limits of scientific reason

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Introduction

I am presenting this paper in the section of the CASTeL DCU SMEC Conference 2022 entitled 'How STEM Education Research Can Inform Policy'. It is a crucial philosophical question to ponder and to get right in contemporary Ireland for a number of different and intersecting reasons. A perfect storm of reasons that includes a rapid advancing globalising and digitising world, a highly scientific and technological society and the increasing disparities in injustices and inequalities between a minority of super wealthy (elite) people and a growing majority of people struggling to make ends meet and to aspire to a good life.

It is happening at a time where Europe and Ireland appear to be emerging from the coronavirus pandemic only to be faced with the Russian war against Ukraine and the threat to the European peace project. A time of economic stress with growing inflation, increasing interest rates and the potential for industrial unrest. A storm taking place in a post-truth era when democracy is under threat of slow suffocation, from on one hand a populist far-Right movement promoting a populist anti-science stance and on the other a relentless push for a narrow science view of 'scientism' that only allows a technocratic lens of evidence as the one lens to view humanity and education for a market-led view for human capital change and development (Edling & Mooney Simmie, 2020; Verma & Apple, 2021).

In the last two decades of this century, the field of education has undergone rapid change in its positioning in the academy and in government policy priorities. For more than fifty years education was firmly positioned in the social sciences, underpinned by the foundational disciplines of history of education, philosophy of education, sociology of education and the psychology of education. After the Gulbenkian Commission Report in 1996, the western world set about amalgamating all the sciences. The field of education was to become a social science, a natural science and an applied science but not in equal measure. Now many of education's more complex and sophisticated concepts, such as *Bildung,* being and becoming, democracy and public interest values were quickly diminished if not entirely removed or lost to a new discourse of learning and situated learning (Ball, 1995; Biesta, 2012, 2013, 2016, Selwyn & Gašević, 2020). Transdiciplinarity became central, STEM education was introduced, inquiry based learning, evidence-based policy making and new technocratic modes of management and measurement started to dominate (Hattie, 2012; Stohlmann, 2019).

To date the field of education divides between those who argue that education is a moral, intellectual and apolitical endeavour and those who argue that education is a moral, intellectual and political endeavour. The latter argue for recognition of the political because of the inextricable links between knowledge and power [privilege] and the deliberate intentionality of educators to bring about change [through seeking to change the gaze of students in a preferred and publicy stated policy (political) direction] (Freire, 1971/2018).

For those whose research and theorisations lie in this latter field of critical studies, in my case in the field of critical feminist research policy analysis, our studies of public policy and practices are concerned with understanding and critically interpreting the representation and framing of reforms in education and in STEM education and seeking to reveal the hidden assumptions embedded in the definition of problems. My research questions aim to critically interrogate connectivity between national and global reform movements and the contribution made by research, including qualitative studies that are often neglected in public policy reports and yet can explain the multiple dilemmas and possibilities inherent in policy imperatives of change. Research questions that are not only concerned with curriculum, pedagogy and assessment as selections from culture but with expansive questions of what it means to be human in this early part of the 21st century, how to live well with self and with others and partake in the shared responsibility of co-constructing a just global world. Critical questions of who benefits are never far away as is grappling with theoretical perspectives provided by critical sociology and philosophy (Mooney Simmie & Moles, 2011, 2020).

My research studies analyse policies in education and in STEM education (in relation to teaching and teacher professional development) taking policy backgrounds and contexts into account and contrasting this with education understood as a practice of human freedom [emancipation] and transformative possibility. This view of education is found in the philosophical writings and theorisations of Paulo Freire (Freire, 2018/1971) and Maxine Greene (Greene, 2017) and related theorists and underpins my reflexive positioning in all of my research and policy studies (e.g. Galvin & Mooney Simmie, 2019; Mooney Simmie, 2007, 2021; Mooney Simmie & Lang, 2019; Mooney Simmie & Edling, 2019; Mooney Simmie, Moles & O'Grady, 2019; Mooney Simmie & Moles, 2020, 2011; Mooney Simmie & Sheehan, 2022). Education as a practice of freedom acknowledges the aspiration for nurturance of an inner (soul) life and for critical mediation with the wider social and material world. The discipline of education therefore does not stop at a focus on 'self' and 'resilience' or indeed at the edge of the classroom or 'institution'. Within the aims for education, and STEM education, the teacher works within a number of paradoxes, including seeking to induct children and young people - through qualification, socialisation and subjectification - into the reliable and changing canon of knowledge and into the cultural world(s) and at the same time always making space for something new and better to emerge (Ball, 1995, 2003, 2021; Biesta, 2012, 2013, 2016; Edling & Mooney Simmie, 2020).

It is in the discursive gaps between policy and practices that this journey of human being and becoming and change plays out as well as securing the reform needs of the state and of industry. Minding the gap between policies and practices therefore becomes the leadership task of teachers, teacher educators and school leaders (Mooney Simmie & Sheehan, 2022). This is in keeping with an existentialist view of the irreducibility of human dignity and the need to retain spaces for democracy to flourish in any dynamic democratic society (Lynch, 2022). This articulation of the former purpose of education is often refered to by Biesta (2013) as the 'beautiful risk' of education – paraphrasing the words of WB Yeats as the lighting of a fire rather than the filling of a pail - while the latter purpose is defined by Edling and Mooney Simmie (2020) as the teacher and teacher educators' democratic assignment.

While one of education's tasks has always been to secure democracy - in self-proclaimed democratic nation states - how this is done has varied and is not always agreed. A rather thin version of democracy relies on teaching about and for democracy and inculcation into the regulatory norms of obedience necessary for becoming a compliant member of civil society. By contrast a thicker view of democracy [a reconstructivist view] understands that while induction into the existing social order is necessary this is not sufficient and more is needed (Edling & Mooney Simmie, 2020). Democracy needs to have the agility and flexibility to change as change is required. Therefore, students need to experience at first-hand democracy as a living project in schools and colleges and enjoy safe spaces to present contrarian views of society and debate controversial *Socio-Scientific Issues* (SSI), such as genetic engineering, climate change, artificial intelligence (Hodson, 2003). Clearly a new activist imaginary is needed in schools and colleges that invites students and teachers to experience and to play their part in the (re)construction of the world (Edling & Mooney Simmie, 2020).

I justify my selection of critical research policy studies in education, and in STEM education because such studies call on the social sciences to interrupt public discourses of policy texts

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and practices in ways that reveal contemporary knowledge-power interplays and the framing of teachers and students [increasingly as units of human capital] within the intersectionalities of social justice and gender justice. Over time my studies started to also draw from feminist theorisations of Maxine Greene and others (Greene, 2017). What feminists bring to critical studies is the capability to widen the problem beyond a reductionist framing and the foregrounding of the issue of gender beyond a dualistic world dominated by either patriarchy and/or matriarchy. I am interested in critical feminist scrutiny of gendered relations of power in education and STEM education policy, how gender is defined and how gender issues can become essentialised and quickly silenced, domesticated and/or neutralised.

In this SMEC 2022 proceedings, I assert that pertinent questions of this kind need to be asked of scientific literacies and STEM education policies given the traditional essentialist nature of these subject areas and their continued dominance in state systems as hyper rational fields of endeavour and a pipeline for STEM related industry and research.

I assert here that if students of STEM subjects in schools and colleges are to be introduced to the benefits of access to a good life –and playing their part in the co-construction of a just society and global world - coming from immersion in STEM Education [e.g. access to counter-intuitive thinking, scepticism, curiosity, experimentation, divergent thinking], and in decolonising ways in the classrooms and schools then it is vital STEM Pedagogies draw from epistemological plurality and are not confined to just one dominant STEM Pedagogy, such as found in policy aspirations for students and teachers to work in schools as if they were emulating professional 'scientists' and/or adopting one engineering model of STEM Pedagogy, a model of continuous improvement and problem-solving (Margot & Kettler, 2019; Stohlmann, 2019). This is a central argument at the heart of this critique.

STEM Pedagogies if they are to support emancipatory and transformative possibility in education need to be considered in the plural rather than in the singular and within policy recognition that not everything of value in human development and change can be atomised and measured. While I argue that management and metrics clearly play a role in the necessary scientific knowledge base for education, any overreliance on management and measurement – in STEM Policy Education – has the potential to be deeply damaging to the human spirit, human flourishing, the moral development of the child and young person and to the necessary immeasurable love labor, care and the relational heart work of teaching and teacher learning and the wider critical aims of a dynamc democracy and public interest values (Biesta, 2012, 2013, 2016; Edling & Mooney Simmie, 2020; Lynch, 2022; Mooney Simmie, 2021)

Ball et al. (2011) showed that policy should never be made equal to practice in a series of studies in *Discourse Cultural Studies in the Politics of Education*. Their papers arose from case studies of the policy process with a number of schools in London. Ball (1995, 2003) and other sociologists in education argue that if policy is made equal to practice then we achieve a *Totally Pedagogised Society* based on a narrow functionalist view of individualism and institutionalism. Fielding (2007) points to the intellectual poverty and social costs arising when schools and educational institutions are redefined as *High-Performing Learning Organisations* in a market-led discourse of learning.

My research interest is in the primacy of the student and teacher as subjects, where the objective is always in the service of the subjective (Mooney Simmie & Moles, 2011, 2020). I argue that working from an essentialist view - advocating for one model of STEM Pedagogy - may well result in intellectual poverty in the STEM classroom and exert a social cost for chidren and

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young people, especially for girls and boys coming from lower socio-economic and different cultural backgrounds in contemporary schooling in Ireland.

I have structured the paper as follows. First, I interrogate the theories of pedagogy and show how pedagogy is viewed in teacher education and in research as a contested construct. Second, I conduct a critical scrutiny of the postpositivistic stance advocated in contemporary STEM Education Policy that moves beyond former views of epistemic knowedge in favour of techné and prioritisation of skills, competences and science-in-context. Third, I conduct a critical review of a select STEM literature and the (re)positioning of scientific literacy. Finally, I conclude with key insights as the study reveals new thinking for securing scientific literacies for all, a hypothesis I argue is worthy of further research and consideration.

Theories of Pedagogy

Pedagogy can be viewed using multiple ontological and socio-cultural lenses. A critical scrutiny of these lenses is nowadays urgently needed given the recent global policy imperatives from the state and industry to push deeper into the classroom in order to mandate how policy must be implemented through select pedagogical practices. Policy imperatives and mandates that are taking place against the backdrop of western education coming under intense pressure in terms of new crises in the economy and politics. Crises in the economy and politics have always and ever been the seed-bed for educational policy change and reform (Arendt, 1954). In a time of fear it may be harder for the state to push back on corporate lobbyists and other powerful vested interests in order to reflect more deeply about the most appropriate pathway forward for human and societal change and development.

The politically expedient thing for policymakers appears to require positivistic research – using its prowess in mathematical modelling and data analysis - to provide evidence-based solutions as best approximations for a future that can be controlled and predicted (Gulbenkian Commission, 1996). Evidence-based syntheses coming from large scale quantitiative studies broker no philosophical arguments and open no public spaces for refutation and contestation. Philosophical insights and theorisations are considered as nothing more than (personal) opinions that have no standing in comparison to fact and number. Several recent and timely philosophical studies reveal many real and symbolic dangers with this misrepresentation of science in the field of education (McIntyre, 2011; Rømer, 2019; Selwyn & Gašević, 2020).

Gore (1993) draws from a critical feminist perspective to argue in her doctoral thesis that pedagogies of struggle are necessary to take into account the tensions, contradictions and differential power relations embedded in all pedagogical practices. This notion of pedagogy as struggle retains the complexity, incoherence and messiness of the discursive spaces between policies and practice, the need for teachers to be trusted to make localised autonomous judgements and to pay attention to the particular needs of children and young people rather than implement a universalist routine of diagnostics and evaluation within a prescripted model of human capital theory (Lynch, 2022; Mooney Simmie & Moles, 2020; Tan, 2014).

In a seminal paper, Lingard (2007) provides a rich overview of the field of pedagogical theory showing how the terrain divides between abstract, political and theoretical perspectives and empiricist reality perspectives. Lingard (2007) shows how pedagogy is simultaneously interested in questions of ‘knowledge generation’ and ‘identity negotiation’. This suggests that rather than one model, no matter how sophisticated that policymakers need to acknowledge the complex interweave between knowledge acquisition and co-construction and the negotiation

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of identity and knower dispositions taking place in classrooms and revealed to the student by way of for instance, the recognition, care and valuing of students, the inner directed moral commitment of teachers and school leaders to act as co-inquirers.

Lingard et al. conducted a large-scale research project in pedagogy in Australia – the Queensland School Reform Longitudinal Study – mapping, analysing and theorising teacher pedagogies as Productive Pedagogies in the context of new schools reform agendas. Findings from the study conducted between 1998 and 2000 showed that while teachers were for the most part caring in their practices they generally offered low intellectual challenges. A Pedagogy of Indifference was also found in relation to recognition and celebration of human 'difference' and diversity and the plurality of human condition. This is a finding that is worthy of deeper interrogation when we consider teaching science and mathematics, engineering and technology and computer science subjects to children and young people in contemporary Ireland. Within the STEM disciplines how do policy makers, teacher educators and teachers in Ireland view this 'identity negotiation' aspect of the pedagogy task?

According to the theorisations of Nancy Fraser (Fraser, 2009), the 'difference' domain needs to move beyond mere recognition and inclusion of the Other to a more activist imaginary in relation to social justice, gender justice and epistemic justice. Lingard (2007) cautions against the mandating of particular pedagogies at system level as he argues that this would be highly 'restrictive of teachers' professional practices and professional conversations, and forgets that trust is central to effective pedagogical reform' (p.262). This point is also taken up by Mooney Simmie and Moles in studies of teachers subjectivities showing how the system puts teachers' bodies and souls to work for the principle of the market-place rather than for facilitating openness and appropriate levels of risk (Mooney Simmie & Moles, 2011, 2020).

Nowadays, philosophical studies of pedagogy theory – such as found in critical pedagogy, pedagogy as praxis, productive pedagogies and speculative pedagogies – seek to (re)conceptualise the necessary struggle for pedagogies within an open invitation to disrupt prescription within the academy and public policy making. Such theories provide a rich understanding that pedagogy is not the static and fixed concept that is often portrayed in reform policies of pedagogy expressed as disciplinary power and the pursuit of prediction.

Any argument for better control and prediction as the optimal way forward to navigate a future of uncertainty in education and pedagogy is today highly questionable in a global world emerging from the Coronavirus pandemic. This viral interruption on a global scale, suggests that preparation for life-long education is best served by focused experiences in the present, premised on grappling with a future of uncertainty and a transformative view of pedagogy.

Postpositivistic stance in STEM Pedagogy

In the early years of this century, education and STEM Education policies focused on what type of new student and teacher was needed for a 21st century of new requirements coming from a rapidly globalising and digitising world and future workforce. New alliances and assemblages happened quickly as forms of democratic governance replaced former notions of democratic nation states. Slogans such as 'we are all in this together' shut down spaces for debate of contrarian views, nowadays often reframed as negative thinking and even deviant thinking. The OECD alongside large scale quant studies introduced a new ideal type of teacher, student and school as units of human capital within the primacy of the economy and the subjugation of moral, social, cultural and political considerations (Mooney Simmie, 2021).

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The classroom was flipped from former views of an inner directed professional teacher toward a new direction of student-centred, inquiry-oriented and collaborative learning and the new role of the teacher as facilitator of students' learning needs. It was now the responsibility of the teacher and school to ensure that every child was included and the role of the state in this regard was reduced to quality assurance only. Wider issues of inequality and injustice were reframed as issues of the individual and the responsibility of the excellent teacher and the autonomous school and no longer the responsibility of the state and society (Lynch, 2022).

A modernist view of epistemé was changed in favour of a postmodern view of techné. This can be seen in STEM education policies that advocate for teaching that facilitates inquiry and evidence based learning, teacher-led professional development, culturally sensitive ways of teaching and the use of real world exemplars (Margot & Kettler, 2019; Stohlmann, 2019). The emphasis on techné is connected to socio-cultural contexts, interdisciplinarity, multidisciplinarity, transdisciplinarity, nature of science, science-in-context, skills sets and competences. This new SMART (*Self-regulated, Motivated, Adaptible, Responsible and Technologically competent*) STEM student and teacher need to learn to fit in with a consensus view of the ideal human while in constant comparision with manageable and measureable outputs and performances of 'what works best' (Hattie, 2012; Rømer, 2019).

Any holistic criticism of this model of STEM Pedagogy needs to identify the possible beneficience of this pedagogical approach as well as drawbacks. Here I posit that giving students affordances to partake in a model of continuous improvement and problem-solving provides opportunities for students to think through probing questions as they learn how to conduct independent research, to use digital technologies, to gain in perseverance, to build resilience and to work with peers to learn how to engage in design thinking and critical thinking about real world problems (Margot & Kettler, 2019; Stohlmann, 2019). However, drawbacks are to be found in the formulaic and technocratic thinking that underpins this pedagogical approach, and in the inherent assumption that all learning is codifiable and measurable and connected to self-regulation and personal perseverance and resilience- and not interdependent and deeply connected to differential power relations, cultural contexts and privilege and public policy constraints. The dominance of this model of STEM Pedagogy denies other pedagogies, including the necessity for problem-posing, the need for interplays with theory and pedagogies of struggle (Gore, 1993; Lingard, 2007, Verma & Apple, 2021).

Critical Review of STEM literacies

Science has a unique way of looking at the world with its own language, grammar, syntax, scientific methods, research approaches, modes of analyses, ethics of research and its own academic/professional communities of practice. The natural sciences place strong reliance on rational reasoning, personal detachment, neutrality, objectivity, counter-intuitive knowledge and empirical rationality. While the canon of scientific knowledge is a reliable source it is also a dynamic system where new knowledge once accepted in the scientific community replaces former knowledge. Science has a complex and uneven history and philosophy and it is nowadays argued from several directions that science teachers need to be fully conversant with this history and philosophy (Cobern & Loving, 2020).

Here I assert that philosophically informed STEM teachers may be best placed to develop curiosity and scepticism in their pedagogical approaches as they open new spaces for creative and critical thinking with students while, at the very same time, assuring the acquisition of content knowledge and the negotiation of subjectivities (Mooney Simmie & Moles, 2020). STEM Pedagogy as a human and social endeavour requires teachers to engage with the living

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contradictions of their practices, to breathe life into the STEM curriculum, to display care and affectivity while animating students to actively engage with the many controversial SSI issues in ways that display ethical awareness and a new activist imaginary in order to support wise political decision-making in the co-construction of the world (Hodson, 2003; Hodson & Wong, 2014). In this way STEM education involves teaching STEM content knowledge to children and young people in different ways, approaches that support induction into the social order while making way for something new to emerge (Edling & Mooney Simmie, 2020).

The concept of science literacy was first introduced into the school curriculum in the 1950s and was primarily centred on the needs of the economy and national security (Li & Guo, 2021). The intention was to project a positive image of science with the purpose of keeping alive the public commitment of funding for scientific research and a pipeline of qualified scientists. Variations on this theme have lasted for more than seventy years and reveal how science literacy is a changing cultural and socio-political concept that is highly dependent on the needs of the era (Bybee & McCrae, 2011).

Erduran, Kaya & Avraamidou (2020) open the question of the reconceptualisation of science literacies in school science and show how they are underpinned by issues of social justice and the necessity for productive interplays between science education and the wider world. They position the problem within crises such as migration, vaccine equity and intersectionalities playing out between people of different class, race, caste, gender, ethnicity and religion. They argue that science education needs 'to support science teachers' learning of strategies to promote students understanding of NOS and social justice in unison' (p.109) and 'to promote a just and democratic society by valuing diversity' (p.110). They refuse a narrow consensus view of science education and their human rights perspective affords respect for all.

The case for philosophically literate STEM teachers is made by Cobern & Loving (2020) with the purpose of guarding against a narrow 'scientism' (p.213), which they describe as an authoritarian firm view of science that seeks to present absolute truth and a final form. They support STEM teachers engaging in philosophical co-inquiry as this will support the interruption of routinized practices and assist their articulation of the many hidden assumptions and paradoxes underpinning teachers' contradictory practices. Their study signals a strong turn to the humanities to support deep learning and problematizing the type of science literacies needed today and moving away from just one way of looking at science.

The concept mapping of science literacy was first carried out by Roberts (2007) and presented as Vision I (*theoria*) and Vision II (*techné*). Vision I arises from a fundamental (epistemic) understanding of knowledge that emphasises science as a discipline with propositional and procedural knowledge. This reflects a positivistic stance that seeks detachment from the living contradictions of practice and socio-cultural and political entanglements with the wider world. Vision I gave way in this century to a broader socio-cultural perspective - Vision II - a post-positivist stance that is advocated by the state and by industry, in STEM Education Policy that is sensitive to socio-cultural context (science-in-context), interdisciplinarity and learning about SSI issues. However, Vision II is narrowly focuses on the instrumental, on excellent instruction, on learning about issues rather than any activist imaginary seeking to critically interpret and/or to grapple with controversial SSI issues.

In recent times, a third vision (Vision III) is advocated in the critical science literature. Vision III, includes Vision I and Vision II approaches to knowledge acquisition and identity negotiation and, at the very same time recognises the need for an activist imaginary that

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includes attention to criticality and reflexivity. Vision III understands science as a human endeavour, a sociological project taking place in schools and in the public forum of an ethical and political (democratic) society. Vision III draws from critical theory, critical consciousness and reflexivity and moves the problem beyond instruction and meaning-making to deep learning and critical mediation with others and with the wider socio-cultural (political-scientific-highly-technological) world.

Hodson and Wong (2014) critique the consensus view of the nature of science that has taken hold of much of the literature in STEM education, with the aim of providing clarity of definition, standards, and benchmarks and argue that this has ‘a strong whiff of orthodoxy and carries the implication that those who disagree with the specification will be considered deviant’ (p.2644). They fear that a ‘consensus view promotes a static picture of science and fails to acknowledge important differences among the sciences’ (p. 2645). Sjöström and Eilks (2021) present a Vision III concept of science literacies using the concept of *Bildung* in recognition of the broader educative task of learning how to live well as persons in a fast changing scientific and highly technological society and global world. They argue for a new concept of science literacy that broadens its focus, and recognises its reflexive dimension as a sociological construct in a globalising world. Their theorisation of *Critical Reflexive Science Literacy* is framed as ‘a politicised vision of science education aiming at dialogical emancipation, critical global citizenship, socio-eco-justice’ (p.82).

Conclusions

When extolling the advantages that science brings to humanity and the world, such as vaccination successes by scientists without borders in the coronavirus pandemic, it can be easy to gloss over the many cautionary tales from the history of science. There are limits to scientific reason that need to be acknowledged (McIntyre, 2021). This is especially important in political systems that claim to be democratic, where majority rule is designed to work within a paradoxical understanding that the public space always allows for contrarian views and the protection of minority views and human rights (Edling & Mooney Simmie, 2020).

My argument here is that if evidence (metrics) becomes the one (dominant) lens to judge the success of STEM Education then policymakers will have fallen headlong into a narrow ideology of scientism (Hyslop-Magison & Naseem, 2010). Scientism offers a misrepresentation of STEM education through failing to acknowledge other ways of knowing and to having the intellectual humility and the moral fortitude to accept that there are limits to scientific reason (McIntyre, 2021). Here I have shown that there are undeniable merits in introducing students and teachers to using evidence to make claims, such as drawing from counter-intutive knowledge in their practices and using STEM Pedagogy for problem-solving and a journey of improvement. However, in an era of post-truth and at a time of a new crisis in politics and in the economy any overreliance on metrics and management fails to acknowledge the primacy of the human subject at the heart of education and overrides the many complex and sophisticated concepts associated with being and becoming human, with entering a lifelong journey of being educated including for example, the ethical and relational nature of STEM Education, the immensurable love labor, care and affectivity needed for a wholesome journey of human development and the need for securing spaces between policies and practices that assure human emancipation and the possibility of a dynamic democracy.

The current postpositivistic drive toward *techné*, with policy imperatives for consensus is shutting down spaces for authentic dialogue, building trust, contrarian views and ultimately for opening spaces for new thinking and the not-yet-thought. One Australian school principal explains some of the detrimental consequences of this rather narrow policy imperative: 'In closing down dialogue and setting normative standards, an evidence hierarchy is inherently anti-democratic, as it closes the public space, reducing social relations to obligations…..the barriers go up……what should be open to question and not reductively represented as self-evident, including research methodologies and outcomes, are standardized and ranked' (Howie, 2020, p. 683).

I have argued here that STEM Education is a human and relational endeavour, a sociological project that needs to be understood as an open and dynamic system - for assuring human emancipation as well as living well in a vibrant dynamic democracy - rather than a static and predictable system. This 'beautiful risk of education' (Biesta, 2013) includes the necessity for epistemological plurality and the need to acknowledge in STEM education policy in Ireland that not everything of value in 'identity negotiation' as human development and change can be codified and measured. It is a hypothesis worthy of further research and consideration.

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Addressing transition issues in mathematics and physics through practitioner inquiry

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ABSTRACT

This study reports on the implementation of a teacher professional learning programme designed to develop teachers' competencies in designing rich tasks that support student learning across transitions in mathematics and physics. Primary and secondary teachers were supported to conduct their own Practitioner Inquiry (PI) and design and implement rich tasks in their classrooms. This study reflects on the experiences of four teachers of mathematics and physics who collaborated as part of a professional learning community over a nine-month period. The findings of this study were identified from analysing teachers' reflections on their experiences of designing and implementing rich tasks in their classrooms and examining the impact of these tasks on their students' learning through practitioner inquiry. Examples of rich tasks prepared by teachers will be discussed along with the challenges identified by teachers in carrying out practitioner inquiry and designing appropriate rich tasks.

KEYWORDS

Practitioner Inquiry, Teacher professional learning, Transitions, Mathematics and Physics learning

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Introduction

Between the ages of 10 and 16, students face a range of educational transitions such as transitions across school systems (e.g. primary level to second level), transitions between different teachers, transitions across subjects (for example from general/broad science curriculum to a specialised physics curriculum and transitions across mathematics and physics) and several other social transitions. These transitions present several challenges for both students and teachers, as from the ages of 10 upwards, students experience new curricula and specialist teachers in these subjects. The implications of difficult transitions are associated with decline in academic performance, negative attitudes towards learning and students' wellbeing (Kaur et al., 2022). These challenges are particularly prevalent in mathematics and physics where students' negative experiences act as barriers to their learning and result in disengagement and disinterest for these subjects. Findings from a recent systematic review on mathematics and science transitions suggest the important role of learning environment and teachers' instructional practices in shaping students' experiences of these transitions as well as their interest and identity in subjects of physics and mathematics (Kaur et al., 2022). Therefore, student engagement in authentic learning opportunities is crucial for developing their conceptual understanding and improved learning (Stein et al. 2008; Sullivan et al., 2016).

Rich tasks have been identified as a valuable approach for designing differentiated activities that address students' learning needs and interests (Bobis et al., 2021). Rich tasks, a term more widely used in the context of mathematics, refer to authentic learning opportunities that are accessible to a range of students, promote productive struggle and are characterised by real-life applications of learning (Piggott, 2011; Sheffield, 2003). Several characteristics and learner outcomes of rich tasks have been identified, e.g. Rich tasks have a focus on inquiry, improve questioning, promote reasoning and problem solving, encourage collaboration and provide opportunities for critical thinking (NRICH). Such tasks can provide a useful scaffolding tool to enhance student learning in cognitive, behavioural and affective domains. However, for a sustained impact, teachers must be supported in both designing and implementing rich tasks and investigating how these tasks impact student learning in their own classrooms.

Practitioner Inquiry (PI) is a model of teacher professional learning defined as the "systematic, intentional study of one's own professional practice" (Dana & Yendol-Hoppey, 2014, p.12). By systematic engagement in enactment and reflection, the purpose of PI is to improve classroom practices with a focus on student centred learning. It provides educators with the tools to problematize their own teaching practices, and critically reflect on their beliefs and assumptions (Cochran-Smith & Lytle, 2009; Dana & Yendol-Hoppey, 2014, 2020). Many studies have established the powerful impact of PI on teachers' professional growth as well as on student learning experiences (Ermeling, 2010; Nichols & Cormack, 2017). Interchangeably referred to as 'teacher research', 'teacher inquiry' or 'action research', PI has emerged as a research tradition that 'highlights the role classroom teachers play as knowledge generators' (Dana & Yendol-Hoppey, 2020, p.5). Practitioners ask questions or wonderings, gather data to explore their wonderings, analyze data and make changes in their practice based on the knowledge they construct and share findings with others (ibid). By developing an inquiry stance, teachers become aware and responsive of their students' needs, and take evidence-based decisions to bring meaningful change in their classroom practices. A valuable context where teachers can engage in PI in a supportive and collegial environment, is a professional learning community (PLC) of teachers. While PI has a focus on a teacher's own practices, PLC as a professional learning approach provides opportunities for teachers to collaborate, share ideas and learn from the practice of other teachers. Through exchange of ideas and professional

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dialogue, effective PLCs promote a culture of inquiry among teachers and are characterised by a shared vision and curiosity about student learning (Cochran-Smith & Lytle, 2009).

A criticism around PI is that it takes a considerable amount of time and space for teachers to delve deeper into practitioner inquiry, collect quality evidence and reflect critically on the practices undertaken (Ponte, 2002). However, despite this challenge, studies have shown that teachers who engaged in PI develop a higher confidence in the use of innovative classroom practices, consequently resulting in an improvement of pupils' learning and engagement (Ermeling, 2010; Nichols & Cormack, 2017).

Study context and aims

The aim of this study is to investigate teachers' experiences of carrying out a practitioner inquiry and examine the influence on their student learning in mathematics and physics. This research is carried out as part of a larger-scale programme that aims to support teacher professional learning to address transition issues in mathematics and physics with students aged 10-16 years (STAMPEd, n.d.). The programme facilitates teachers to inquire into their own practice, collaborate as a professional learning community (PLC) and design and implement rich tasks in their classrooms (Grimes & McLoughlin, 2021). The model adopted in this study to support teachers conducting a practitioner inquiry as part of a PLC has been described by Grimes and McLoughlin (2021), shown in Figure 1.

Figure 1. *Practitioner inquiry stages (source: Grimes & McLoughlin, 2021)*

This programme is developed using an Educational Design Research (EDR) approach (Lovatt, Grimes & McLoughlin, 2020), and data from this study was gathered as part of the EDR framework for the programme. This study examines four Irish teachers' experiences of conducting a practitioner inquiry as part of a PLC over a nine-month period and addresses the research question: ***What are teachers' experiences of using practitioner inquiry to address transition issues in mathematics and physics?***

Methodology

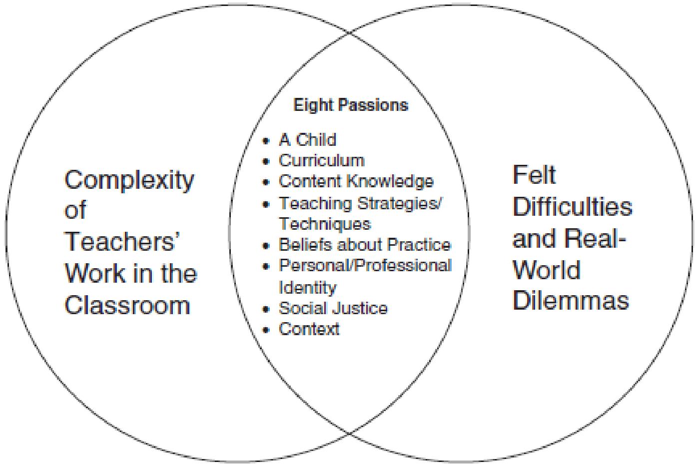
Four in-service teachers (one primary and three post-primary) formed a PLC and carried out a PI (referred to as Teacher 1 to Teacher 4). Seven PLC workshops, facilitated by STAMPEd project researchers, were facilitated as two-hour online workshops (due to Covid-19 pandemic) over a nine-month period, from September 2021 to May 2022. These workshops focused on developing teachers' understanding of practitioner inquiry and to support them to systematically inquire into their own practice.

Table 1. *Overview of PLC workshops*

Workshop (WS)	***Focus of workshop***
WS1 (Sep 2021)	Teachers identified and discussed transition issues. PLC established.
WS2 (Oct 2021)	Factors that influence transitions identified in literature mapped to factors identified by teachers. Teachers identified their own passions and were introduced to the concept of rich tasks.
WS3 (Nov 2021)	Introduction to PI. Teachers proposed a PI question.
WS4 (Dec 2021)	Features of rich tasks introduced
WS5 (Jan 2022)	Teachers engaged in co-designing rich tasks.
Between WS5 and WS6, one-to-one meetings were held between teachers and one researcher.	
WS6 (May 2022)	Understanding and interpreting PI data.
WS 7 (May 2022)	Teachers shared their PI and discussed experiences at the Showcase event.

In the first workshop, teachers were asked to discuss and reflect on the key issues and challenges of transitions in education and transitions across mathematics and physics. These discussions promoted sharing and exchanging of experiences between the teachers and supported the establishment of a PLC that had a shared goal of supporting students across mathematics and physics transitions. The second workshop facilitated teachers to identify their passions and introduced them to the concept of rich tasks. Teachers reflected on their own practice through the lens of eight passions conceptualised by Dana and Yendol-Hoppey (2020) (Figure 2). Using these passions as inspiration, teachers identified their own passions in education and delved deeper into their passion to come to a personal question about their practice. This is the first step towards a researchable PI question. For example, a strong inclination of Teacher 1 towards advocating equity and social justice led them to inquire into how language could be made more accessible to students across mathematics and physics transitions.

Figure 2. *Eight passions for developing practitioner inquiries (source: Dana & Yendol-Hoppey, 2020)*



The next two workshops (WS3 and WS4) introduced teachers to PI and features of rich tasks. In WS5, teachers engaged in codesigning rich tasks in mathematics and physics, using a structured approach. This supported teachers in designing rich tasks to implement with their students as part of their own PI. Throughout these workshops, teachers deepened their understanding of PI and how it can be used examine their students' learning. Students' learning experiences were evaluated by teachers in their own classrooms, using a variety of methods such as class observations, written feedback, student interactions, whole class discussions, assessment using rich tasks and students' views on the use of approaches used for their PI.

Findings

The teachers in this study conducted their PI in different physics and mathematics topics. Table 2 presents the passion related to teachers' PI question and the education level they focussed on.

Table 2. *Overview of teacher's practitioner inquiry questions*

Participant	*Education level**	*Teacher's Passion*	*Practitioner Inquiry Question*
Teacher 1	Senior cycle	Equity/Social Justice	How can I improve the physics classroom environment for my EAL students?
Teacher 2	Junior cycle	The curriculum	How does the use of visual strategies with student-generated questions impact student understanding in Speed/Distance/Time and Trigonometry?
Teacher 3	Junior cycle	Teaching strategies	How does Peer Feedback Effect Higher Academic Achieving Students in Maths?
Teacher 4	Upper Primary	Content knowledge	How can using visual strategies support students' learning and confidence in answering 6, 7, 8 and 9 multiplication facts?

*In Ireland, students attend primary school typically between the ages of 5 and 12, the junior cycle of secondary school between the ages of 12 and 15 and the senior cycle of secondary school between the ages of 15 and 18

A brief overview of each teacher's practitioner inquiry is provided below.

Teacher 1

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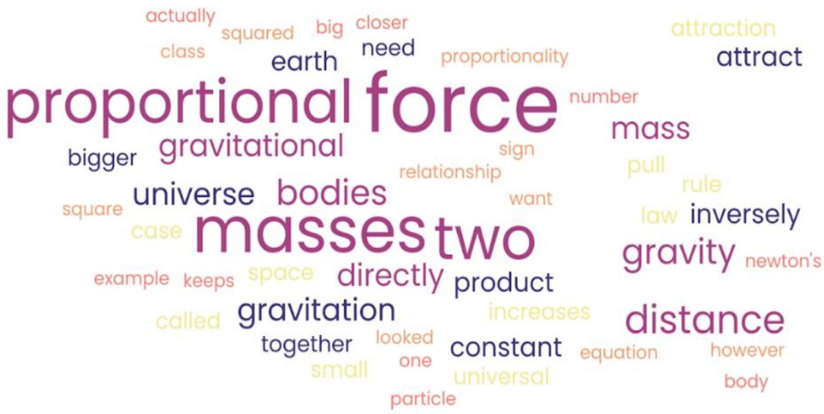
Grounded within the realm of social justice, and their passion for equity in the classroom, Teacher 1 engaged in PI with a focus on exploring how to make physics and mathematics more accessible for students for whom English was not their first language. Teacher 1 focused on creating the right learning environment in the classroom, collaborated with the EAL (English as an Additional Language) and MFL (Modern Foreign Language) teachers and paid special attention to students' identities. In creating a positive learning environment, they used a variety of strategies such as word banks, summarising exercises after each activity, comprehension, videos of experiments, infographics, visual presentations, and use of Google speakers in the classroom. Throughout the process, Teacher 1 ensured that students are well aware of the fact that the teacher is cognizant of their learning needs so that they can be more open in turn to ask for the support they need. The teacher identified a useful strategy to obtain feedback on students' learning was to summarise students' responses after every activity and put them in a word cloud to capture feedback on how that concept was understood by students. Figure 3 shows a word cloud generated by Teacher 1 to investigate students' understanding of the concept of 'Force'.

Figure 3. *Word cloud generated from students' responses*



Another strategy that proved really beneficial was the use of Google speakers in the classroom which provided the required information about the topic and also described the source of information to students. Not only did this help students in understanding the related topic but also helped them in developing the skill of identifying a safe, and trustworthy source of information, and distinguishing between reliable and unreliable sources.

Teacher 1 made the following observations as they reflected on their practitioner inquiry

- *Everyday became a language day… every class was an opportunity to discuss and enjoy language*
- *Changing teacher practice leads quickly to a change in student interaction.*
- *Students began to request translations further examples images and context*
- *Students initiated conversations about language and words.*
- *In general students began to ask more questions and have independent discussions-students appear more confident.*

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Teacher 1 noted that students' awareness of their teachers' cognizance of the language challenges had a very positive impact on classroom learning. Such a mindful approach to students' identities noticeably improves students' confidence. Learning happened organically with these students and all students looked for opportunities to learn, discuss and share. The task, although conducted in physics, led to greater student interest in exploring language for other subjects and purposes too. They also noted that the use of a word cloud allowed them to reflect on their own focus during the lesson, and what concepts may need further attention; in this case, they were concerned by the low prominence of the word *particle* in the word cloud.

Teacher 2

Concerned by a significant drop in students' mathematics and physics performance as they transition to the second year of their secondary school, Teacher 2 engaged in PI with a drive to support student learning through real life contexts, using visual strategies.

Integrating mathematics and physics using visual strategies, Teacher 2 focused on the topics of Trigonometry and Speed-Distance-Time. The tasks involved a site visit (school playground) where students took pictures to look for shapes and variables that they could measure. From these pictures, students generated questions, solved them and then used these questions to teach and/or challenge their peers. Figure 4 shows an example of student generated questions using visual strategies.

Figure 4. *Student generated questions using visual strategies*

The task was perceived as enjoyable by all students. Teacher 2 noted that all students performed better using the visual strategies and student generated questions. A key challenge however emerged as the time taken to conduct the task. Teacher 2 shared that the initiative took approximately twice as long than usual time taken (with teacher-directed classroom teaching) to complete. This meant that the class in which these visual strategies were implemented, lagged behind other classes in content coverage with respect to the time specified in curricular specifications. Although all students enjoyed the activity, the high-achieving students did not want to repeat it and said that it took a long time - '*Quicker the old way. This took a long time.*'; *'I liked the activity but more work for an easy topic'.* Low-ability students preferred the tasks and found the questions easier than traditional text-book questions - *'I prefer the questions we made. They are easier than the book ones.'; 'Good fun and I understand it now.'*

Reflecting on their PI, Teacher 2 concluded that students who usually found these topics difficult to grasp, showed a clearer understanding of the concepts. Their performance scores were better after the task. Especially in the case of weaker students, they enjoyed the task and showed increased confidence. Thus, while the tasks proved beneficial for all student groups, gains in conceptual understanding and performance scores were reported to be higher for weaker students as compared to the high achieving students.

Teacher 3

Intrigued to explore the potential of a variety of teaching strategies, Teacher 3 chose to examine how peer feedback influences higher achieving students in mathematics. Guided by literature around peer feedback and discussions with the members of their PLC, Teacher 3 made the hypothesis- 'Students who are "underachieving" at Mathematics benefit greatly from feedback but find it difficult to give feedback to "over-achieving" students in Mathematics, hence limiting the over-achieving students benefits from Peer Feedback''.

Teacher 3 engaged in this inquiry with a class of second year ordinary level mathematics students. The class had no prior experience of peer feedback, and this was the first time they engaged in such activity. Students worked in groups to give feedback on their peers' work for the given tasks. The groups were formed in a way that each group had a similar mix of high achieving and under achieving students. Students were given a task and a feedback sheet to write their feedback to another person in their group. The activity was repeated with three different mathematics tasks on the topics of 'Financial mathematics' and 'Area'. After each task, Teacher 3 discussed the type and quality of peer feedback with the whole class. To examine the change in students' performance as a result of peer feedback, Teacher 3 collected students' performance scores in three tests each for pre-feedback and post-feedback. Teacher 3 analyzed the results of the pre- and post-feedback tests in the following way:

- The average result of each student over three tests pre-feedback.
- The average result of each student over three tests post-feedback.
- The overall class average pre-feedback and post-feedback.

Other than this data, Teacher 3 also made observations for students' engagement during peer-feedback activity and asked them to reflect on their experiences of engaging in peer-feedback. Reflecting on the results of their PI, Teacher 3 observed that students had started to feel comfortable in writing feedback for their peers and the quality of feedback gradually improved after each task. The results for the overall class average performance increased by 7.13% in the post-feedback tests.

However, as Teacher 3 analysed the data, they observed that analysis of average performance calculated for 'students who scored above 50%' and 'students who scored below 50%' in the pre-feedback tests results showed distinct differences. The average performance of students who scored above 50% in the pre-feedback tests decreased by 9.64%. On the other hand, the average performance of students who scored less than 50% in the pre-feedback tests improved by 7.13% in the post-feedback test results. This indicated that peer-feedback benefited low-achieving students more than the high-achieving students. Teacher 3 concluded that under-achieving students in mathematics did not possess a deep enough understanding of the topic to give feedback to those who did. This limited the benefits of peer feedback for high-achieving

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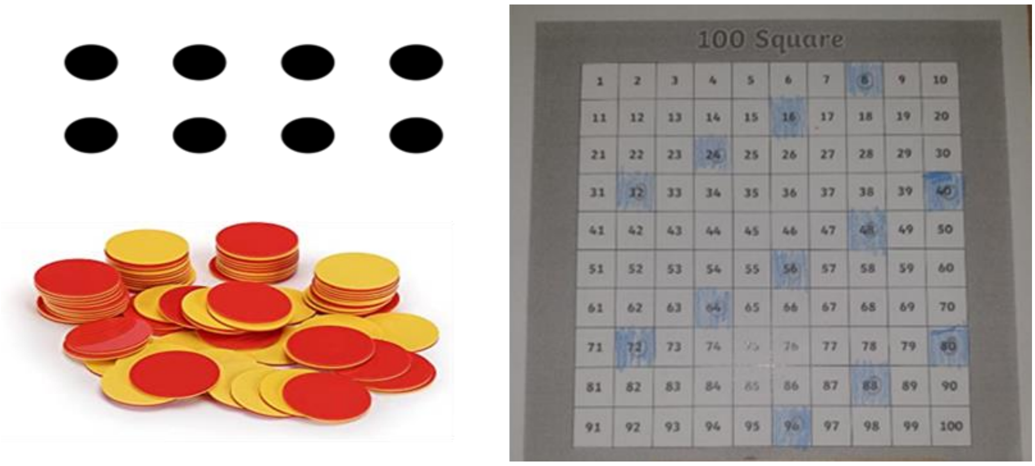
students in terms of improvement in their mathematics performance. This was reflected in the average results of the pre- and post-feedback tests.

Teacher 4

Focusing on content knowledge for transition to post-primary mathematics, Teacher 4 (a primary school teacher), used practitioner inquiry to investigate ways to alleviate maths anxiety and explored the role of visual strategies to support students' learning and confidence in answering 6, 7, 8 and 9 multiplication facts. Addressing this subject-specific transition, Teacher 4 used a variety of visual strategies (examples shown in figure 5).

Figure 5. *Examples of visuals used by Teacher 4*



After exploring multiple strategies, Teacher 4 realised that it was the connection to what students already know rather than the strategies used, that helped build students' confidence. Teacher 4 discovered that when students could see a problem that they are familiar with, it helped build students' confidence to attempt questions that were new to them and seemed difficult. This led Teacher 4 to structure their classes around students' prior knowledge so as to mitigate their anxiety in maths. Throughout the inquiry, the focus was not on right answers but on students' confidence to attempt new questions that they had not seen earlier.

Reflecting on the experiences of PI, Teacher 4 shared that initially one of the two students was reluctant to attempt any of the given questions but structuring tasks around students' prior knowledge instilled confidence in these students and they showed greater self-esteem in working out the steps of the given problems.

Reflecting on their experiences of practitioner inquiry, Teacher 4 made the following observations.

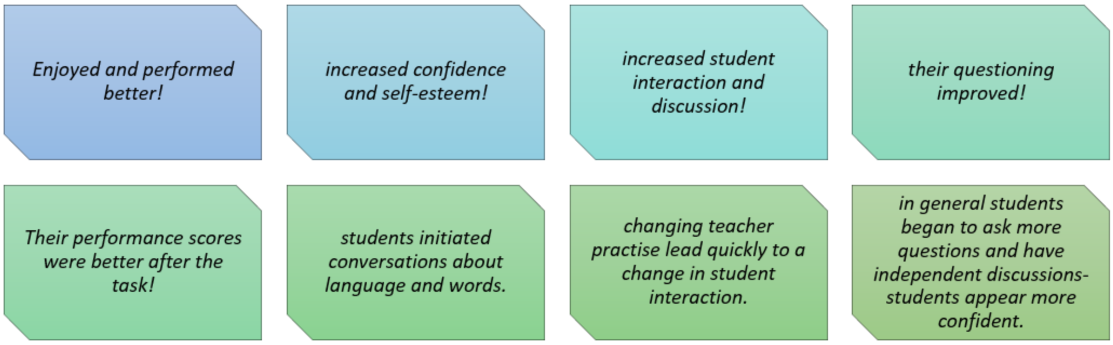
- *The intervention gave students strategies to have the confidence to attempt multiplication facts they previously didn't.*
- *When teaching multiplication facts in future, I will reuse steps 1, 4 and 5 most frequently in an effort to set future pupils up for success and reduce the anxiety around having to remember every fact.*

- *I will look at the students' summer Maths assessments to see if they were able to generalise these strategies to other Maths topics.*

Discussion and Conclusion

Overall, all teachers reported positive effects of PI on their own professional learning as well as on their students' learning. Their students enjoyed active participation in classroom learning and achieved better performance scores after the activity. Teachers reported increased student interactions and discussions and student questioning improved. Overall, students showed increased confidence and self-esteem towards learning. Some observations made by teacher inquirers are summarised in figure 6.

Figure 6. *Teachers' reflection of students' learning experiences*



At the end of the study, teachers shared the implications of their PI at a sharing event and reflected on their experiences of being part of the PLC over the 9 months. Their feedback provided insights into the value of PI for these teachers. 'Reflection' and 'Enactment' emerged as the two key aspects of the programme. Being cognizant of their students' identities, learning needs and their misconceptions, helped these teachers to reflect and modify their instruction as required at each stage. A key challenge noted by teachers is the time and space to engage in PI. Developing an inquiry stance needs time to delve deeper, observe, reflect, and modify which becomes challenging with time-bound curriculum (Dana & Yendol-Hoppey, 2020; Ponte, 2002). Despite these challenges, teachers in this study showed a willingness to engage and continually develop their skill of critical inquiry to improve students' learning experiences and for their professional growth.

In this study, teachers' engagement in the inquiry of their own practice provided them first-hand evidence of a positive impact of PI on students' learning and self-regulation skills. These teachers highlighted the importance of focussing their PI on addressing issues that negatively influence students' experiences of transitions in mathematics and physics, at primary, lower and upper second level. The findings presented in this study add to the existing body of literature around PI. Teachers appreciated the exchange of dialogue and feedback within their PLC and articulated this in the final sharing event. The use of PLC as a platform to develop inquiry stance amongst teachers, offers insights for other teacher professional learning programs, suggesting that PLCs can be a useful platform for developing an inquiry stance among teachers.

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Problem-solving Potential (PsP) in the regular mathematics classroom

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ABSTRACT

A student's Problem-solving Potential (PsP) is defined by their mindset, their mathematical resilience, and the problem-solving skills they possess. This triad construct of PsP was developed as part of a doctoral study, and investigated amongst six cohorts of highly-able mathematics Transition Year students through an educational intervention. Prior research into mindsets, largely spearheaded by Dweck (2006), found a relationship between achievement and growth-orientated mindsets; which extol the virtues of learning over "looking smart", and the value of making mistakes, among other attributes. Mathematical resilience is further subdivided into value (belief that mathematics is important), struggle (acknowledgement that struggle is a valuable part of learning mathematics), and growth (referring to growth mindsets) (Kooken et al., 2016). Prior research of mathematical resilience focussed on the development of this concept amongst low-achieving students; whilst our research investigated its development within highly-able students. There is a popular belief amongst educational researchers that mathematics is best learnt through the construction of knowledge by the learner, and mathematical problem-solving is one approach that creates this opportunity for all learners (Mason et al., 2010). Our educational intervention utilised collaborative problem-solving, and was designed to: introduce strategies for problem-solving; encourage reflection on the problem-solving process; provide opportunities for the extension of problems; and develop communication skills. In this paper, we will highlight the benefit of developing PsP in the mathematics classroom for highly-able students by discussing the relevance of each aspect of the construct through the findings of the doctoral study; and also how the development of PsP may impact lower-achieving students.

KEYWORDS

Problem-solving Potential, problem-solving skills, mindsets, mathematical resilience, collaboration

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Introduction

It has long been believed that mathematics is best learnt through the construction of the learner's own knowledge, and problem-solving has been lauded as one effective means of doing so (Hyland, 2018). Numerous researchers have explored the benefits of developing the skills for problem-solving amongst students. However, to be improve your potential to problem-solve, there is more than skills required. Problem-solving skills, mathematical resilience and a growth mindset each play a role in one's Problem-solving Potential (Fitzsimons, 2021). This paper will explore PsP and the intervention designed to nurture it, while discussing how they may apply to the broader context of the regular mathematics classroom.

Background

Mathematics education in Ireland has undergone changes in the past 15 years, first through 'Project Maths' (DES, 2010), and then through the new Junior Cycle (DES, 2017). Both of these developments brought a renewed call for problem-solving within second-level mathematics (Byrne et al., 2021), although research has suggested that teachers have struggled to be given adequate time allocations or resources to allow for this to occur (O'Meara & Prendergast, 2017). Concerns were raised in the early stages of 'Project Maths' that teachers were not receiving sufficient support to prepare them for the changes required in their teaching under the new curriculum (Grannell et al., 2011); while Byrne et al (2021) suggested that teachers should be given an abundance of continued professional development for the new Junior Cycle to avoid similar failures.

One further aspect of concern with these curriculum changes was the education of highly-able students (Lubienski, 2011). These students rely on classroom differentiation and out-of-school programmes to cater for their diverse educational needs (NCCA, 2007), despite calls from researchers for greater attention for this student cohort (Riedl Cross et al., 2014). Their performances on international assessments have been stagnant and below average over the past 30 years, whilst the general student population performed consistently above average and low-achieving students showed marked improvements (Cunningham et al., 2016; McGrath, 2017). In a bid to address the additional educational needs of these students, Problem-solving Potential was developed as a construct.

Problem-solving Potential (PsP)

PsP is a triad construct developed as a part of a doctoral study that outlines how a student's potential to problem-solve in mathematics is influenced by: the skills for problem-solving they possess; their level of growth mindset; and their mathematical resilience. Dai's (2020) definition of potential reflects upon intrinsic characteristics and traits, and the order of importance they are assigned within an individual reacting to their experiences or environment; but also that this may be shaped by external factors, such as resources or teaching. The importance of problem-solving to mathematics has long been known (Schoenfeld, 1992), and its benefits to the development of highly-able students' abilities has been well-researched (Sriraman, 2003). While the 'skills' associated with problem-solving form a non-exhaustive list, which further depend on the level of mathematics being studies, they include: calculation skills, strategy selection, communication, explanation, reflection, creativity, expansion, and many more. The further engrossed in the study of mathematics a study becomes, the more skills they will encounter and indeed require. It is only through the exposure to problem-solving that they will develop these skills.

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Although there is an abundance of research in the field of mindsets, there exists a gap in this research specific to highly-able students (Esparza et al., 2014). When a student is focussed solely on their test scores, such that an experience of failure or repeated failure leads to feelings of inadequacy or stupidity, they are said to possess a fixed mindset (Yeager & Dweck, 2012). Conversely, a student who values their mistakes and effort as a means to learning is said to have a growth mindset (Dweck, 2006). Research has found that a student's mindset is strongly correlated with their performance in a subject, and may even be a good predictor of a(Blackwell et al., 2007) future decline or incline in grades . With regards to highly-able students, while they may not experience failure commonly, there are fears that they develop negative traits of perfectionism, and seek to hide mistakes rather than to learn from them (Mofield & Parker Peters, 2018). Further concerns have been raised about praising students' performance rather than their effort (Boaler, 2013). Although some students may exhibit fixed mindsets, multiple research projects have shown that a student's mindset may be altered through intervention (Blackwell et al., 2007; Esparza et al., 2014).

Kooken et al (2013) defined mathematical resilience through the domains of value (the extent to which a student values the study of mathematics in their life), growth (in reference to growth mindsets) and struggle (the extent to which a student identifies struggle as a part of the learning process). Students who were highly mathematically resilient were found to show smart strategy selection in problem-solving, to crave discussion, to question mathematical ideas, and to exert the attributes of a growth mindset (Johnston-Wilder & Lee, 2010). Much of the early research into this field has focussed on two areas – how mathematical resilience may be improved, and how it impacts upon low-achieving students. With regards to the former, research has found that the development of "*coaches*" for mathematical resilience may have a positive impact on a student's beliefs (Johnston-Wilder et al., 2013). The doctoral study completed by the author was the first investigation of mathematical resilience amongst highly-able students.

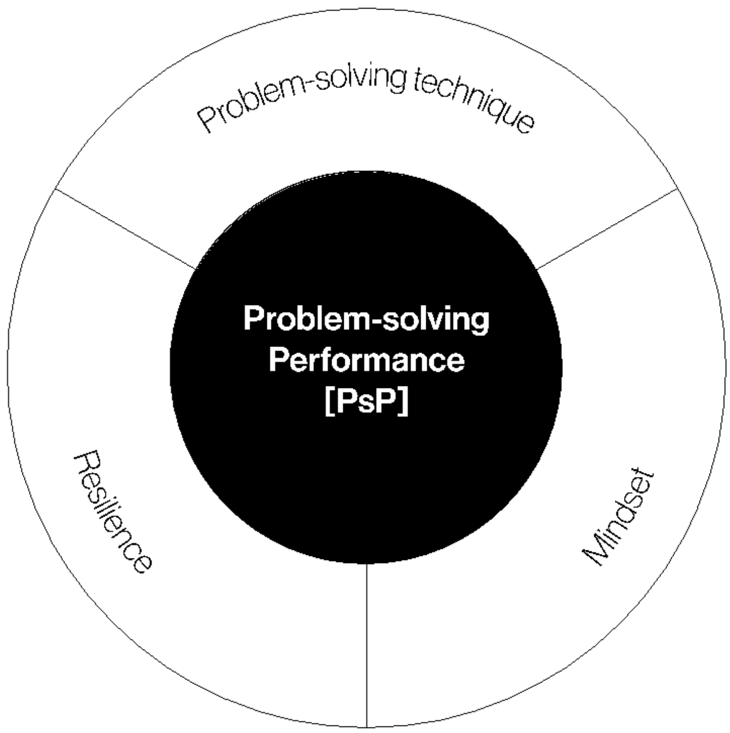

Figure 1 Problem-solving Potential (PsP)

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Mathematics Intervention

The mathematics intervention was developed following a rigorous literature review, and implemented across six cohorts of highly-able, transition year students through the Centre of Talented Youth, Ireland (CTYI). Transition Year was deemed as the most-appropriate time for the intervention for a number of reasons: there is no set assigned curriculum for students; other years are highly time-sensitive due to the vast curricula to be covered by teachers, etc. Two time-variations of the intervention were utilised: a 14-week programme, one day per week for 14 weeks; and a 3-week programme, for 14 days over this period. The students completed a two-hour class and a one-hour tutorial each day. While the layout of the class and tutorial were largely identical, the students were required to complete a written diary reflection for one problem during the tutorial. Each aspect of the mathematics intervention was designed under the aim of developing the PsP of highly-able students.

Instructional Design

Problem-solving heuristics have been prevalent in research for decades, with Polya's steps of problem-solving still widely referenced to this day (Polya, 1945). Mason et al (2010) developed 'stages' of problem-solving, which built upon the work of Polya, and created a system of "Rubric writing" to navigate the problem-solving process. One notable addition was also the extension of problems, allowing for the problem-solver to display their mathematical creativity and restart the problem-solving cycle. While the problem-solving process has been well-researched and advanced through the years, there has been no clearly defined model specific to collaborative problem-solving, despite repeated reports of collaborative problem-solving as an essential skill in the 21st Century (OECD, 2017). Hence, the CoPs model was designed to bridge this gap in research. This model represents the problem-solving processes encountered when working collaboratively.

Collaborative problem-solving encourages the development of individual problem-solving skills, combined with the skills of collaboration, such as communication and the verbalisation of reasoning. It has also been found that highly-able students work effectively in a group of their peers who share similar motivations. Groups of 3 or 4 students were created on the first day of each cohort of students and remained unchanged for the duration.

Problem-solving strategies are essential to the process of solving a problem (Posamentier & Krulik, 2015). Early in the development process, the decision was made to introduce seven strategies organically to students through carefully-chosen problems (Fitzsimons & Ní Fhloinn, 2019). These strategies were chosen due to their prominence in previous literature (Krulik & Rudnick, 1989; Mason et al., 2010; Schoenfeld, 1982): visuals, patterns, generalising & specialising, conjectures, assumptions & questioning, structure, and working backwards.

The role of the facilitator within a problem-solving classroom has been well-outlined in previous literature (Dolmans et al., 2005), and the intervention utilised this role to: ask probing questions of students throughout the process; ensure all students were participating; provide a scaffold for the process where necessary; and to monitor progress of individuals. Furthermore, the facilitator provided positive messages of both resilience and growth mindsets throughout the intervention. As the intervention progresses, the role of the facilitator diminishes, as the students become familiar with the procedures required of them.

Intervention Content

Due to the vast number of resources available online or in literature, the decision was taken to carefully-select existing problems, rather than to create new ones. These problems were curated under themes for each day of the intervention - the first seven themes being those of the aforementioned problem-solving strategies; followed by four contextual themes after the four strands of Junior Cycle mathematics (DES, 2017); and finally three days of general problem-solving. The 'diary' problem for each tutorial followed the same theme as the class. As the participants of the intervention were transition year students, all chosen problems were solvable through Junior Cycle mathematics.

Classroom Design

The classroom was prepared each day before the arrival of the students. Four individual tables were combined in a square pattern for each group. The problems were introduced through a presentation broadcast by a projector. Groups completed their workings on A1 size sheets of paper that were distributed by the facilitator, with extra sheets provided when necessary. While the application of student roles in groupwork may be utilised in research to ensure all members of a group are motivated and participating (Huss, 2006), the 'house rules' and dynamic of the CoPs model require this of the students on this intervention, and thus the introduction of student roles was not deemed necessary. After observation of six cohorts of students participating on the intervention, the author believes this was the correct decision.

Regular Classroom

As previously mentioned, Transition Year (TY) was deemed the most appropriate year for a mathematics intervention to occur for the doctoral study, and this remains true for any school-based intervention. The TY guidelines offer suggestions as to what should be taught to students, but also firmly state that curricula and teaching strategies are to be decided by each individual school (DES, 1994). The guidelines do, however, also emphasise that TY should not be equipped as a third year of study towards the Leaving Certificate (DES, 1994, p. 2). It is also known that both the Junior Cycle and the Leaving Certificate are time-constraining for teachers (NCCA, 2013). TY serves as the ideal stage of second-level education for the existence of an intervention for highly-able mathematics students. The flexibility within the TY guidelines would also allow schools to adopt such an intervention to fit their needs, while not placing pressure on schools by introducing one as mandatory.

A problem-solving intervention in TY would also build upon the unifying strand in the Junior Cycle (DES, 2017), and explore the previous three years content in greater depth. As a part of the doctoral study, the intervention was implemented in two time-variations, and the results of each variation statistically analysed. No statistically significant differences were found between the variations. Further research is now needed as to how effective the intervention can be in a regular school setting, although the individual features are easily transferable.

Less-Able Students

Thus far, PsP has been investigated as a singular construct in the context of highly-able students only. There is further research needed to explore it's benefits to all students. However, an examination of previous research yields the benefits of each aspect separately.

Mathematics anxiety is an issue of great concern amongst less-able students in the study of mathematics (Ashcraft, 2002). Mathematics anxiety can lead to a mental block for students, whereby they disengage from the subject and develop intrinsic barriers to their learning (Gabriel & Barthakur, 2020). Johnston-Wilder et al (2015) found that developing a student's mathematical resilience through the use of "*coaches*" and positive messaging helped those who had developed the 'growth zone model' to illustrate how a student must navigate outside their comfort zone to learn, but may be guided by a coach to avoid entering the anxiety zone.

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Figure 2 *Growth Zone Model*

Further to this, the development of a growth mindset may also be beneficial in tackling mathematics anxiety amongst less-able students (Boaler, 2018). Hwang et al (2017) found that fixed mindsets amongst low-achieving students were a greater predictor of declining results over time than fixed mindsets amongst high-achieving students.

As previously discussed, the role of the facilitator in collaborative problem-solving is multi-faceted. The facilitator may scaffold the learning for their students, and can be as invasive as necessary in the process. For less-able students, the facilitator may become more hands-on than usual to help the students to navigate through a problem, without becoming too overwhelmed by the problem.

Conclusion

The mathematics intervention designed is a purpose-built programme for highly-able mathematics students in Transition Year in Ireland, which is of great importance to these students. The intervention has possible implications for the encouragement of mathematical talent and potential amongst highly-able students in schools. Participation on the intervention can provide students with stronger problem-solving skills that may benefit their study of mathematics in the Leaving Certificate.

With regards to general or less able students, while PsP has not yet been researched with cohorts of these groups, each individual aspect of the construct has clear and defined benefits for these students. The application of this construct within the regular classroom requires research in the near future.

Faulkner et al (2021) recently found that a sample of undergraduate students in Ireland did not display a level of improvement in problem-solving that was expected following the overhaul of the second-level mathematics curriculum. Further to this, they outlined how students may be experiencing "*helplessness*" when they encounter unfamiliar problems. The development of PsP within students has the potential to alleviate concerns such as these when they move beyond second-level education.

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OPEN ACCESS

Teaching mathematics out-of-field and the journey to obtaining mathematics teacher certification

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ABSTRACT

The misassignment of teachers, with respect to their qualification, results in teachers teaching mathematics out-of-field (OOF). OOF mathematics teaching is an international area of concern, with research documenting the existence of the practice in Australia, the United States, Germany and England, and the negative effects that the practice can have on teachers' lives, student learning and the professional standards of teaching. Research conducted in Ireland has demonstrated the prevalence of teachers being assigned to teach mathematics OOF in post-primary schools. In response to the issue of OOF mathematics teaching, the Irish government funded the Professional Diploma in Mathematics for Teaching (PDMT), a professional development programme for teachers teaching mathematics OOF, enabling them to obtain mathematics teacher certification. The content of the PDMT, then, adheres to the Teaching Council of Ireland's curricular requirements for teaching mathematics. This research employs the construct of first-person mathematics-related (1st PM-R) teacher identity to capture the learning trajectory of a participant on the PDMT. 1st PM-R teacher identity refers to the teacher's self-understandings in relation to mathematics teaching. These self-understandings are stories told by the teacher about themselves to a third party. This paper reports on the 1st PM-R teacher identity of Mary, a certified business studies and accounting teacher teaching mathematics OOF, whilst undertaking the PDMT. Thematic analysis and sociolinguistic tools were used to analyse interview data to obtain insights regarding Mary's 1st PM-R teacher identity, and the ways in which her 1st PM-R teacher identity was reshaped over her involvement in the PDMT. The findings suggest that professional development programmes have the capacity to impact 1st PM-R teacher identity, in particular, with regard to how the teacher believes they are seen by school management and their students' parents; however, other factors, such as colleagues and previous experience learning mathematics, may be more significant in shaping the teacher's 1st PM-R teacher identity in relation to their teaching practices. The findings from this research may have implications for the development of mathematics professional development programmes and the criteria for determining mathematics teacher certification.

KEYWORDS

Teacher identity, professional development, out-of-field teaching, mathematics education

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Introduction

In 2009, a research study by Ní Ríordáin and Hannigan (2009) discovered the widespread existence (48%) of teachers being assigned to teach mathematics in Irish post-primary schools without the requisite mathematics teacher certification. This practice of teacher mis-assignment, which results in teachers teaching mathematics out-of-field (OOF) (Ingersoll, 1999), has also been documented in Australia (Hobbs, 2013; Weldon, 2016), the US (Van Overschelde & Piatt, 2020), England (Crisan & Rodd, 2014), Germany (Bosse & Törner, 2015) and South Africa (Du Plessis et al., 2015). The growing prevalence of OOF teaching, then, is of growing concern to those who advocate for teacher professional standards, given that the practice of teacher mis-assignment largely ignores the perspective that to be an effective teacher one must obtain a credentialed level of content and pedagogical knowledge in a particular subject (McConney & Price, 2009). Therefore, across the various jurisdictions reporting on the incidence of OOF teaching, there have been a variety of approaches implemented to address the issue. For instance, a centralised approach in the US involved the Department of Education enacting policy to ensure that students were taught by 'highly qualified' mathematics teachers (e.g., No Child Left Behind), while at a more localised level in Australia, a Victorian university provided a mathematics professional learning programme for teachers teaching mathematics OOF (e.g., Vale et al., 2011). Ireland, too, has sought to address OOF mathematics teaching, and it is Ireland's approach, the development of the State-funded, two-year, part-time, blended learning programme, the *Professional Diploma in Mathematics for Teaching* (PDMT), that is the focus of this paper.

The PDMT, established in 2012 by the Department of Education and Skills[1] (DES), is structured in line with the requirements of the Teaching Council to enable in-service teachers teaching mathematics OOF to add mathematics to their teacher certification. The programme, for which there is no fee incurred by the participants, was and continues to be delivered by a national consortium of Higher Education Institutions. To date, the DES has provided over €8 million in funding for the PDMT, accounting for three cohorts of teachers (approximately 1,100) graduating from the programme and catering for a further 300 teachers who are currently undertaking the programme. As a result of this investment in the PDMT, the latest research suggests that approximately 17% of the mathematics teacher workforce in Ireland are graduates of the programme, while the proportion of the workforce that are teaching OOF has reduced (~25%) (Goos et al., 2021). The PDMT then has changed the landscape of mathematics teaching in Ireland; yet, the impact of this programme on the lives and teaching practices of those involved requires further consideration, particularly given that the PDMT was established following the implementation of the reformed post-primary mathematics curriculum, Project Maths. This research paper provides some insights in this regard by documenting Mary's journey, a business teacher with six years' experience, who found herself teaching mathematics OOF and subsequently, opted to undertake the PDMT to formally add mathematics to her teacher certification. Prior to commencing her studies on the PDMT, Mary had been teaching mathematics in her school for one year, attended other professional development courses in mathematics and collaborated with fellow mathematics teachers in her school; thus, she had accumulated some experience and expertise in the subject area. Therefore, Mary, like other teachers teaching mathematics OOF, should not be viewed or researched from a deficit perspective (Törner, 2014); instead, a holistic approach, such as teacher identity, which encapsulates both cognitive and affective-motivational components should be employed (Hobbs, 2013).

[1] In October 2020, the DES was renamed as the Department of Education.

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The construct of mathematics-related teacher identity offers a viable approach for studying teachers, such as Mary, who are teaching mathematics OOF, given that their mathematics-related teacher identity is continuously negotiated and reshaped as their beliefs and attitudes interweave with their pedagogical content knowledge and content knowledge. This ongoing amalgam of cognitive and affective-motivational components shapes one's self-understandings in relation to mathematics teaching, otherwise termed, one's *first-person mathematics-related* (1st PM-R) *teacher identity*. This paper provides a short overview of 1st PM-R teacher identity, before detailing how Mary's 1st PM-R teacher identity was reconstructed over her time completing the PDMT. In doing so, this paper sheds light on how a professional development programme along with other factors shape teachers' self-understandings in relation to mathematics teaching.

Teacher Quality and Teaching Quality

It is widely acknowledged that what teachers *know* and what teachers *do* impacts on students' learning. Unsurprisingly then the connection between what teachers know (teacher knowledge), what teachers do (teacher practices) and the subsequent learning that occurs (student learning) has been the focal point of mathematics educational research for numerous years. Yet, in spite of a plethora of research in this area, the links between mathematical knowledge, classroom teaching and learning outcomes remain unclear (Askew & Venkat, 2020). Therefore, research is still required to deepen our understanding of the connection between mathematics teacher knowledge and mathematics teachers' practices. To assist in researching the connection between teacher knowledge and teacher practice, Kaplan and Owings (2002) demarcate between *teacher quality* and *teaching quality*. Teacher quality refers to:

> the inputs that teachers bring to the school, including their demographics, aptitudes, professional preparation, college majors, teacher examination scores, teacher licensure and certification, and prior professional experiences. (Kaplan & Ownings 2002, p. 4)

Teacher quality then encapsulates a set of attributes, outlined by teacher certification criteria and developed through teacher education curricula and programmes, which predict that the teacher will be successful in the classroom (Goe, 2007). Therefore, teacher certification acts as the professional benchmark for teacher quality (Kaplan & Ownings 2002), and provides those who are certified with the identity of a qualified teacher. This reflects an acquisitionist perspective of identity, in that it refers to something one *has* (Darragh, 2016). Teaching quality is concerned with "what teachers do with what they know to promote student learning inside the classroom" (Kaplan & Ownings 2002, p.4). It includes creating a positive learning environment, choosing appropriate instructional goals and assessments, using the curriculum effectively and implementing varied instructional behaviours that assist students to learn to a high level. Teaching quality is manifested through identity enactment within the classroom, reflecting a participationist view of identity as something one *does* (Darragh, 2016).

Teacher Identity

Identity, from the participationist perspective, can be conceptualised as "about 'doing' ways of being for self and others", and thus, is inextricably linked with practice (Watson, 2006, p. 509; Wenger, 1998). Given the link between identity and practice, it follows then that teacher identity is inextricably linked to the practice of teaching and subsequently, impacts on teaching quality. Teacher identity is then a unifying construct encompassing *who* one is as a teacher and *what* one does as a teacher. The significance of teacher identity for teaching is surmised by Sachs (2005):

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> Teacher professional identity then stands at the core of the teaching profession. It provides a framework for teachers to construct their own ideas of 'how to be', 'how to act' and 'how to understand' their work and their place in society. Importantly, teacher identity is not something that is fixed nor is it imposed; rather it is negotiated through experience and the sense that is made of that experience. (p. 15)

In the context of teaching mathematics OOF, when a teacher is assigned to teach mathematics without holding the requisite qualifications they must embark on a journey to develop a sense of *who* they are as a mathematics teacher and *what* they do as a mathematics teacher in their classroom. They must construct and, as the process of identification is continuously ongoing, reconstruct their sub-identity in relation to being a mathematics teacher. Bosse and Törner (2015) refer to this sub-identity as mathematics-related teacher identity.

Mathematics-Related Teacher Identity

Mathematics-related teacher identity is, in Gee's (1999) terms, a situated identity, given that it is enacted and recognised in social settings, such as the school and classroom. The recognition aspect of identity involves reflection as one continuously forms and reforms their self-understandings in relation to others (Holland et al., 1998). Self-understanding then refers to one's situated subjectivity; it is the cognitive and emotional view that one has of oneself and one's social world. By viewing self-understanding and social location in relation to each other, the self is culturally specific. In this way, one can have various self-understandings of who one is. Losano et al. (2017) conceptualise mathematics teacher professional identity as a set of self-understandings related to ways of being, living and projecting into the teaching profession. These self-understandings are socially and culturally constructed with other participants in the world of teaching. This notion draws on Holland et al.'s (1998) definition of identities as one's objectifications of their self-understandings. The self-understandings involve people telling narratives to themselves and others regarding who they are, and trying to act as though they are who they say they are. This research then draws on the work of Sfard and Prusak (2005) to describe these narratives – the objectifications of self-understandings – as 1st person identities. These narratives are described as 1st person, given that they are told by the identifying person (Mary), about the identifying person (Mary), to a third party (the researcher). The distinction of 1st person, then, demarcates who is doing the identifying, reflecting the multiplicity and fluidity of the dynamic construct of identity, while building on the work of Wenger (1998), Holland et al. (1998), Gee (2000), Sfard and Prusak (2005) and Bosse and Törner (2015). In the context of mathematics teaching, these narratives and self-understandings in relation to mathematics teaching are one's 1st PM-R teacher identity. Following Sfard and Prusak (2005), there exists current 1st PM-R teacher identities and designated 1st PM-R teacher identities, and when the gap between current and designated 1st PM-R teacher identities is reduced, learning has taken place. This learning transforms who one is and what one does – it is a matter of identity and reflects the process of becoming a certain person (Wenger, 1998). It follows that 1st PM-R teacher identity is understood to be *multiple*, *transactional* and *relational*; it is both *narrative* and *participatory*, involving the enactment and recognition of situated identities. Primarily, it is constructed, maintained and negotiated through discourse. Hence, data collected to explore and investigate Mary's 1st PM-R teacher identity, documenting her learning whilst undertaking the PDMT to obtain mathematics teacher certification, was qualitative in nature.

Methodology

This paper draws on data from a larger two-year, qualitative doctoral study that explored the mathematics-related teacher identities of five OOF mathematics teachers undertaking the

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PDMT. The case of Mary, one of the five participants in the doctoral study, is the focus of this paper, and in particular, the analysis of interview data, as part of a larger corpus of data, gathered over her involvement in the PDMT. The paper contains the analysis of qualitative data emanating from three interviews, the first of which took place in November 2016 (shortly after Mary had commenced the PDMT), the second in April 2017 (following the observation and video recording of a mathematics lesson taught by Mary) and the final interview in April 2018 (shortly before Mary had completed the programme). The research used standardized open-ended interviews for all five participants, which focussed on extracting narratives in relation to their 1st PM-R teacher identity. Additionally, for interviews 2 and 3, the participants were asked participant-specific questions on the basis of what they had said in the previous interview(s). These questions enabled the participants to further elaborate on some issues that were not formally addressed in the standardized interview protocol, while also affording the opportunity for member checking to assist with researcher reflexivity. A combination of thematic analysis (Braun & Clarke, 2006) and sociolinguistic tools (Gee, 2011a; Sfard & Prusak, 2005) were used to analyse the data. The thematic analysis was supported with the use of the Figured Worlds Tool (Gee, 2011b), which requires an analysis of the typical stories being told, the Big 'D' Discourse Tool (Gee, 2011b), involving an analysis of what kind of identity the person is seeking to enact, and the Telling Identities tool (Sfard & Prusak, 2005), equating identities with stories which are reifying, endorsable and significant. Sfard and Prusak (2005) delineate between current identities, which are stories told about the current state of affairs, and designated identities, reflecting narratives expected to be the case in the future. In relation to this analysis, it should be noted that case studies follow the interpretivist view of multiple social realities with the researcher's view and interpretation being one of many (Cohen et al., 2018); thus, researcher reflexivity was central to the data analysis. It is therefore acknowledged that the research knowledge disseminated in this paper is affected by and refracted through the lens of the researcher.

Findings

For Mary, a number of factors contributed to her ongoing 1st PM-R teacher identity (re)construction: *her experience learning mathematics*; *her motivation to obtain teacher certification*, and *her mathematics teaching practices*. Mary completed a Bachelor of Business degree for her undergraduate studies and worked as a teaching assistant at a third level institution, before completing her postgraduate diploma in business education, which certified her to teach business studies and accounting at post-primary level. To be a business studies and accounting teacher, however, was not always Mary's plan; instead, from the age of twelve, she wanted to become a mathematics teacher, a goal she maintained until she endured a negative experience as a student studying mathematics for the Leaving Certificate.

Learning Mathematics

In the initial interview, Mary remarked that mathematics was her favourite subject in school; she had thoroughly enjoyed the subject up until 3rd year, the final year of the Junior Cycle. Mary completed the higher level mathematics course for the Leaving Certificate; however, this was not a positive experience for her, primarily due to the mathematics teacher that she had.

> I didn't have a good experience in the maths classroom. I didn't appreciate being told I should know things already when I ask for explanations, and I never got explanations and it kind of just spiralled a bit, so then I went into business in college.
> (Mary, Interview 1)

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This experience of learning mathematics influenced Mary's mathematics teaching practices, which she described as being "slightly old fashioned" (Mary, Interview 1). She explains:

> My most common phrase is probably, you could always ask me a question … I probably over emphasise that a lot.
>
> (Mary, Interview 1)

Mary acknowledged that she almost enjoyed teaching mathematics more than business studies or accounting, given that she had now returned to a career she had once imagined and a subject that she was very passionate about.

Mathematics Teacher Certification

Mary noted that given her positive disposition towards mathematics, she was very happy to add the subject to her teacher certification; however, this was not her primary motivating factor for undertaking the PDMT. Instead, Mary remarked that she was concerned at the prospect of her students' parents opposing her teaching and discovering that she was not fully qualified to teach the subject. Mary described her feelings when teaching mathematics OOF in comparison to teaching her in-field subjects:

> I was more worried … they're going I already have the qualification, I am one hundred per cent, I am certified to teach this subject compared to going into something where you're not and there's a worry if something goes wrong along the way that there's going to be parents complaining about you and that the first thing that is going to be said is, "what are her qualifications?"
>
> (Mary, Interview 1)

From the outset of the PDMT, Mary did not feel that being certified to teach mathematics would change her teaching practices, and following her studies on the PDMT, despite acknowledging the positive effect that the programme had on her confidence in her mathematical content knowledge, she believed that her teaching practices remained unaltered.

Mathematics Teaching Practices

For Mary, the PDMT did not impact on her mathematics teaching practices; instead, she highlighted that other factors, such as the pedagogical approaches she adopted from her business teaching, learning from her experience teaching mathematics and by observing other teachers teaching mathematics, influence her practice. She remarked:

> I don't think having the 'piece of paper' changes your teaching necessarily; it's other things that impact on that all the time.
>
> (Mary, Interview 3)

Mary believed that the PDMT did not alter her teaching practices due to the significant focus on the developing mathematical content knowledge (MCK), as opposed to mathematical pedagogical content knowledge (MPCK). She explained:

> There's very, very, very little emphasis on how to actually teach [mathematics], and the how to teach it would be far more beneficial. It's all focused on the maths.
>
> (Mary, Interview 3)

Mary's belief regarding the emphasis of the PDMT on developing MCK reflects the guidelines in the Request for Tender of the DES, which outlined that the programme must enable participants to meet the Teaching Council's criteria of 60 European Credit Transfer System (ECTS) credits of study in mathematics-related modules and 5 ECTS credits in the study of the teaching of mathematics. Mary was aware of this criteria and it's determining effect on the structure of the PDMT, as she noted:

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> We have to have certain credits, certain subjects, certain topics to meet what the Teaching Council requires in order for us to be … qualified maths teachers. So in terms of what they can put in the course, they were strict in that – I think that's had an effect.

(Mary, Interview 3)

Through the PDMT, Mary obtained 60 ECTS credits in mathematics-related modules and 15 ECTS credits in the teaching of mathematics modules, and she was subsequently qualified to teach mathematics across all years and levels at post-primary school. Mary acknowledged that she felt more confident in her MCK, and that she felt in-field with regards to teaching mathematics up to the Senior Cycle ordinary level course of study. She maintained, however, that despite her studies of intensive mathematics modules, she was not ready to teach the Senior Cycle higher level curriculum.

> [I'm] probably closer to in-field now than out-of-field, but maybe not kind of fully there. Like I mostly have the expertise for what I'm doing … I suppose I'm nearly qualified now, but … if I had to go into higher level [Senior Cycle] maths now, I wouldn't feel that I'd have the expertise for that.
> (Mary, Interview 3)

Mary surmised that after finishing the PDMT, she would then have the time available to specifically study the content on the Senior Cycle higher level curriculum, which would enable her to feel more comfortable to teach that course of study.

In effect, Mary believed that the PDMT altered her participation in the mathematics teacher community because she felt she was now worthy of giving her opinion at department meetings, owing to her qualification, and it gave her a sense of security, if her teaching was questioned by others. Thus, the PDMT impacted on Mary's 1st PM-R teacher identity in terms of her *teacher quality*, given that she had accumulated the requisite certification deemed to predict success in the classroom. By contrast, Mary's 1st PM-R teacher identity tells the story that her mathematics teaching practice did not change from her participation in the PDMT. For Mary then her *teaching quality* was unaffected by completing a programme to obtain mathematics teacher certification. These findings, perhaps, raise some questions for mathematics teacher certification requirements and consequently, mathematics teacher education programme development.

Conclusion

Mary's journey to mathematics teacher certification presented her with the opportunity to cement or reify her status as mathematics teacher; it provided her with an opportunity to pursue the career path that she had once intended on following, to develop her confidence in her mathematical knowledge and to offer validation to her opinions when expressed in mathematics department meetings. However, the journey to mathematics teacher certification did not, according to her, impact on her enacted mathematics-related teacher identity in the classroom. It should be noted that from the outset, it was not part of Mary's designated 1st PM-R teacher identity that the PDMT would alter her practice, and so, if the aspirations to tell different stories for the future were not in existence prior to undertaking the PDMT, then it was going to be difficult for the programme to impact on her practice. With that being said, it is well understood that prospective teachers' existing images and beliefs serve as a filter for making sense of the knowledge and experience they encounter during preservice preparation (Feiman-Nemser, 2001); thus, these taken-for-granted beliefs need to be addressed in preservice teacher education. It may well be the case then that these pre-existing images and beliefs may be heightened in the context of OOF teachers, given their teaching experience. Consequently, there may be greater demands placed on OOF mathematics teacher education programmes to address these taken-for-granted beliefs to ensure they can effect change in teachers' 1st PM-R teacher identity in relation to their teaching practice. It may also be the case, as Hodgen and Askew (2007) suggest, that significant changes in one's 1st PM-R teacher identity may not become apparent, even to the person themselves, until an extended period has elapsed after the professional development programme. As such, this is a limitation of this study, given that the final interview took place shortly before Mary had completed her studies on the PDMT. In any case, the findings here do raise questions regarding how mathematics teacher education programmes can meaningfully impact on teachers' narratives of their practice as part of their 1st PM-R teacher identity – in essence, their *teaching quality*. Mary's opinion reported on here in this paper in relation to the PDMT failing to impact on her practice and her sense of being unprepared to the teach the Senior Cycle higher level curriculum was echoed by the other participants in the larger doctoral study. Therefore, given that the requirement for obtaining ECTS credits in the teaching of mathematics has been removed from the Teaching Council's criteria for mathematics teacher certification (Teaching Council, 2020), it remains to be seen the impact that possible routes to mathematics teacher certification, which exclude the study of the teaching of mathematics, have on *teaching quality*.

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How can the philosophy of education inform STEM Education Policy in schooling and higher education in a post-Covid pluralist and democratic Ireland: Growing back better

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ABSTRACT

In this paper I make the case to open for critical scrutiny the purpose of STEM education policy in schooling and higher educaton in a post-Covid pluralist and democratic Ireland. Until now the policy (political) framing (representation) of STEM education policy in Ireland and elsewhere draws from a postpositivist stance of techné that is advocated by the state and industry and connected to transdisciplinarity, nature of science, science-in-context, skills sets and evidence-based inquiry scaffolded through one engineering model of STEM Pedagogy. The SMART (*Self-regulated, Motivated, Adaptible, Responsible and Technologically competent*) STEM student and teacher learns to fit in with a consensus view of the ideal human and demonstrate their comparative performance as measureable outputs ('what works best'). The critical scrutiny of STEM literature conducted here shows that we live in a fast globalising and digitising world where UNESCO (2021) asks us reimagine a new social contract for education. It is a timely question given that children and young people are nowadays growing up in a highly scientific and technological society where questions of the good life and STEM literacies need to be freshly interrogated. Here I share insights gleaned from a select literature review revealing the dilemmas of our time and offering new signposts forward. STEM education that balances science, philosophy and practical wisdom and underscores the limits of scientific reason in order to prepare students on one hand to combat populist anti-science attitudes and on the other to prevent falling into a narrow 'scientism'.

KEYWORDS

STEM education policy, Ireland, postpositivist, techné, STEM pedagogy. SMART student, critical scrutiny, select literature review, limits of scientific reason

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Introduction

I am presenting this paper in the section of the CASTeL DCU SMEC Conference 2022 entitled 'How STEM Education Research Can Inform Policy'. It is a crucial philosophical question to ponder and to get right in contemporary Ireland for a number of different and intersecting reasons. A perfect storm of reasons that includes a rapid advancing globalising and digitising world, a highly scientific and technological society and the increasing disparities in injustices and inequalities between a minority of super wealthy (elite) people and a growing majority of people struggling to make ends meet and to aspire to a good life.

It is happening at a time where Europe and Ireland appear to be emerging from the coronavirus pandemic only to be faced with the Russian war against Ukraine and the threat to the European peace project. A time of economic stress with growing inflation, increasing interest rates and the potential for industrial unrest. A storm taking place in a post-truth era when democracy is under threat of slow suffocation, from on one hand a populist far-Right movement promoting a populist anti-science stance and on the other a relentless push for a narrow science view of 'scientism' that only allows a technocratic lens of evidence as the one lens to view humanity and education for a market-led view for human capital change and development (Edling & Mooney Simmie, 2020; Verma & Apple, 2021).

In the last two decades of this century, the field of education has undergone rapid change in its positioning in the academy and in government policy priorities. For more than fifty years education was firmly positioned in the social sciences, underpinned by the foundational disciplines of history of education, philosophy of education, sociology of education and the psychology of education. After the Gulbenkian Commission Report in 1996, the western world set about amalgamating all the sciences. The field of education was to become a social science, a natural science and an applied science but not in equal measure. Now many of education's more complex and sophisticated concepts, such as *Bildung,* being and becoming, democracy and public interest values were quickly diminished if not entirely removed or lost to a new discourse of learning and situated learning (Ball, 1995; Biesta, 2012, 2013, 2016, Selwyn & Gašević, 2020). Transdiciplinarity became central, STEM education was introduced, inquiry based learning, evidence-based policy making and new technocratic modes of management and measurement started to dominate (Hattie, 2012; Stohlmann, 2019).

To date the field of education divides between those who argue that education is a moral, intellectual and apolitical endeavour and those who argue that education is a moral, intellectual and political endeavour. The latter argue for recognition of the political because of the inextricable links between knowledge and power [privilege] and the deliberate intentionality of educators to bring about change [through seeking to change the gaze of students in a preferred and publicy stated policy (political) direction] (Freire, 1971/2018).

For those whose research and theorisations lie in this latter field of critical studies, in my case in the field of critical feminist research policy analysis, our studies of public policy and practices are concerned with understanding and critically interpreting the representation and framing of reforms in education and in STEM education and seeking to reveal the hidden assumptions embedded in the definition of problems. My research questions aim to critically interrogate connectivity between national and global reform movements and the contribution made by research, including qualitative studies that are often neglected in public policy reports and yet can explain the multiple dilemmas and possibilities inherent in policy imperatives of change. Research questions that are not only concerned with curriculum, pedagogy and assessment as selections from culture but with expansive questions of what it means to be human in this early part of the 21st century, how to live well with self and with others and partake in the shared responsibility of co-constructing a just global world. Critical questions of who benefits are never far away as is grappling with theoretical perspectives provided by critical sociology and philosophy (Mooney Simmie & Moles, 2011, 2020).

My research studies analyse policies in education and in STEM education (in relation to teaching and teacher professional development) taking policy backgrounds and contexts into account and contrasting this with education understood as a practice of human freedom [emancipation] and transformative possibility. This view of education is found in the philosophical writings and theorisations of Paulo Freire (Freire, 2018/1971) and Maxine Greene (Greene, 2017) and related theorists and underpins my reflexive positioning in all of my research and policy studies (e.g. Galvin & Mooney Simmie, 2019; Mooney Simmie, 2007, 2021; Mooney Simmie & Lang, 2019; Mooney Simmie & Edling, 2019; Mooney Simmie, Moles & O'Grady, 2019; Mooney Simmie & Moles, 2020, 2011; Mooney Simmie & Sheehan, 2022). Education as a practice of freedom acknowledges the aspiration for nurturance of an inner (soul) life and for critical mediation with the wider social and material world. The discipline of education therefore does not stop at a focus on 'self' and 'resilience' or indeed at the edge of the classroom or 'institution'. Within the aims for education, and STEM education, the teacher works within a number of paradoxes, including seeking to induct children and young people - through qualification, socialisation and subjectification - into the reliable and changing canon of knowledge and into the cultural world(s) and at the same time always making space for something new and better to emerge (Ball, 1995, 2003, 2021; Biesta, 2012, 2013, 2016; Edling & Mooney Simmie, 2020).

It is in the discursive gaps between policy and practices that this journey of human being and becoming and change plays out as well as securing the reform needs of the state and of industry. Minding the gap between policies and practices therefore becomes the leadership task of teachers, teacher educators and school leaders (Mooney Simmie & Sheehan, 2022). This is in keeping with an existentialist view of the irreducibility of human dignity and the need to retain spaces for democracy to flourish in any dynamic democratic society (Lynch, 2022). This articulation of the former purpose of education is often refered to by Biesta (2013) as the 'beautiful risk' of education – paraphrasing the words of WB Yeats as the lighting of a fire rather than the filling of a pail - while the latter purpose is defined by Edling and Mooney Simmie (2020) as the teacher and teacher educators' democratic assignment.

While one of education's tasks has always been to secure democracy - in self-proclaimed democratic nation states - how this is done has varied and is not always agreed. A rather thin version of democracy relies on teaching about and for democracy and inculcation into the regulatory norms of obedience necessary for becoming a compliant member of civil society. By contrast a thicker view of democracy [a reconstructivist view] understands that while induction into the existing social order is necessary this is not sufficient and more is needed (Edling & Mooney Simmie, 2020). Democracy needs to have the agility and flexibility to change as change is required. Therefore, students need to experience at first-hand democracy as a living project in schools and colleges and enjoy safe spaces to present contrarian views of society and debate controversial *Socio-Scientific Issues* (SSI), such as genetic engineering, climate change, artificial intelligence (Hodson, 2003). Clearly a new activist imaginary is needed in schools and colleges that invites students and teachers to experience and to play their part in the (re)construction of the world (Edling & Mooney Simmie, 2020).

I justify my selection of critical research policy studies in education, and in STEM education because such studies call on the social sciences to interrupt public discourses of policy texts and practices in ways that reveal contemporary knowledge-power interplays and the framing of teachers and students [increasingly as units of human capital] within the intersectionalities of social justice and gender justice. Over time my studies started to also draw from feminist theorisations of Maxine Greene and others (Greene, 2017). What feminists bring to critical studies is the capability to widen the problem beyond a reductionist framing and the foregrounding of the issue of gender beyond a dualistic world dominated by either patriarchy and/or matriarchy. I am interested in critical feminist scrutiny of gendered relations of power in education and STEM education policy, how gender is defined and how gender issues can become essentialised and quickly silenced, domesticated and/or neutralised.

In this SMEC 2022 proceedings, I assert that pertinent questions of this kind need to be asked of scientific literacies and STEM education policies given the traditional essentialist nature of these subject areas and their continued dominance in state systems as hyper rational fields of endeavour and a pipeline for STEM related industry and research.

I assert here that if students of STEM subjects in schools and colleges are to be introduced to the benefits of access to a good life –and playing their part in the co-construction of a just society and global world - coming from immersion in STEM Education [e.g. access to counter-intuitive thinking, scepticism, curiosity, experimentation, divergent thinking], and in decolonising ways in the classrooms and schools then it is vital STEM Pedagogies draw from epistemological plurality and are not confined to just one dominant STEM Pedagogy, such as found in policy aspirations for students and teachers to work in schools as if they were emulating professional 'scientists' and/or adopting one engineering model of STEM Pedagogy, a model of continuous improvement and problem-solving (Margot & Kettler, 2019; Stohlmann, 2019). This is a central argument at the heart of this critique.

STEM Pedagogies if they are to support emancipatory and transformative possibility in education need to be considered in the plural rather than in the singular and within policy recognition that not everything of value in human development and change can be atomised and measured. While I argue that management and metrics clearly play a role in the necessary scientific knowledge base for education, any overreliance on management and measurement – in STEM Policy Education – has the potential to be deeply damaging to the human spirit, human flourishing, the moral development of the child and young person and to the necessary immeasurable love labor, care and the relational heart work of teaching and teacher learning and the wider critical aims of a dynamc democracy and public interest values (Biesta, 2012, 2013, 2016; Edling & Mooney Simmie, 2020; Lynch, 2022; Mooney Simmie, 2021)

Ball et al. (2011) showed that policy should never be made equal to practice in a series of studies in *Discourse Cultural Studies in the Politics of Education*. Their papers arose from case studies of the policy process with a number of schools in London. Ball (1995, 2003) and other sociologists in education argue that if policy is made equal to practice then we achieve a *Totally Pedagogised Society* based on a narrow functionalist view of individualism and institutionalism. Fielding (2007) points to the intellectual poverty and social costs arising when schools and educational institutions are redefined as *High-Performing Learning Organisations* in a market-led discourse of learning.

My research interest is in the primacy of the student and teacher as subjects, where the objective is always in the service of the subjective (Mooney Simmie & Moles, 2011, 2020). I argue that working from an essentialist view - advocating for one model of STEM Pedagogy - may well result in intellectual poverty in the STEM classroom and exert a social cost for chidren and

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young people, especially for girls and boys coming from lower socio-economic and different cultural backgrounds in contemporary schooling in Ireland.

I have structured the paper as follows. First, I interrogate the theories of pedagogy and show how pedagogy is viewed in teacher education and in research as a contested construct. Second, I conduct a critical scrutiny of the postpositivistic stance advocated in contemporary STEM Education Policy that moves beyond former views of epistemic knowedge in favour of techné and prioritisation of skills, competences and science-in-context. Third, I conduct a critical review of a select STEM literature and the (re)positioning of scientific literacy. Finally, I conclude with key insights as the study reveals new thinking for securing scientific literacies for all, a hypothesis I argue is worthy of further research and consideration.

Theories of Pedagogy

Pedagogy can be viewed using multiple ontological and socio-cultural lenses. A critical scrutiny of these lenses is nowadays urgently needed given the recent global policy imperatives from the state and industry to push deeper into the classroom in order to mandate how policy must be implemented through select pedagogical practices. Policy imperatives and mandates that are taking place against the backdrop of western education coming under intense pressure in terms of new crises in the economy and politics. Crises in the economy and politics have always and ever been the seed-bed for educational policy change and reform (Arendt, 1954). In a time of fear it may be harder for the state to push back on corporate lobbyists and other powerful vested interests in order to reflect more deeply about the most appropriate pathway forward for human and societal change and development.

The politically expedient thing for policymakers appears to require positivistic research – using its prowess in mathematical modelling and data analysis - to provide evidence-based solutions as best approximations for a future that can be controlled and predicted (Gulbenkian Commission, 1996). Evidence-based syntheses coming from large scale quantitiative studies broker no philosophical arguments and open no public spaces for refutation and contestation. Philosophical insights and theorisations are considered as nothing more than (personal) opinions that have no standing in comparison to fact and number. Several recent and timely philosophical studies reveal many real and symbolic dangers with this misrepresentation of science in the field of education (McIntyre, 2011; Rømer, 2019; Selwyn & Gašević, 2020).

Gore (1993) draws from a critical feminist perspective to argue in her doctoral thesis that pedagogies of struggle are necessary to take into account the tensions, contradictions and differential power relations embedded in all pedagogical practices. This notion of pedagogy as struggle retains the complexity, incoherence and messiness of the discursive spaces between policies and practice, the need for teachers to be trusted to make localised autonomous judgements and to pay attention to the particular needs of children and young people rather than implement a universalist routine of diagnostics and evaluation within a prescripted model of human capital theory (Lynch, 2022; Mooney Simmie & Moles, 2020; Tan, 2014).

In a seminal paper, Lingard (2007) provides a rich overview of the field of pedagogical theory showing how the terrain divides between abstract, political and theoretical perspectives and empiricist reality perspectives. Lingard (2007) shows how pedagogy is simultaneously interested in questions of 'knowledge generation' and 'identity negotiation'. This suggests that rather than one model, no matter how sophisticated that policymakers need to acknowledge the complex interweave between knowledge acquisition and co-construction and the negotiation

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of identity and knower dispositions taking place in classrooms and revealed to the student by way of for instance, the recognition, care and valuing of students, the inner directed moral commitment of teachers and school leaders to act as co-inquirers.

Lingard et al. conducted a large-scale research project in pedagogy in Australia – the Queensland School Reform Longitudinal Study – mapping, analysing and theorising teacher pedagogies as Productive Pedagogies in the context of new schools reform agendas. Findings from the study conducted between 1998 and 2000 showed that while teachers were for the most part caring in their practices they generally offered low intellectual challenges. A Pedagogy of Indifference was also found in relation to recognition and celebration of human 'difference' and diversity and the plurality of human condition. This is a finding that is worthy of deeper interrogation when we consider teaching science and mathematics, engineering and technology and computer science subjects to children and young people in contemporary Ireland. Within the STEM disciplines how do policy makers, teacher educators and teachers in Ireland view this 'identity negotiation' aspect of the pedagogy task?

According to the theorisations of Nancy Fraser (Fraser, 2009), the 'difference' domain needs to move beyond mere recognition and inclusion of the Other to a more activist imaginary in relation to social justice, gender justice and epistemic justice. Lingard (2007) cautions against the mandating of particular pedagogies at system level as he argues that this would be highly 'restrictive of teachers' professional practices and professional conversations, and forgets that trust is central to effective pedagogical reform' (p.262). This point is also taken up by Mooney Simmie and Moles in studies of teachers subjectivities showing how the system puts teachers' bodies and souls to work for the principle of the market-place rather than for facilitating openness and appropriate levels of risk (Mooney Simmie & Moles, 2011, 2020).

Nowadays, philosophical studies of pedagogy theory – such as found in critical pedagogy, pedagogy as praxis, productive pedagogies and speculative pedagogies – seek to (re)conceptualise the necessary struggle for pedagogies within an open invitation to disrupt prescription within the academy and public policy making. Such theories provide a rich understanding that pedagogy is not the static and fixed concept that is often portrayed in reform policies of pedagogy expressed as disciplinary power and the pursuit of prediction.

Any argument for better control and prediction as the optimal way forward to navigate a future of uncertainty in education and pedagogy is today highly questionable in a global world emerging from the Coronavirus pandemic. This viral interruption on a global scale, suggests that preparation for life-long education is best served by focused experiences in the present, premised on grappling with a future of uncertainty and a transformative view of pedagogy.

Postpositivistic stance in STEM Pedagogy

In the early years of this century, education and STEM Education policies focused on what type of new student and teacher was needed for a 21st century of new requirements coming from a rapidly globalising and digitising world and future workforce. New alliances and assemblages happened quickly as forms of democratic governance replaced former notions of democratic nation states. Slogans such as 'we are all in this together' shut down spaces for debate of contrarian views, nowadays often reframed as negative thinking and even deviant thinking. The OECD alongside large scale quant studies introduced a new ideal type of teacher, student and school as units of human capital within the primacy of the economy and the subjugation of moral, social, cultural and political considerations (Mooney Simmie, 2021).

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The classroom was flipped from former views of an inner directed professional teacher toward a new direction of student-centred, inquiry-oriented and collaborative learning and the new role of the teacher as facilitator of students' learning needs. It was now the responsibility of the teacher and school to ensure that every child was included and the role of the state in this regard was reduced to quality assurance only. Wider issues of inequality and injustice were reframed as issues of the individual and the responsibility of the excellent teacher and the autonomous school and no longer the responsibility of the state and society (Lynch, 2022).

A modernist view of epistemé was changed in favour of a postmodern view of techné. This can be seen in STEM education policies that advocate for teaching that facilitates inquiry and evidence based learning, teacher-led professional development, culturally sensitive ways of teaching and the use of real world exemplars (Margot & Kettler, 2019; Stohlmann, 2019). The emphasis on techné is connected to socio-cultural contexts, interdisciplinarity, multidisciplinarity, transdisciplinarity, nature of science, science-in-context, skills sets and competences. This new SMART (*Self-regulated, Motivated, Adaptible, Responsible and Technologically competent*) STEM student and teacher need to learn to fit in with a consensus view of the ideal human while in constant comparision with manageable and measureable outputs and performances of 'what works best' (Hattie, 2012; Rømer, 2019).

Any holistic criticism of this model of STEM Pedagogy needs to identify the possible beneficience of this pedagogical approach as well as drawbacks. Here I posit that giving students affordances to partake in a model of continuous improvement and problem-solving provides opportunities for students to think through probing questions as they learn how to conduct independent research, to use digital technologies, to gain in perseverance, to build resilience and to work with peers to learn how to engage in design thinking and critical thinking about real world problems (Margot & Kettler, 2019; Stohlmann, 2019). However, drawbacks are to be found in the formulaic and technocratic thinking that underpins this pedagogical approach, and in the inherent assumption that all learning is codifiable and measurable and connected to self-regulation and personal perseverance and resilience- and not interdependent and deeply connected to differential power relations, cultural contexts and privilege and public policy constraints. The dominance of this model of STEM Pedagogy denies other pedagogies, including the necessity for problem-posing, the need for interplays with theory and pedagogies of struggle (Gore, 1993; Lingard, 2007, Verma & Apple, 2021).

Critical Review of STEM literacies

Science has a unique way of looking at the world with its own language, grammar, syntax, scientific methods, research approaches, modes of analyses, ethics of research and its own academic/professional communities of practice. The natural sciences place strong reliance on rational reasoning, personal detachment, neutrality, objectivity, counter-intuitive knowledge and empirical rationality. While the canon of scientific knowledge is a reliable source it is also a dynamic system where new knowledge once accepted in the scientific community replaces former knowledge. Science has a complex and uneven history and philosophy and it is nowadays argued from several directions that science teachers need to be fully conversant with this history and philosophy (Cobern & Loving, 2020).

Here I assert that philosophically informed STEM teachers may be best placed to develop curiosity and scepticism in their pedagogical approaches as they open new spaces for creative and critical thinking with students while, at the very same time, assuring the acquisition of content knowledge and the negotiation of subjectivities (Mooney Simmie & Moles, 2020). STEM Pedagogy as a human and social endeavour requires teachers to engage with the living contradictions of their practices, to breathe life into the STEM curriculum, to display care and affectivity while animating students to actively engage with the many controversial SSI issues in ways that display ethical awareness and a new activist imaginary in order to support wise political decision-making in the co-construction of the world (Hodson, 2003; Hodson & Wong, 2014). In this way STEM education involves teaching STEM content knowledge to children and young people in different ways, approaches that support induction into the social order while making way for something new to emerge (Edling & Mooney Simmie, 2020).

The concept of science literacy was first introduced into the school curriculum in the 1950s and was primarily centred on the needs of the economy and national security (Li & Guo, 2021). The intention was to project a positive image of science with the purpose of keeping alive the public commitment of funding for scientific research and a pipeline of qualified scientists. Variations on this theme have lasted for more than seventy years and reveal how science literacy is a changing cultural and socio-political concept that is highly dependent on the needs of the era (Bybee & McCrae, 2011).

Erduran, Kaya & Avraamidou (2020) open the question of the reconceptualisation of science literacies in school science and show how they are underpinned by issues of social justice and the necessity for productive interplays between science education and the wider world. They position the problem within crises such as migration, vaccine equity and intersectionalities playing out between people of different class, race, caste, gender, ethnicity and religion. They argue that science education needs 'to support science teachers' learning of strategies to promote students understanding of NOS and social justice in unison' (p.109) and 'to promote a just and democratic society by valuing diversity' (p.110). They refuse a narrow consensus view of science education and their human rights perspective affords respect for all.

The case for philosophically literate STEM teachers is made by Cobern & Loving (2020) with the purpose of guarding against a narrow 'scientism' (p.213), which they describe as an authoritarian firm view of science that seeks to present absolute truth and a final form. They support STEM teachers engaging in philosophical co-inquiry as this will support the interruption of routinized practices and assist their articulation of the many hidden assumptions and paradoxes underpinning teachers' contradictory practices. Their study signals a strong turn to the humanities to support deep learning and problematizing the type of science literacies needed today and moving away from just one way of looking at science.

The concept mapping of science literacy was first carried out by Roberts (2007) and presented as Vision I (*theoria*) and Vision II (*techné*). Vision I arises from a fundamental (epistemic) understanding of knowledge that emphasises science as a discipline with propositional and procedural knowledge. This reflects a positivistic stance that seeks detachment from the living contradictions of practice and socio-cultural and political entanglements with the wider world. Vision I gave way in this century to a broader socio-cultural perspective - Vision II - a post-positivist stance that is advocated by the state and by industry, in STEM Education Policy that is sensitive to socio-cultural context (science-in-context), interdisciplinarity and learning about SSI issues. However, Vision II is narrowly focuses on the instrumental, on excellent instruction, on learning about issues rather than any activist imaginary seeking to critically interpret and/or to grapple with controversial SSI issues.

In recent times, a third vision (Vision III) is advocated in the critical science literature. Vision III, includes Vision I and Vision II approaches to knowledge acquisition and identity negotiation and, at the very same time recognises the need for an activist imaginary that

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includes attention to criticality and reflexivity. Vision III understands science as a human endeavour, a sociological project taking place in schools and in the public forum of an ethical and political (democratic) society. Vision III draws from critical theory, critical consciousness and reflexivity and moves the problem beyond instruction and meaning-making to deep learning and critical mediation with others and with the wider socio-cultural (political-scientific-highly-technological) world.

Hodson and Wong (2014) critique the consensus view of the nature of science that has taken hold of much of the literature in STEM education, with the aim of providing clarity of definition, standards, and benchmarks and argue that this has ‘a strong whiff of orthodoxy and carries the implication that those who disagree with the specification will be considered deviant’ (p.2644). They fear that a ‘consensus view promotes a static picture of science and fails to acknowledge important differences among the sciences’ (p. 2645). Sjöström and Eilks (2021) present a Vision III concept of science literacies using the concept of *Bildung* in recognition of the broader educative task of learning how to live well as persons in a fast changing scientific and highly technological society and global world. They argue for a new concept of science literacy that broadens its focus, and recognises its reflexive dimension as a sociological construct in a globalising world. Their theorisation of *Critical Reflexive Science Literacy* is framed as ‘a politicised vision of science education aiming at dialogical emancipation, critical global citizenship, socio-eco-justice’ (p.82).

Conclusions

When extolling the advantages that science brings to humanity and the world, such as vaccination successes by scientists without borders in the coronavirus pandemic, it can be easy to gloss over the many cautionary tales from the history of science. There are limits to scientific reason that need to be acknowledged (McIntyre, 2021). This is especially important in political systems that claim to be democratic, where majority rule is designed to work within a paradoxical understanding that the public space always allows for contrarian views and the protection of minority views and human rights (Edling & Mooney Simmie, 2020).

My argument here is that if evidence (metrics) becomes the one (dominant) lens to judge the success of STEM Education then policymakers will have fallen headlong into a narrow ideology of scientism (Hyslop-Magison & Naseem, 2010). Scientism offers a misrepresentation of STEM education through failing to acknowledge other ways of knowing and to having the intellectual humility and the moral fortitude to accept that there are limits to scientific reason (McIntyre, 2021). Here I have shown that there are undeniable merits in introducing students and teachers to using evidence to make claims, such as drawing from counter-intutive knowledge in their practices and using STEM Pedagogy for problem-solving and a journey of improvement. However, in an era of post-truth and at a time of a new crisis in politics and in the economy any overreliance on metrics and management fails to acknowledge the primacy of the human subject at the heart of education and overrides the many complex and sophisticated concepts associated with being and becoming human, with entering a lifelong journey of being educated including for example, the ethical and relational nature of STEM Education, the immensurable love labor, care and affectivity needed for a wholesome journey of human development and the need for securing spaces between policies and practices that assure human emancipation and the possibility of a dynamic democracy.

The current postpositivistic drive toward *techné*, with policy imperatives for consensus is shutting down spaces for authentic dialogue, building trust, contrarian views and ultimately for opening spaces for new thinking and the not-yet-thought. One Australian school principal explains some of the detrimental consequences of this rather narrow policy imperative: 'In closing down dialogue and setting normative standards, an evidence hierarchy is inherently anti-democratic, as it closes the public space, reducing social relations to obligations…..the barriers go up……what should be open to question and not reductively represented as self-evident, including research methodologies and outcomes, are standardized and ranked' (Howie, 2020, p. 683).

I have argued here that STEM Education is a human and relational endeavour, a sociological project that needs to be understood as an open and dynamic system - for assuring human emancipation as well as living well in a vibrant dynamic democracy - rather than a static and predictable system. This 'beautiful risk of education' (Biesta, 2013) includes the necessity for epistemological plurality and the need to acknowledge in STEM education policy in Ireland that not everything of value in 'identity negotiation' as human development and change can be codified and measured. It is a hypothesis worthy of further research and consideration.

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Research Paper
Keywords: Higher Education, University, Skills, Practical's, Intervention, Chemistry, Undergraduate

How to write a lab report- A hands-on approach to improve writing skills on chemistry undergraduate students.

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Writing a scientific lab report is an important skill that students develop during their undergraduate course. However, first year science students struggle significantly with this task. There usually isn't a clear guide to follow when writing a lab report for the first time and this skill is also not developed fully in high/secondary school. There are several examples where implementing a course or guide for students to improve their scientific writing skills which has resulted in better lab reports (Holstein et al., 2015; Kelly-Laubscher et al., 2017).

Prior to this study, the School of Chemistry at Trinity College Dublin did not have any clear guide for undergraduate students on how to write a lab report. The goal of this study was to improve the lab report writing skills of undergraduate students and to provide them with a guide to develop this important scientific skill. It is proposed that an intervention in this area will also reduce the cognitive load requirements of students while undertaking the chemistry lab practical course since they will be better able to concentrate on the chemistry involved and practical skills that are required. It will also create a common ground for students to build on their report writing skills later.

Initial work began by identifying how the students were already learning to write a lab report and collating the common mistakes that they were making. It was found that students were mainly learning on a trial-and-error basis, where they implemented the corrections from demonstrators into their lab reports to improve them as time went on. Our work also found that the level of feedback and requirements varied significantly from one demonstrator to another, resulting in significant confusion for the students. Initial work also identified common mistakes that could be avoided by providing students with a guide and/or some tips on general scientific report writing.

In response to our findings, an intervention was designed in the form of a tutorial entitled "*How to write a scientific lab report*" which was designed and delivered by two lab demonstrators to the undergraduate students. Attendance at the in-personal tutorial was entirely voluntarily. The material was broad and not specific to chemistry, instead focussing on the general aspects of report writing e.g. presenting data clearly, discussing results as a whole and understanding possible shortcomings.

Evaluation of this intervention was conducted through analysis of student performance afterwards by comparing the grades of those who attended the tutorial to those who did not attend. A significant difference was found between the two cohorts as well as differences in consistency despite the fact that the grading was done by numerous demonstrators. This presentation will discuss this study, the intervention as well as the evaluation results.

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Friday, 24/June/2022 3:00pm - 3:10pm
ID: 104 / PS- 9: 3
Pre-recorded Lightning Talk
Keywords: pSTEM; Gender equality; Role Models

Inspiring through videos: Role Models in pSTEM - You can be what you can see

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This research utilises specifically-produced videos of 10 female role models, representing a range of age-groups and backgrounds, who have pursued or are working in the pSTEM fields of physics, mathematics, computer science and engineering. Based on the ecological framework of factors influencing girls' and women's participation in STEM (UNESCO, 2017), the videos showcase the backgrounds and influences of each of the role models and highlight what they enjoy about what they do. In their conversations, the role models also identify challenges they may have faced in their careers, such as being the only woman in the room, and also share advice on overcoming similar issues. The premise of the initiative is based on research demonstrating that female role models in STEM subjects can mitigate negative stereotypes and offer girls an authentic understanding of a career in STEM (McPherson, Banchefsky, & Park, 2018). By SMEC 2022, all 10 videos will have been produced, with accompanying teacher materials that will be freely downloadable for use in schools. In the next phase of the research, we will investigate the impact of utilising these videos in post-primary classrooms on students' perceptions of and attitudes towards STEM, specifically focusing on the pSTEM subjects. We will also investigate teachers' attitudes towards pSTEM and evaluate their feedback of the materials in order to further develop these resources. Participating schools (n = 10) will view the videos with a class-group over a number of weeks, utilising the educative materials. Class discussions will be based on areas such as: Growth Mindset, Mathematical Anxiety, Cultural Messages, Sense of Belonging and Unconscious Bias. Data will be generated based on research by (McKinney, Sexton, & Meyerson) and will utilise both quantitative and qualitative data, including surveys, focus-groups and semi-structured interviews. Findings will inform further research based on making STEM more inclusive and contribute to initiatives attempting to lessen the gender gap in pSTEM subjects at post-primary and undergraduate level. The 'Lightning Talk' at SMEC will discuss the evolution of the project, the construction of the interviews for the role model videos, selection of the role models, and pilot feedback from teachers and students. Feedback from SMEC attendees will be welcomed and incorporated into the next phase of the research design.

This project is funded by the Higher Education Authority and the Institute of Physics.

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Saturday, 25/June/2022 11:00am - 11:20am
ID: 105 / PS- 10: 1
Research Paper
Keywords: Teacher concerns, classroom based assessment, curriculum reform

"We've just lost 6 weeks of teaching". Mathematics Teachers' feedback on CBAs in Problem Solving: Investigating the implementation

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In 2015 the mathematics curriculum was revised for Junior Cycle with the introduction of classroom-based assessments (CBAs). These CBAs represent a change in students' typical experience of mathematics work and in teachers' roles assessing students' learning. The successful enactment of reform depends on the teachers who will interpret and implement it. However, educational reforms can aggravate teachers' professional concerns and influence students' learning experiences (Charalambous & Philippou, 2010). To support the successful implementation of educational reform, it is therefore important to identify and attend to the concerns of teachers. This research aims to influence policy on educational reform by asking:

What is the nature of Irish secondary mathematics teachers concerns with regards to problem-solving and the associated classroom-based assessment following recent curriculum reforms?

How can teachers be better supported in enacting this curriculum reform?

Hall et al. (1977) proposed seven "Stages of Concern" (SoC) which teachers experience as they enact a reform. More recent studies have identified these stages of concern in teachers' interpretation and implementation of reform (Charalambous & Philippou, 2010) and found a pattern where teachers move through these stages, though not necessarily linearly, as a reform is introduced, implemented, and becomes established (Johnson et al., 2020). It has been suggested that the success of a reform depends on this development of concerns.

This research uses a qualitative approach to provide data on teachers' concerns and feedback around the enactment of CBAs. Semi-structured interviews have been conducted with 16 mathematics teachers, representing a range of teaching experiences (e.g. gender, mathematical background, years of experience etc.) and school contexts (e.g. urban/rural; single-sex/co-ed; DEIS/non-DEIS etc.). The SoC framework informed the design of the interview and data analysis. Findings from the research suggest that teachers lack confidence in their pedagogic skills introducing problem-solving and feel constrained in attempting any change to their traditional classroom practice, due to the concentrated nature of the curriculum content. Teachers' feedback also emphasises the desire to collaborate with other teachers, both in considering approaches and materials, but also to build assurance in their own practice.

From these findings, a professional development intervention with associated curriculum materials will be developed to attempt to better support teachers enacting the CBAs. We hope findings from this research will contribute to policy in enacting future curriculum reforms.

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Friday, 24/June/2022 1:50pm - 2:10pm
ID: 106 / PS- 6: 2
Research Paper
Keywords: STEM, gender gap, interventions, careers, information

Career Aspirations of Female STEM Students

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The STEM gender gap is caused by the interaction of several complex and nuanced factors, all of which need to be considered when designing effective interventions. Providing students, parents and teachers with information about the broad range of career opportunities that STEM can offer is one of the factors frequently discussed in the literature (e.g.Boucher, Fuesting, Diekman, & Murphy, 2017).

A survey of teenage girls in Ireland found that 87% of respondents stated a lack of information about STEM jobs as a barrier to a STEM career (iWish, 2021). Addressing this information deficit is also identified as a specific action amongst the Recommendations on Gender Balance in STEM Education (Department of Education, 2022, p. 9).

The perception that STEM careers aren't compatible with students' desire to work with people or on areas of societal benefit is a commonly held misconception that deters girls from considering STEM (Boucher et al., 2017). Dispelling this stereotype should form a key emphasis for STEM promotion and information campaigns; particularly those targeted at younger teenagers.

This paper presents an account of the career aspirations of undergraduate and postgraduate female STEM students. The research forms part of a qualitative PhD study focussing on the key factors influencing women who do choose STEM careers. Female undergraduate and postgraduate students studying math-intensive STEM fields, including engineering; physics; maths and computer science, in UCC and MTU were interviewed. Thematic analysis is being used to explore the commonalities, if any, amongst these students. Similar career aspirations were identified as one such commonality. The students interviewed are nearing the end of their programme of study in STEM and are considering future career paths. Many have undertaken work placements or internships and have experienced varied career opportunities. Thus, they offer a unique perspective on the interests, motivations and career goals of young women in STEM. This perspective is largely unheard in current discourse and it is hoped that their insights can be used in designing promotion campaigns aimed at encouraging more girls to consider STEM as a personally fulfilling, rewarding and exciting career.

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Friday, 24/June/2022 11:30am - 11:50am
ID: 107 / **PS-2: 1**
Research Paper
Keywords: belonging, equity, physics, gender

Belonging in Physics

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Why do so few women become Physicists? Why does Physics attract so few minoritized students? What messages do those in Physics send about who belongs in our discipline and who does not? How does the culture of physics influence student participation?

“Belonging Uncertainty” is a term to describe the experience of minoritized students in which they are led to question their social connection to a discipline [1]. This experience of uncertainty is one of the factors that impacts undergraduate retention in Physics programs, in which participation of women and people of colour in the USA is historically and consistently low.

The complex overlapping issues that impact the participation of minoritized students can feel very overwhelming to tackle. There are however many publications that go beyond describing the problem and offer guidance to enhance student participation and retention. Educators are beginning to understand that the burden of achieving success for Physics students - especially those who have historically been underrepresented in the discipline - cannot fall on the students themselves. Focussing on student attributes such as mindset and perseverance are missing contextual factors such as the impact of the culture of the discipline, which directly relates to belonging and almost certainly retention.

Some of the large studies into the participation and retention of minoritized students offer concrete advice for faculty and institutions. The report “TEAM UP: the Time is Now” [2], one of the factors they list as impacted the retention of African American students was Belonging. They recommend that “Departments should examine whether their current activities foster physics identity, access their efficacy across race/ethnicity/gender and other social identities and modify such activities as necessary.”.

A longitudinal study by Estrada et. al on the impact of kindness cues notes ““Review of the literature suggests that the current STEM academic context does not consistently provide cues that affirm social inclusion to all members of the academic population, and that policies that address this disparity are essential to broadening STEM workforce development in the United States.””[3]. This highlights the importance of creating an environment where students can feel a sense of belonging to the community in their discipline.

In this talk I will share some of my experiences attempting to tackle belonging uncertainty and create community in an undergraduate institution in California.

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Friday, 24/June/2022 2:30pm - 2:50pm
ID: 108 / PS- 9: 1
Research Paper
Keywords: equity, physics, active learning

Equity practices in the classroom

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Classroom Learning is greatly enhanced by active engagement during class time, but may not improve equity in the classroom. A recent analysis of the impact of gender and race on pre and post concept scores in physics by Ben Van Dussen and Jayson Nissen found that while collaborative learning resulted in higher gains in understanding overall, however they noted " that collaborative instruction did not improve equity because differences between groups were unaffected". [1] Similarly, Pollock, Finklestein and Kost [2] show that the gender gap in gain scores persists for active learning physics classrooms.

How can we tackle these persistent gaps? Who has the opportunity to participate during class? Building trust and community are crucial in encouraging student engagement. This is particularly important in a discipline like Physics, with such lopsided demographics. This talk will describe approaches to broaden the ways that students participate in class by adopting equitable teaching practices that aim to provide more options for students to have a voice in the classroom.

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Friday, 24/June/2022 1:30pm - 1:50pm
ID: 109 / PS- 6: 1
Research Paper
Keywords: mathematics education, covid-19, online teaching, higher education

Getting to grips with online mathematics education during the COVID-19 pandemic

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The COVID-19 pandemic necessitated a move to emergency remote teaching in many universities across the globe, beginning in the early months of 2020. As a result, lecturers and students had to transition to an online form of education at very short notice. Due to the symbolic nature of the subject, online education in mathematics presented additional challenges, in terms of representing mathematical notation and communicating effectively with students online.

In May 2020 and again in May 2021, we undertook an anonymous online survey of mathematics lecturers in higher education, aiming to investigate their experience of emergency remote teaching and any changes to their practice as a result. We received 257 and 190 responses respectively, and respondents were based in 30 countries, primarily in Europe. They reported on the types of hardware and software they used; whether they opted for live sessions or pre-recorded; the main challenges they and their students faced; and the changes to assessment necessitated by the move online.

In this talk, we report upon their reflections of their journeys in online teaching, as they compare their initial experiences of emergency remote teaching with their approaches one year on.

Friday, 24/June/2022 2:50pm - 3:10pm
ID: 110 / **PS- 7: 2**
Research Paper
Keywords: Undergraduate mathematics education; collaborative learning; assessment

To assess or not to assess: Collaborative learning in an undergraduate mathematical sciences programme

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Recent research on undergraduate mathematics students' assessment preferences indicates that students' primary concerns relate to the ability of the chosen composition of assessment methods to discriminate between individual students' mathematical proficiencies (Iannone & Simpson, 2013, 2015). Therefore it is not surprising that while students generally hold positive views about the value of collaboration to their learning in a formative sense, they exhibit concern in relation to the possibility of other students' performance impacting their own grade in an assessed group work context. However outside the context of assessed group work, little research has been conducted on undergraduate mathematics students' participation in informal collaborative learning. In this study we examine the experiences of ten recent mathematical sciences graduates' engagement in informal, self-directed collaborative learning outside of their lectures and tutorials. We also explore their experiences with formally assessed group work, and seek their views on the comparisons between the nature of collaboration in both contexts. To this end, semi-structured, one-to-one interviews were conducted with ten recent mathematical science graduates from a large, Irish university. The transcribed interviews were analysed using thematic analysis. Initial findings suggest a consensus as to the benefits of engaging in informal collaboration with one's peers, both to one's mathematical learning and in a more general, affective sense. However, in agreement with findings documented in the literature, concern was expressed as to the careful implementation of group work as an assessed component of an undergraduate mathematics degree, particularly in relation to the allocation of marks. Students' views on the distinction between the voluntary, informal collaboration they engaged in versus formally assessed group work will be discussed with a view to informing practice on how informal collaborative learning between peers may be best supported in an undergraduate mathematics degree context.

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Saturday, 25/June/2022 11:20am - 11:40am
ID: 111 / PS- 10: 2
Research Paper
Keywords: Mathematics education, Student teachers, Algebra

Learning to teach algebraic thinking: An intervention targeting subject content knowledge of student-teachers

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Learning to teach is a complex and multi-faceted endeavour. Seeking to manage the complexity, novice and prospective teachers frequently draw on their personal experience as students of mathematics. This study sought to support primary school student-teachers in teaching mathematical content that they themselves had not encountered in primary school. Gaps were anticipated therefore both in the student-teachers' mathematical content knowledge and in their understanding of how the content may be taught and learned. The study engaged participants in Germany, Ireland and South Africa in the role of student when they attended a preparation programme for the teaching of functional thinking, and in the role of novice teacher when they taught functional thinking in classrooms.

Knowledge of Content and Students (KCS) is the domain of Mathematical Knowledge for Teaching that describes the knowledge teachers possess about the mathematical content they are teaching and about their students (Hill, et al, 2008). In this paper, we explore the relationship between the KCS of our participants in the domain of functional thinking, and the relationship between their KCS and the instructional quality of their teaching as evidenced from their contributions to focus group interviews. The participants completed pre and delayed-post questionnaires designed to measure their mathematical knowledge for teaching functional thinking. Their experience of enacting their learning from the preparation programme in the classroom was captured through post-lesson reflections and focus group interviews.

The research team analysed the students' contributions to the focus group interviews for evidence of KCS and allocated comments within a framework of 4 levels. In this presentation an analysis will be presented that examines whether a relationship exists between strong KCS as evidenced through the delayed post-questionnaire and the level of KCS enacted in the classroom

Saturday, 25/June/2022 12:20pm - 12:40pm
ID: 112 / PS- 12: 2
Research Paper
Keywords: STEM education policy, techné, research, philosophy, critical scrutiny, emancipatory practices

How can STEM education research and philosophy inform policy in schooling and higher education in a post-Covid pluralist and democratic Ireland

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In this paper I make the case to open for critical scrutiny the purpose of STEM education policy in schooling and higher educaton in a post-Covid pluralist and democratic Ireland (DES, 2017-2026). Until now the policy (political) framing (representation) of STEM education policy in Ireland and elsewhere draws from a postpositivist stance of techné that is advocated by the state and industry and connected to transdisciplinarity, nature of science, science-in-context, skills sets and evidence-based inquiry coming from clinical medicine. The SMART (*Self-regulated, Motivated, Adaptible, Responsible and Technologically competent*) STEM student and teacher learn to fit in with a consensus view of the ideal human and the measureable outputs ('what works best') of the neoliberal institution (Hattie, 2012; Rømer, 2019). Instead the critical scrutiny of STEM literature conducted here shows that we need a new social contract for education knowledge(s) (UNESCO, 2021) and curriculum design that balances science, philosophy and practical wisdom (Sjoström & Eilks, 2021) in order to prepare 'teachers to overcome institutional constraints and to combat both scientism and anti-science attitudes' (Lampert, 2020, p.1419). Hyslop-Margison & Naseem (2010) argue in terms of educating human beings we need to 'nurture intellect and senses, reason and emotion, logic and intuition' (p.ix) and in ways that are not all considered codifiable and measurable (Biesta, 2002; Swartwood, 2021). If Irish education is holistic and aspires to nurture the inner (soul) life of the individual as well as taking into account the material and the social then it is timely to critically scrutinise what indicators can be usefully gleaned from research findings and what aspects, if any, of our shared humanity are uncodifiable and need public acknowledgment in STEM education policy for emancipatory practices.

Friday, 24/June/2022 11:50am - 12:10pm
ID: 113 / PS-2: 2
Research Paper
Keywords: Numeracy; Initial Teacher Education; Numeracy Capabilities

Pre-service teachers' numeracy capabilities

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Pre-service teachers' numeracy capabilities

Kathy O' Sullivan[1,2], Niamh O' Meara[2], Merrilyn Goos[2,3], Paul F. Conway[2]

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Being numerate is an essential part of daily life and numeracy skills are required by everyone in order to engage fully in society. Government bodies and ministers for education around the world have stated that numeracy is a competency that should be learned in school and developing the numeracy capabilities of young people is the responsibility of teachers (Department of Education and Skills [DES], 2011; Australian Curriculum, Assessment, and Reporting Authority [ACARA], 2017). Furthermore, in Ireland the Department of Education and Skills (2011;2015) and the Teaching Council of Ireland (2020) have specified that all teachers are required to teach for numeracy learning across the school curriculum. This is in an effort to ensure that the young people of Ireland have the necessary numeracy skills required to participate in society and contribute to the ever growing economy. Therefore, it is important to recognise the role of teachers and their own numeracy capabilities.

In the following paper, data from a study related to pre-service teachers' numeracy capabilities are reported. The sample for this study comprised of 204 students enrolled in post-graduate initial teacher education programmes at three different universities in Ireland. In an effort to assess pre-service teachers' numeracy capabilities, they were asked to complete seven numeracy tasks. Analysis revealed that eight (3.9%) pre-service teachers were able to answer all 7 numeracy tasks correctly. A further 156 (76.5%) pre-service teachers were able to answer 3, 4, 5 or 6 numeracy tasks correctly. However, there were still a considerable number of pre-service teachers, 32 (15.7%), who were only able to answer either 1 or 2 numeracy tasks correctly. Finally, eight (3.9%) pre-service teachers were unable to answer any numeracy task correctly and only one of these eight pre-service teachers left each answer blank, and a further seven pre-service teachers attempted to answer the numeracy tasks but answered them all incorrectly.

This study revealed that pre-service teachers need to possess mathematical knowledge, along with having the confidence in their own numeracy capabilities. The results showed that teachers need to be given the opportunity to develop their own numeracy capabilities in the ITE programme they are enrolled in and thereafter, learn how to prepare to teach for numeracy learning within their own subject discipline.

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Friday, 24/June/2022 1:50pm - 2:10pm
ID: 114 / PS- 5: 2
Research Paper
Keywords: STEAM, alternative education, curriculum

Towards a framework for STEAM Education in Youthreach in Ireland: Stakeholder perspectives

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Background

STEAM education is a pedagogical approach that merges science, technology, engineering, arts and mathematics with the aim of improving learner engagement, skills/life skills, knowledge and attitudes (Perignat & Katz-Buonincontro, 2019). It can be particularly relevant in alternative educational provision settings such as the Youthreach programme for early school leavers in Ireland (Smyth et al., 2019). In these contexts, the focus may be on enhancing relevant life skills related to future careers and alternative pathways to STE(A)M careers (Perignat & Katz-Buonincontro, 2019).

This research has been conducted as part of the Full STEAM ahead: A partnership approach to STEAM in Youthreach project which aims to support Youthreach staff to implement STEAM education. This paper will provide insights into the needs and perspectives of stakeholders to inform the design of a framework for implementing STEAM Education in Youthreach in Ireland.

Methods

In this two year project, a qualitative approach was used. In year one, interviews were conducted with representatives of national organisations (four individuals) and Youthreach staff (three centre coordinators and three educators) to examine their experiences and understanding of STEAM Education. The programme manager, one individual from a national organisation, completed a weekly reflective diary. In year two, follow up interviews will be conducted with these same stakeholders. Qualitative content analysis was used to analyse gathered data (Elo and Kyngas, 2008).

Key findings

The representatives of national organisations indicated their awareness of the value of STEAM education and highlighted the benefits of STEAM education for learners including improved knowledge, skills and attitudes, aligned with courses (LCA/QQI), and links with career and education pathways. They discussed potential benefits for Youthreach staff including improved content knowledge, pedagogical knowledge and skills. They noted challenges including appropriate professional development, lack of staff confidence and expertise, workload concerns and clarity around alternative pathways to further education and careers in STEAM.

Youthreach Centre Coordinators discussed their plans to coordinate the design and delivery of accredited STEAM education. They focused on the inclusion of a range of learners. They had a focus on increasing their own awareness of and building links with local STEAM organisations.

Youthreach educators discussed developing learners' (life) skills, knowledge and attitudes towards STEAM, leading to national accreditation. They discussed the importance of hands-on, practical, collaborative teaching and learning approaches. Educators felt confident in designing and delivering STEAM education but noted concerns around their lack of expertise in science and engineering aspects of STEAM.

This paper will share details of how STEAM Education was implemented in three Youthreach centres over two years and identify key learnings for implementation in other Youthreach centres. In particular, this study will examine changes in each centre's approach to STEAM Education, i.e., links with the local STEAM industry, awareness of alternative routes to STEAM careers, and plans for STEAM Education modules in their Youthreach centre beyond the end of the two year project.

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Friday, 24/June/2022 11:50am - 12:10pm
ID: 115 / PS-1: 2
Research Paper
Keywords: Affective domain, problem-solving, mathematics education, pre-service teachers, beliefs

The journey or the destination? An investigation into the beliefs of pre-service post-primary mathematics teachers regarding problem-solving.

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It has been widely reported that the affective domain is an important contributor to problem-solving behaviour among students. Cognitive resources available to students are related to the students' beliefs around what they consider useful in learning maths (Schoenfeld, 1983). Problem-solving holds a key position in both Junior Cycle and Senior Cycle curricula in Ireland. Given that much research has shown that the teachers' beliefs about problem-solving play an integral role in building positive attitudes to problem solving among their students, it is essential to investigate the beliefs of prospective mathematics teachers. The aim of this study was to investigate the affective domain of pre-service post-primary mathematics teachers in Ireland. This study was conducted in a university setting and involved the implementation of both quantitative and qualitative measures; the existing Indiana Mathematical Belief Scale (IMB), and open-ended questionnaires. Participants in the survey were enrolled in a module on mathematical problem solving. The open-ended questionnaire asked participants to describe how they felt at different stages during their attempt to solve a mathematical problem. This was then analysed using an inductive approach. A statistical analysis of the IMB (n=169) showed that students strongly believed that an increase in effort can have a positive influence on mathematical ability. However, it was concerning to find that students believe that problem-solving involves learning step-by-step procedures. Another positive finding of the IMB was that students strongly value the understanding of mathematical concepts over memorization of procedures. In contradiction to this, it was found through the analysis of the open-ended questionnaire that students had a greater focus on achieving an answer rather than on the problem-solving process. We discuss the implications for the design of the module, which seeks to support the development of the capacities required for the successful teaching of mathematical problem solving.

Saturday, 25/June/2022 11:40am - 12:00pm
ID: 116 / PS- 10: 3
Research Paper
Keywords: mathematical identity, narrative inquiry, narrative analysis, transition, thematic analysis

Using a narrative approach to study the transition to higher-level education

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This paper presents the results of a longitudinal study into the mathematical identity of science and engineering students (MISE) in Dublin City University.

The goal of the research was to expand on previous mathematical identity research in Ireland by including science and engineering students since they study a significant amount of mathematics at university level.

Mathematical identity is considered to be one's relationship with mathematics, including knowledge of the subject and perception of oneself and others.

This qualitative study was conducted over four years using a narrative approach to mathematical identity.

The study involved thirty-two participants from science and engineering courses in DCU, including several students of science education who have since qualified as teachers.

All participants completed an online open-ended questionnaire on mathematical identity in their first year of university.

A further 5 participants contributed to focus groups and 6 participants took part in narrative interviews at the final stage of data collection.

The conclusions are derived from participants' mathematical identity narratives which were developed through several stages of data collection involving both thematic and narrative analysis.

Representing the multiple voices which contributed to the construction of these narratives is a key concern of narrative studies.

Thus I will demonstrate the process of moving from codes to themes to narratives since there is no one definition for what counts as a narrative.

The findings highlight several issues that affected multiple participants and may affect a broader cohort of students than were included in the study.

I also present some unique features of mathematical identity that arose in this context and discuss what conclusions can be drawn from these.

Friday, 24/June/2022 2:30pm - 2:50pm
ID: 117 / PS- 7: 1
Research Paper
Keywords: Lesson Study, STEM, Teacher collaborative learning, Boundary crossing

STEMunities: Fostering teacher learning in STEM through Online Lesson Study

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Lesson Study (LS) describes a model of collaborative Professional Development (PD) where a group of teachers come together to research, plan, teach, observe and reflect on a research lesson with a group of learners. LS, which originated in Japan over 100 years ago, has been credited with enabling teachers to cross boundaries of practice, thus overcoming the relative isolation they can often experience in their professional work. Despite its effectiveness and popularity, LS has faced criticism due to issues of sustainability, and the requirement for broader structurally supportive conditions to be place in order to leverage its benefits for teachers' learning. Online Lesson Study (OLS) represents a contemporary adaptation to the LS model, where digital tools such as Zoom and Google Drive are utilised to provide opportunities for teacher learning in ways not possible through traditional face-to-face LS. This paper presents a critical reflection on the author's recent novel experience facilitating the first OLS ever conducted in Ireland, where they used OLS as a boundary object to support the collaborative professional learning of a group of Irish primary teachers who taught in three different schools. The schools involved were part of an existing inter-school Shared Education partnership who had chosen a STEM curricular focus. The aim of the OLS in this instance was twofold: Firstly, to foster participants' achievement of relational agency, i.e. the capacity to engage in joint collaborative work for mutual benefit, by introducing them to OLS as a sustainable form of PD which can potentially support their collaborative practice within and between their schools. Secondly, the OLS aimed to support the teacher participants to co-construct the unique knowledge required to teach in and about STEM, conceptualised as STEM Knowledge for Teaching (STEMKT). The author's critical reflection, which derives from their reflective diary and field notes, draws from Schön's (1983) notion of reflection-on-action, as well as Brookfield's (2016) critical lenses and is theoretically framed by emerging literature which proposes LS as a vehicle for teacher agency. Particular attention will be drawn to some of the practical and ethical dilemmas faced by the author while engaging in this work during the COVID-19 pandemic, and how navigation through these required flexibility and reflexivity.

Friday, 24/June/2022 2:50pm - 3:10pm
ID: 118 / PS- 8: 2
Research Paper
Keywords: mathematics support, attendance, COVID restrictions, engagement, online learning

Exploring attendance data at a mathematics support centre during and after campus closures due to COVID-19

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In this talk, we consider the impact of campus closures on the Mathematics Learning Centre (MLC) in Dublin City University (DCU) in the wake of COVID restrictions which required online teaching. We also look at the return to in-person support and consider student engagement with the service.

Up to March 2020, the MLC operated as an in-person drop-in service in the university's main library. Any DCU student who needed additional mathematics support could "drop in" without making a booking in advance and get help from a tutor. From March 2020, and throughout the academic year 2020-21, the majority of university teaching in DCU took place completely online. By necessity, mathematics support took a different format to the previous in-person drop-in centre. Students could avail of twenty-five minute sessions online via Zoom with a tutor, and they could attend alone or as part of a small group as per their preference. Since the return to teaching in-person for this academic year 2021-22, the MLC room is open again as a support centre, but with a reduced capacity, and students are required to book in advance and sign in every hour. A reduced, online support offering is also available to students in the evenings.

Although previous papers have reported on MLC attendance in DCU and more generally, this is the first time that hourly attendance data has been available in DCU. We will consider attendance patterns among first and second year students, compared to older year groups, to highlight any emerging trends. We will also look at in-person attendance by those who used the online service last year.

The available data can be used to investigate how supports might be re-oriented now that many students have experienced both online and in-person mathematics support in the university. It is hoped that this localised study can be supported by further research into the challenges posed to mathematics support more generally as we transition back to in-person learning in Ireland. Such research might demonstrate whether that transition is ongoing, and to what degree the field has adapted to the change in students requirements/expectations of mathematics support post-COVID restrictions.

Saturday, 25/June/2022 11:40am - 12:00pm
ID: 119 / PS- 11: 3
Research Paper
Keywords: uncertainty, laboratory, physics, measurement

Students' views on the quality of covarying data

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Students often obtain experimental measurements of two covarying quantities that do not exactly follow a simple relationship. We have investigated the criteria first-year and second-year university students use to answer free response questions about the quality of covarying secondary data, and possible actions that would increase the trustworthiness of the data itself or a conclusion based on it. We have focussed on the use of uncertainty in the measurement to guide their decisions.

Our work builds on research on students' understanding of measuring a single variable from the late 1990s and early 2000s [1]. This research analysed the written responses to questions focusing on decisions about data collected for a single quantity (often a length). A framework for interpreting students' reasoning characterized as "point", "set", and "mixed" paradigms was developed to classify students' actions and reasoning. "Point" reasoning is guided by the belief that any measurement provides a single value that could be the "true" value, and that the uncertainty associated with the measurement of a particular quantity could, in principle, be zero. "Set" reasoning is underpinned by the belief that each measurement is an approximation to the "true" value with a non-zero uncertainty, and is part of a set of measurements that collectively gives information on the variable. Many students appeared to "mix" point and set reasoning. Some used data analysis procedures consistent with set reasoning, like calculating the mean, but gave interpretations consistent with point reasoning, like not considering the spread in the data.

We extend this work by giving our students free response questions pertaining to covarying data with a number of outliers. Each question asked whether the data could be trusted, and how it could be used to derive a quantity or support a conclusion [2]. The contexts were simple and familiar enough that students could reasonably be expected to know or infer a theoretical relationship between the variables, but the relationships were not given. Neither were any hints given that they could use uncertainty in the data as a criterion. In doing so, we tried to mimic a real laboratory situation in which they had completed a set of measurements, and had to consider what to do next.

We found that students considered factors independent from the actual values of the data (e.g. agreement with theory/expectation or controlling variables), related to the quality of the raw data (e.g. were the outliers acceptable), and related to the quality of the derived quantity (e.g. did each pair of data points yield a sufficiently similar value for the derived quantity). Students proposed to improve the data in different ways (e.g. with better equipment or taking greater care) or to use the data set with provisos (e.g. using only "good" data points). To find a derived quantity from covarying data, our students proposed to calculate the mean, use individual data points, or use a best fit line. The spread in the data was not seen as an essential part of measurement.

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Friday, 24/June/2022 3:10pm - 3:30pm
ID: 120 / PS- 8: 3
Research Paper
Keywords: Socioscientific Issues, primary science, socioscientific reasoning, scientific literacy

The development of primary school students' socioscientific reasoning competencies through socioscientific issues and the Irish primary science curriculum

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Abstract

Scientific literacy is widely regarded as one of the most important goals of Science Education (Siarova, Sternadel, & Szonyi, 2019). Scientific literacy relates to how an individual uses their scientific knowledge and skills to participate as active citizens in society. Research indicates that teaching science through Socioscientific Issues (SSIs) has the potential to achieve this goal (Hancock, Friedrichsen, Kinslow, & Sadler, 2019). However, there is a dearth of international literature on the impact of SSIs-based education on the development of primary/elementary students' scientific literacy. Within an Irish context, SSIs-based education is not a feature of the Irish primary science curriculum and therefore its potential is not fully realised and is under examined in the teaching of science.

This study sought to explore whether the teaching of primary science through SSIs has an impact on enhancing upper primary school students' scientific literacy competencies; namely the development of students' socioscientific reasoning competencies. Seven primary school teachers participated in a professional learning course aimed at developing teacher confidence and competence pertaining to the teaching of primary science through SSIs and associated pedagogies. These teachers and the students in their classes (*n*=158 students) participated in this multiple-site case study whereby they taught primary science through SSIs over a six-month period. A mixed-methods pragmatic research design was utilised to assess its impact on students' socioscientific reasoning where multiple data sources were collected concurrently including student questionnaires, student focus group interviews and teacher semi-structured interviews.

Findings indicate that teaching primary science through SSIs had a positive impact on the development of primary school students' socioscientific reasoning competencies. Enhancements in student science content knowledge, NoS understanding and scientific inquiry skills were also evident. Students demonstrated enhanced ability to engage in socioscientific argumentation and in most cases students were able to apply their science content knowledge and skills to socioscientific reasoning whereby students made informed decisions pertaining to SSIs relevant to their everyday lives. The findings suggest that teaching primary science through SSIs has the potential to develop upper primary school aged students' scientific literacy competencies where students become prepared and empowered for active and responsible participation in a complex, democratic society. This study recommends that SSIs-based education and socioscientific reasoning be explicit features of primary/elementary science curricula both nationally and internationally and that this should be supported by teacher professional learning opportunities.

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Saturday, 25/June/2022 11:20am - 11:40am
ID: 121 / PS- 11: 2
Research Paper
Keywords: Computer Science Landscape, CAPE Model, diversity, inclusion, equity

The Irish Computer Science Landscape. Is Computer Science available to all? *

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Computer Science (CS) and Coding are formal subjects offered on the Irish post-primary curriculum. Coding and Computational Thinking are being proposed as components of the new primary curriculum. What challenges and barriers exist regarding the implementation of Computer Science at both primary and post-primary? What type of school is currently offering Computer Science in Ireland? What is the profile of the students studying this subject?

Looking through a lens filtered on diversity, gender balance, and equality, this research attempts to answer these questions by evaluating Ireland's current and proposed Computer Science (CS) learning opportunities. Underpinned by the CAPE model (Fletcher & Warner, 2021) "Capacity for", "Access to", and "Participation in" CS education, qualitative and quantitative data will be gathered to provide a detailed view of the Irish Computer Science landscape and to evaluate its equity.

This paper will present preliminary findings related to the CS landscape. A list of school-level factors that determine the access to CS/JC Coding offering in schools will also be discussed. Findings from this study will be of interest to educational policymakers, initial teacher educators, and second-level teachers in Ireland and beyond

***Research supported by Google**

Fletcher, C. L., & Warner, J. R. (2021). CAPE: A Framework for Assessing Equity throughout the Computer Science Education Ecosystem. Communications of the ACM, 64(2), 23–25. https://doi.org/10.1145/34423734.

Friday, 24/June/2022 2:10pm - 2:30pm
ID: 122 / PS- 5: 3
Research Paper
Keywords: Practitioner Inquiry, Rich tasks, Teacher development, Primary-Secondary transition, Mathematics and Physics learning

Addressing transition issues in mathematics and physics through practitioner inquiry

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This study reports on the implementation of a teacher professional learning programme designed to develop teachers' competencies in designing rich tasks that support student learning across transitions in mathematics and physics. Primary and secondary teachers were supported to conduct their own Practitioner Inquiry (PI) and design and implement rich tasks in their classrooms. This study reflects on the experiences of four teachers of mathematics and physics who collaborated as part of a professional learning community over a nine-month period. The findings of this study were identified from analysing teachers' reflections on their experiences of designing and implementing rich tasks in their classrooms and examining the impact of these tasks on their students' learning through practitioner inquiry. Examples of rich tasks prepared by teachers will be discussed along with the challenges identified by teachers in carrying out practitioner inquiry and designing appropriate rich tasks.

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Acknowledgements

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Friday, 24/June/2022 1:30pm - 1:50pm
ID: 123 / PS- 4: 1
Research Paper
Keywords: teacher professional learning, pre-service teacher education, immervise learning experiences

Deepening pre-service STEM teacher professional learning: Designing a STEM Teacher Internship Programme

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If teachers are to design authentic learning experiences which integrate core STEM competences within real-world contexts, it is essential that they have first hand experience in these contexts themselves (Hurley, Butler & McLoughlin, 2021). "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. 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" (Darling-Hammond et al., 1995, p. 2).

This study will present the motivation for and design of the STEM Teacher Internship (STInt) programme developed by the authors together with Accenture and the 30% Club. The STInt programme provides pre-service teachers (PSTs) with an opportunity to complete a 12-week paid summer internship in STEM roles in industry. The objectives of the STInt Programme are to enhance the capacity of pre-service teachers to promote diverse STEM education and career pathways; to support a professional learning community of teachers with a shared interest in connecting STEM in the classroom with STEM in the wider world; and to support long-term collaborative education-industry partnerships in Ireland. This study will present data collected using pre- and post- surveys with thirty-one PSTs who participated in the STInt programme in summer 2019 and completed internships in nineteen host companies. The concerns and expectations identified by PSTs prior to starting their internship along with the experiences and challenges identified by PSTs immediately after completing their internship will be discussed. Findings from these interns' experiences have been used to inform the (re)design of the programme.

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Saturday, 25/June/2022 11:00am - 11:20am
ID: 124 / PS- 11: 1
Research Paper
Keywords: Research practice partnership, teacher education, science education

Outcomes of a Research Practice Partnership with Novice Physics Teachers

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This study reports on the experiences of six novice physics teachers in their first year teaching as a newly qualified teacher. Professional learning communities engage in deliberate and purposeful professional dialogue to learn from practice with the power to change school culture, teacher impact and student achievement (Dana & Yendol-Hoppey, 2015). Building on this approach research practice partnerships (RPPs) offer an accessible model to facilitate meaningful learning in the context of negotiating teachers' problems of practice (Penuel, Coburn and Gallagher, 2013). An RPP is defined as: "Long-term, mutualistic collaboration between practitioners and researchers that are intentionally organized to investigate problems of practice and solutions for improving district outcomes" (Coburn et al., 2013, p.2).

In this study novice physics teachers formed a research practice partnership (RPP) with two science education researchers (both authors) over an 8-month period. Four RPP meetings were held with teachers during their first year of teaching and all meetings were facilitated online (because of the COVID 19 pandemic). The meetings followed Penuel's RPP model (Penuel & Gallagher, 2017). At the end of this four-meeting cycle, teachers were asked to reflect on their experience of participating in the RPP. The researchers also completed reflections after each of the RPP meetings. All participant data was thematically analysed according to Braun and Clarkes approach. Overall, the findings indicated that teachers valued the opportunity to share and discuss their experiences with other teachers. The teachers reported an increase in confidence arising from participation in RPP meetings – they had space to reflect on their practice and discuss their problems of practice with other practitioners. Similarly, the researchers valued the experiences of discussing and learning from teachers' experiences. However, researcher reflections also identified key challenges to fostering and nurturing mutualistic relationships within the RPP.

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Friday, 24/June/2022 2:10pm - 2:30pm
ID: 125 / PS- 4: 3
Research Paper
Keywords: Outdoor learning, place-based learning, education for sustainability, nature connection, science education

Beyond fieldwork in science – place-based outdoor learning as a pedagogy for education for sustainability through science

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Fieldwork has traditionally been a part of the study of science. Instead of gathering data or evidence in a laboratory or classroom, fieldwork allows for the gathering of data, through observation or measurement, in a real environment. Place-based outdoor learning can be described as a pedagogy which supports learning and development across a range of domains, with the outdoors providing the context, resources, setting and/or space for rich experiential and authentic learning (Kelly et al. 2022). In the context of science education, such outdoor learning can include traditional fieldwork as described above but moves it beyond observation and measurement to teaching and learning which allows for the affective domain to be engaged and wider education goals to be achieved. This paper will share an initial review of the research which explores this relationship between cognitive and curricular learning in science and affective and holistic learning, when a place-based outdoor learning pedagogy is adopted. The review is set in the context of the redevelopment of the Primary Curriculum (NCCA 2022), where key competencies for all learners are set out including ‘Being an active citizen’ and ‘Foster wellbeing’. It is suggested that such place-based outdoor science learning can contribute in a much more meaningful way to education for sustainability and not just the environmental pillar but the social and economic one too. The may address the long standing imbalance in science education which has largely considered the environmental pillar.

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Saturday, 25/June/2022 12:40pm - 1:00pm
ID: 126 / PS- 12: 3
Research Paper
Keywords: mathematics, mindset, resilience, problem-solving, collaborative

Problem-solving Potential (PsP) in the regular mathematics classroom

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A student's Problem-solving Potential (PsP) is defined by their mindset, their mathematical resilience, and the problem-solving skills they possess. This triad construct of PsP was developed as part of a doctoral study, and investigated amongst six cohorts of highly-able mathematics Transition Year students through an educational intervention. Prior research into mindsets, largely spearheaded by Dweck (2006), found a relationship between achievement and growth-orientated mindsets; which extol the virtues of learning over "looking smart", and the value of making mistakes, among other attributes. Mathematical resilience is further subdivided into value (belief that mathematics is important), struggle (acknowledgement that struggle is a valuable part of learning mathematics), and growth (referring to growth mindsets) (Kooken et al., 2016). Prior research of mathematical resilience focussed on the development of this concept amongst low-achieving students; whilst our research investigated its development within highly-able students. There is a popular belief amongst educational researchers that mathematics is best learnt through the construction of knowledge by the learner, and mathematical problem-solving is one approach that creates this opportunity for all learners (Mason et al., 2010). Our educational intervention utilised collaborative problem-solving, and was designed to: introduce strategies for problem-solving; encourage reflection on the problem-solving process; provide opportunities for the extension of problems; and develop communication skills. In this paper, we will highlight the benefit of developing PsP in the mathematics classroom for highly-able students by discussing the relevance of each aspect of the construct through the findings of the doctoral study; and also how the development of PsP may impact lower-achieving students.

Saturday, 25/June/2022 12:00pm - 12:20pm
ID: 127 / PS- 12: 1
Research Paper
Keywords: teacher identity; professional development; out-of-field teaching; mathematics education

Teaching mathematics out-of-field and the journey to obtaining mathematics teacher certification

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The misassignment of teachers, with respect to their qualification, results in teachers teaching mathematics out-of-field (OOF) (Ingersoll, 2005). OOF mathematics teaching is an international area of concern, with research documenting both the existence of the practice in Australia, the United States, Germany and England, and the negative effects that the practice can have on the teachers' lives, student learning and the professional standards of teaching. Research conducted in Ireland has demonstrated the prevalence of teachers being assigned to teach mathematics in secondary schools without having the necessary certification (Ní Ríordáin & Hannigan, 2011). In response to the issue of OOF mathematics teaching, the Irish government funded the Professional Diploma in Mathematics for Teaching (PDMT). The PDMT is a professional development programme for teachers teaching mathematics OOF which enables them to obtain mathematics teacher certification. The content of the PDMT, then, adheres to the Teaching Council of Ireland's criteria for being deemed qualified to teach mathematics at secondary school level. To research participants on the programme, and thereby, to conduct research on teachers teaching OOF, it is essential to adopt a holistic approach that considers cognitive and affective-motivational dimensions of being a teacher (Bosse & Törner, 2015). Therefore, the construct of mathematics-related teacher identity (MRTI) offers a viable means to research OOF mathematics teachers as it lends itself to exploring what it means to teach out-of-field. This research adopts a cultural, discursive psychological approach, with identity conceived as being multiple, relational, transactional, and primarily constructed, maintained, and negotiated through discursive practices. Given the multiplicity of identity, this research is concerned with first-person MRTI – the teacher's self-understandings in relation to mathematics teaching. First-person MRTI, then, refers to the stories told by the teacher about themselves to a third party (in this case, the researcher). This paper reports on the first-person MRTI of Mary, a teacher teaching mathematics OOF whilst participating on the PDMT programme. Thematic analysis and sociolinguistic tools were used to analyse interview data to obtain insights regarding Mary's MRTI and the ways in which her MRTI was reshaped over her involvement on the PDMT. The findings suggest that professional development programmes have the capacity to impact MRTI, in particular, with regard to how the teacher believes they are seen by school management and students' parents; however, other factors, such as colleagues and previous experience learning mathematics, may be more significant in shaping the teacher's MRTI in relation to their classroom practices. The findings from this research may have implications for the development of mathematics professional development programmes and the criteria for determining mathematics teacher certification.

ID: 128 / PS- 13: 1
Symposium
Keywords: Student STEM learning, Teacher Learning

Workshop: Connecting Across Subjects to Support Student and Teacher Learning

Aine Woods, Shane Flanagan, Caitriona Cronin
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The STEM Education Policy Statement 2017 -2026 (*Department of Education and Skills, 2017*) identifies an ecosystem with the STEM learner at the centre. The Framework for Junior Cycle 2015 (*Department of Education and Skills, 2015*) also places the learner at the centre of the learning experience, and the development of learning outcomes-based specifications provides flexibility for Irish teachers to plan for learning which has school and student context relevance. In addition, the Framework for Junior Cycle emphasises the significant contribution teacher collaboration makes to teachers' professional development.

As the STEM Education Policy indicates, STEM education involves consideration of the 4 disciplines identified in the acronym. A quality STEM education requires a development of understanding both within and across disciplines. However, a recent report from the Department of Education Inspectorate suggests that the compartmentalisation of subjects at post primary level in Ireland may present a barrier to "developing thematic and cross-curricular approaches to curriculum delivery". (*Department of Education, 2020*). In addition, teachers are often time poor and such collaboration across subjects can be perceived as an added burden.

AS CPD providers JCT have been exploring ways to support teachers to collaborate in a way that is manageable for them, and which will allow them to support their students in connecting learning across subjects. Vasquez (2015) identifies a possibility for different levels of integration of the STEM disciplines. With students concurrently engaging with concepts in different subjects, such as science classes and mathematics classes, and with the teachers explicitly referencing the learning happening in other subjects the possibility exists to support students to recognise the connections across subjects of STEM knowledge, skills, and competencies. Vasquez (2015) suggests that such multi-disciplinary approaches are worthwhile and are a good starting place to counteract the compartmentalisation identified in Irish schools. Working with teachers this year we have found that when students are then given an opportunity to apply this learning to engage with innovative and creative approaches to real world challenges the real-world relevance of classroom learning becomes apparent, and integration at a transdisciplinary level (Vasquez, 2015) can be achieved. In addition, through collaborative conversations, where teachers collaborate across subjects and interrogate their own understandings, the possibility exists for deep professional learning.

We hope to actively engage participants with classroom materials from mathematics and science classrooms and to consider with them the potential that exists for deeper STEM learning when students and teachers are supported to connect across subjects. We will also engage with evidence captured this past year from Irish schools and consider whether the potential of the specifications can be further realised through such approaches within schools.

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Friday, 24/June/2022 2:50pm - 3:00pm
ID: 129 / PS- 9: 2
Pre-recorded Lightning Talk
Keywords: Subject leadership, Mathematics, Pre-service primary teachers, Peer community

Growing with peers: Promoting subject leadership in mathematics in Irish primary schools

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The research literature on leadership in mathematics education is substantial (Driscoll, 2017; Burke, 2021). However, consideration of leadership in pre-service educational programmes is a relatively recent phenomenon (King et al., 2019).

In this talk, we report on research in progress relating to an innovative module (SG410) on Subject Leadership in Mathematics Education taken by students in their fourth year of the BEd (Primary) at DCU, who have chosen a specialism in Mathematics Education. SG410 was offered for the first time in the academic year 2020-21. In that year, 18 students took the module, while 24 took it in 2021-22.

The module is conceptualised as a community of practice involving mathematics educators, mathematicians and student teachers. Students are expected to integrate their understanding of mathematics with a facility for pedagogy. It is anticipated that engagement in the module will prepare students to assume a leadership role among future colleagues in the teaching of mathematics in primary schools. Learning outcomes for SG410 include: articulation of connections between mathematical concepts, procedures and activities for teaching; design of rich mathematical tasks and development of authentic assessment procedures related to their use; and promotion of competence and confidence in the teaching of mathematics among peers.

To achieve these outcomes, and the last one in particular, students were required to conceive, design, implement and report on a project in mathematics education involving their non-specialist BEd peers (known as 'groupies'). They were required to present the final version of their report in poster form.

The data available for analysis in the research project (known as 'PRiME2') were: students' postings to an online forum during the course of the module; the posters themselves; an individual contribution in the form of a paragraph for their CV highlighting their project work; and students' (anonymous) evaluation of the module.

The focus of this talk is the posters themselves and how they provided evidence of student growth over the course of the module. The poster titles [with additional clarification of their content indicated in parentheses, where necessary] were:

Why Collaboration Supports Children's Engagement in Problem-solving Tasks?

Are we Really Doing Maths? [mathematical identity and integration with maths]

Maths in the Outdoors Meets Minecraft

Visual Arts as a Real-life Context for Supporting Understanding of Ratios

Hitting the Sweet Spot [integrating science and mathematics in the primary classroom]

How can Low Threshold High Ceiling Tasks Influence Mathematical Self-Efficacy Beliefs?

The posters demonstrate how these prospective subject leaders of mathematics in primary schools can grow and develop through interrogating their practice in the community of their peers.

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Friday, 24/June/2022 12:10pm - 12:30pm
ID: 130 / PS-3A: 3
Research Paper
Keywords: Anglo-German School, biology education, HPS in biology

Physiological Botanical Instructional Artefacts of the "Anglo-German School"

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In this work, the author presents artefacts produced from the 1960s to the present day which were employed in botanical education in teacher education and second-level instruction up to the present day in Ireland. The author focuses in particular on artefacts associated with experimental physiological botany invented in the 19th century which had a lasting legacy in biology education, and the author argues for their retention in syllabi and their worth as investigative activities which promote scientific skills and processes. The theoretical background to this work is that history, philosophy of science (HPS) (Jenkins, 1994) approach to teaching and learning biology has a worthwhile contribution to make in biology education, but heretofore, HPS has been largely focussed on the physical sciences (Heering & Winchester, 2014). HPS in science education can and should make use of historical apparatus (Cavicchi & Heering, 2022) especially since many schools still possess them. The late 19th century saw a huge expansion of experimental science in the botanical realm – in parallel with the 19th-century arms race – and development in physiological botany in particular, and a timeline of innovations and discoveries is presented which informs an understanding of the development of botanical education or instruction. In the German states this was notable in the area of plant growth with the invention of the recording auxometer by Pfeffer and the clinometer by Von Sachs; and the potometer in the Anglophone world, for example, Bretland (UK), Francis Darwin (UK), Bose (India), Ganong (Canada/USA) and Thoday (UK), Garreau of France for a different type of device also termed a potometer. In the main, the potometer appears to present a particular problem since teachers tended to have found it difficult to set up and use, and in the end lack of knowledge of photosynthesis undermined its basic working assumption. Finally, the bubbler apparatus – a version of which is still used – attributed to Wilmott is reviewed and alternatives in biology at all levels is suggested. The paper will be presented with examples of the artefacts as used in botanical education.

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Friday, 24/June/2022 12:10pm - 12:30pm
ID: 131 / PS-1: 3
Research Paper
Keywords: Climate Change Education, Primary Science, Ireland, Mauritius

Teaching about Climate Change through Primary Science Education: A Comparative study between Ireland and Mauritius

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Climate change education (CCE) supports learners to understand and address the impacts of the climate crisis, empowering them to act as agents of change, and as such, it is placed at the core of the strategic targets of the United Nations Sustainable Development Goals. STEM disciplines of knowledge enable citizens to measure, analyse, design and advance the physical environment (DES 2016), and therefore has a crucial role to play in ensuring young people develop the requisite competencies to work and live in a way that 'safeguards environmental, social and economic wellbeing, both in the present and for future generations' (UN, 2016). While, there is an increasing body of research exploring the position and nature of CCE in national curricula and education systems, comparative research in this area is scarce.

This paper presents findings from a research project which investigates the degree to which the primary science curricula of Ireland and Mauritius support CCE and to explore the extent to which qualified primary teachers in both jurisdictions feel enabled and supported to teach about climate change through science education. The paper draws on a content analysis of the primary national curricula in Ireland and Mauritius, as well the findings from surveys and focus groups with primary teachers in both countries. The paper thus provides a comparative analysis of the breadth and depth of CCE in primary science in the two countries, before considering how primary teachers perceive the barriers and supports when enacting these curricula.

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Friday, 24/June/2022 12:10pm - 12:30pm
ID: 132 / PS-2: 3
Research Paper
Keywords: STEM, assessment, digital tools, transversal skills, teacher professional learning

Integrated STEM from theory to practice and digital assessment of transversal skills

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Development of transversal skills is an ongoing priority in educational policy at national and European level. STEM, as an integrated concept, is a potentially rich site of the application of skills drawn together from distinct disciplines in the real world. How such skills may be developed and assessed using digital tools is the focus of the Assessment of Transversal Skills in STEM Erasmus+ project. Following an introduction to the project itself, this presentation will give an overview of some of the desk-based research conducted during the project's establishment phase; an insight into the rollout of the ATS STEM developed framework to Irish schools and the evaluation of this intervention.

The project was underpinned by a series of reports that analyzed and synthesized findings: on STEM education policy, STEM education in schools, formative assessment of key STEM skills, and digital platforms to enable the assessment. These were used to create a conceptual framework for integrated STEM teaching. The framework sought to translate key elements of research into learning designs that teachers could use to develop and enact research-informed assessment focused pedagogies for STEM (Butler et al., 2020).

During the Covid-19 pandemic teacher mentors worked with teachers using the ATS STEM learning design framework. the design and implementation of this pilot and the related teacher professional development was conducted with careful partnership with schools to reflect the uncertainty and restrictions imposed by the pandemic and the specific needs and context of the Irish education system.

Finally an evaluation of the intervention was conducted in the pilot schools. The evaluation (Kirwan et al, 2021) provided case studies of digital assessment practices, tools and methodologies in Ireland's compulsory education sector using integrated STEM teaching. It also served to highlight the challenges of using digital assessment practices. A final report documented the workings of the evaluation of the project from developing and adapting a research protocol to formulating results and conclusion based on the gathered data. It found that the initial selection of digital tools for assessment to be key; that tools should address critical formative assessment components and be multifunctional; and highlighted challenges to implementing scalable and replicable approaches.

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ID: 133 / Posters: 2
Poster
Keywords: STEAM, Art, Technology, Teaching, Learning

Using Digital Learning Resourcesto Engage Students in Art

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This project involved using Nearpod as a learning resource. The lessons engage students as part of a synchronous and asynchronous approach. Technology is used to enhance teaching and learning in Art

In developing my resources, I followed the DADDIE model.

Define I looked at the learning outcomes to create an interactive Art lesson on a digital technology platform for remote learning

Analyse I included a Kahoot quiz to test learner's knowledge as well as the Nearpod reports which show student participation on each slide

Design Included interactive content such as Google arts and culture and VR content.

Develop I wanted to create visual content that would be accessible to all learners. I included STEAM based element by using a VR field Trip to the Van Gogh Museum so students could experience the Art works

Implement Involved sending out the code to Nearpod and Kahoot for students to participate

Evaluate Included looking at both platforms reports to assess participation as well as tracking what slides students had difficulty with.

This involved sending a code to access the resource on a phone addressing the digital divide in a Youthreach setting. Participation in the lesson meant that I could track learners' use of the resource. I also created a quiz with Kahoot for learners to test themselves on the content. Data and scores from the quiz are also recorded.

Evaluation

I decided that Nearpod is the most suited digital technology platform to provide Art lessons in a remote setting. Students just need to enter the code to the app or a browser and participate. There is a Synchronous setting which you can teach live through Zoom. There is also an Asynchronous option which is student paced. Having both options is suited to the different types of learners. I was able to embed video in the lessons and add a collaborate board for peer learning. The VR element allows students to use technology to experience paintings up close.

Reflection

I originally used Kahoot for a quiz after the lesson but later realised that Nearpod has a quiz feature which I could use. This way students have a complete lesson on the one platform. This suits the learners in a Youthreach setting as not to introduce too many different TEL's. Students were more engaged with the interactive content instead of a PowerPoint Lesson. I progressed my learning by attending the Nearpod Camp Engage, which was important in terms of my professional development. I hope to integrate different digital technologies and resources into my practice in the future.

Glossary

DADDIE An acronym for Define, Analyse, Design, Develop, Implement and Evaluate - An iterative instructional design model.

Asynchronous Allows for flexible learning for your own schedule.

Synchronous learning means you will virtually attend a class in real time

VR Computer simulation of real or imaginary systems that enables a user to perform operations on the simulated system

STEAM Science Technology Engineering Art and Maths

TEL Technology Enhanced Learning

Resources

https://nearpod.com/resources

https://bit.ly/3u5TJ8E

https://events.nearpod.com/camp-engage

https://artsandculture.google.com

https://kahoot.com

Friday, 24/June/2022 2:30pm - 2:50pm
ID: 135 / PS- 8: 1
Research Paper
Keywords: student-led, problem based learning, research projects

Designing a structured student-led research project

Antonio Martin-Carrillo[1], Lorraine Hanlon[1], Alex Oscoz[2], Gilles Bergond[3], Santos Pedraz[3]
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Research projects at undergraduate and graduate levels are typically offered to students from an available list and allocated on a “first comes first served”, based on students grades or through matching the student’s top desired projects. This can lead to students having to work on projects where they lack strong interest, affecting their motivation and overall performance. At the beginning of their research projects, students are normally given some literature on the topic and immediate access to data and/or research facilities so they can start taking measurements. While this seems engaging, it often leads to confusion since, in many cases, students do not know exactly what they are doing or why they are doing it (Winchester & Salji 2016).

Here, we present the design of a structured student-led research project course. In this course, students design their own research project under some given constrains based on project timeline and academic staff research expertise. This approach gives the students a sense of control and ownership of their projects and maximises their engagement and motivation (e.g. Kotecha 2011). The students are given a clear pathway towards the completion of their research projects based on the typical steps followed in research: literature review, data analysis preparation, project proposal and research. Students approach the first two sections following problem-based learning steps based on Svinicki & McKeachie (2014). Each section of the pathway is marked for the students as a milestone and requires the submission of a report. This offers a way of assessing the feasibility of the project, the student’s progress and an opportunity to provide feedback to the students. In this scenario, the literature review is seen as the threshold that defines the research topic as well as the key scientific questions that the student is aiming at studying within their project (Winchester & Salji 2016).

As a practical case, we describe in detail the design of a full year, 10 ETCS credits, astronomical project course for final year undergraduate students. This course is part of the Physics with Astronomy degree at the University College Dublin and has been running successfully, with this design, for the last 5 years.

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Friday, 24/June/2022 2:10pm - 2:30pm
ID: 137 / PS- 6: 3
Research Paper
Keywords: introductory algebra; conceptual understanding; transition to third level; diagnostic testing; online assessment; concept inventory.

How well do high achieving undergraduate students understand school algebra?

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The aim of this research is to investigate how well students entering tertiary level education in Ireland understand school algebra. As part of a larger project, a 31-item test was developed to assess first year undergraduate students' understanding of basic concepts within algebra. The test was administered online to students studying at least one mathematics module at tertiary level and received 327 responses. Perhaps unsurprisingly, the results demonstrated a very high level of understanding among students, as befits their level of study relative to the difficulty of the test. However, one subsection of the test stood out as being disproportionately difficult for these students. The section focused on valid solutions of equations and inequalities. The items in question are described in detail in this article, as is the associated data. Our analysis shows that this topic is an area of concern even for high achieving undergraduates and so deserves further attention. We conclude with a discussion of the implications of this research and details of the larger project.

Friday, 24/June/2022 11:30am - 11:50am
ID: 138 / PS-1: 1
Research Paper
Keywords: Inquiry based learning. STEM. Virtual learning. Online collaboration. Frontiers science.

FRONTIERS: Virtual Collaboration in Action

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The EU FRONTIERS project focused on a key priority area of Education – STEM. The project partners came from a wide range of STEM activity and expertise; from Astronomy to Physics to research, to education. The consortium set out to empower science teachers to affect change by enabling them to bring frontiers science into the classroom. Twenty-one innovative educational activities and demonstrators/online resources were created during the project and organised according to categories of frontier physics, from basic physics to astronomy, cosmology and high energy physics.

The demonstrators were underpinned by a 5 stage inquiry approach. Minner et al. (2009) point out that whether it is the scientist, student, or teacher who is doing or supporting inquiry, the act itself has some core components as defined by the National Research Council (NRC). The NRC describes these core components from the learner's perspective as ‘‘essential features of classroom inquiry’’ (NRC, 2000, p. 25) and include:

(1) Learners are engaged by scientifically oriented questions.

(2) Learners give priority to evidence, which allows them to develop and evaluate explanations that

address scientifically oriented questions.

(3) Learners formulate explanations from evidence to address scientifically oriented questions.

(4) Learners evaluate their explanations in light of alternative explanations, particularly those reflecting

scientific understanding.

(5) Learners communicate and justify their proposed explanations.

A major challenge arising during the lifetime of the FRONTIERS project was the Covid-19 pandemic. The main impact was that many of the in-situ plans had to be implemented in a virtual setting which involved redesigning the one-week international summer and winter schools in 2020 and 2021. The alternative approach enabled us to achieve and even exceed the project goals.

Drawing on both quantitative and qualitative data collection and analysis, partners evaluated the impact of the project outputs. Onwuegbuzie and Turner (2007) note that combining elements of qualitative and quantitative research approaches in one study provides breadth and depth of understanding and corroboration. Questionnaires and focus group data collection methods were utilised in the evaluation of the international e-schools. Zoom was used to host the international e-schools and Google Slides facilitated the teacher working groups.

A key feature of the International e-School was establishing working groups of participating teacher to work collaboratively to create their own interdisciplinary resources based on the FRONTIERS Demonstrators. A priority for the International e-Schools was to promote and facilitate participating teachers to work collaboratively with fellow professionals to explore the online resources. The success of this was highlighted in the project focus group findings with participants. The focus group participants commented that the collaborative design of the e-schools helped to develop a deeper understanding of the content and educational resources by allowing the professionals to explore and develop the resources together. The demonstrators developed by partners and the teacher created resources are available on the Frontiers website [http://www.frontiers-project.eu/frontiers-educational-resources/]

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ID: 139 / **Posters: 1**
Poster
Keywords: Primary mathematics and science, rich mathematical tasks

Hitting the Sweet Spot

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This research reports on a project designed to encourage authentic cross-curricular integration with mathematics beyond the use of a common theme. The aim of this inquiry was to demonstrate effectively the integration of mathematics and science concepts and skills through an appropriate rich task with a view to exploring the use of rich tasks to integrate science and mathematics in the primary classroom.

We recruited a convenience sample of 12 participants from within the B.Ed. final year cohort. The rich task that was investigated was to establish what was the most sugar that could be dissolved in 100ml of water. Each participant was given the necessary equipment of sugar, a measuring jug, a teaspoon, hot, warm and cold water and a fizzy drink. In this rich task, detailed instruction was avoided where the participants were expected to come up with their own conclusions that they got from the experiment. This was encouraged by allowing participants to represent their findings through discussion or visual representations (Schoenfeld, 2016).

From this investigation, a shift in attitudes towards the integration of mathematics and science was noted. This investigation led to the participants discussing the many different mathematical concepts that could be brought into fair-test investigations in science such as measuring the height and speed of the falling parachute. Due to the student centred, real-world approach and multiple modalities used across the task, it appeared a new cross-curricular awareness towards authentic integration of mathematics and science arose from this investigation (Liston, 2018). The participants were enabled to develop a deeper conceptual understanding within each discipline, mathematics and science while also simultaneously developing the necessary skills in both disciplines through a meaningful context (Rowley & Cooper, 2009).

In the poster presentation that summarises the findings, we conclude that rich tasks must present relevant content to the specific group i.e. children engaging in rich mathematical tasks, as it promotes their enjoyment and engagement (Busher & Harris, 2000). Furthermore, as researchers, we now feel more confident in our approaches to integrating mathematics and science as well as conductors of research as it has given us the necessary skills to become leaders of mathematics education in the classroom.

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ID: 140 / **Posters: 3**
Poster
Keywords: Integration with mathematics, confidence in teaching mathematics, engaging mathematical experiences

Are we really doing mathematics?

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There is considerable evidence in research literature to show that students' attitudes towards, and performance in, mathematics are strongly influenced by their mathematical experiences. Teaching practices which emphasise the relevance of mathematics and connect to students' experiences promotes student engagement (Martin et al., 2012). Thus, as final year preservice teachers undertaking a Major Specialism in Mathematics Education, we investigated how integrating mathematics with geography could offer an enriching learning experiences and positively influence preservice teachers' confidence in and attitudes towards teaching mathematics.

We conducted our research by hosting an event namely 'An Outdoor Geography Trail' and invited 15 of our peers from the Bachelor of Education (B.Ed. 4) to attend. The focus of our research was to determine how the provision of mathematically rich tasks through authentic integrative experiences with geography would influence their beliefs on teaching and learning mathematics. Our research was carried out over three stages; before, during and after the event. Prior to the event, we carried out a pre-test survey to investigate our peers' confidence in teaching all subject areas. During the event, we facilitated three mathematically rich tasks integrated with geography. Each of the tasks were designed to promote engagement in the mathematical learning process. We evaluated our peers' experiences of such tasks through the use of mathematical talk and questioning. Following the event, our peers completed a post-event survey. This survey placed a greater emphasis on mathematics, allowing us to assess our peers' understanding of the mathematical content and to determine their views of integrating mathematics with another subject area. We evaluated if their perspectives changed from the pre-event survey to post-event survey.

Prior to the event, participants indicated that were not as confident in their ability in mathematics as they are in other subjects in the curriculum with no participant indicating that they were 'very confident' and 44% stating that they were 'neither confident or unconfident' or simply 'unconfident'. Furthermore, we found that our peers were unfamiliar of integration with mathematics. During the event, peers used words 'fun', 'enjoyable' and 'active' to describe the tasks. In the post-event survey, we posed the question 'Could you see yourself facilitating similar activities in future classrooms?" to which 81.8% of our peers responded 'yes'.

In conclusion, our peers were more aware of how to provide mathematical learning opportunities in integrative ways that do not involve the rote application of traditional formulae or methods. We considered this evidence as an indication of our peers improved attitude to mathematics, having greater confidence in teaching mathematics and consideration for integrating it with other subjects.

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Friday, 24/June/2022 1:30pm - 1:50pm
ID: 141 / PS- 5: 1
Research Paper
Keywords: STEM Leadership

Creating STEM Culture in Schools through STEM Leadership Institute

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Abstract

The Science, Technology, Engineering and Mathematics (STEM) workforce plays a key role in the sustained growth and stability of a country's economy and helps a nation remains a world leader. STEM education creates critical thinkers, increases science literacy, and enables the next generation of innovators. Innovation leads to new products and processes that sustain the economy. The STEM Leadership Institute was developed at the Southern Connecticut State University in the United States of America. Participating school leaders and educators have been asked to complete comprehensive STEM Leadership Need Assessment Survey. The purpose of this study was to gather information about educators' needs and priorities for preparing and developing STEM educators and leaders. The findings of this study inform our efforts to develop and support future collaboration between policymakers, educational administrators, STEM educators, and institutions of higher education and science learning, in pursuit of strategic planning for implementing high-quality STEM education in all K-12 schools. Particularly, the findings of this study help educators explore what are STEM leaders' professional development interests and their needs. Participants also have the opportunity to suggest an addition to the plan or to add further comments and ideas to promote STEM education for all students.

Educational leaders can make significant strides in STEM implementation in schools through collaborative efforts and the dissemination of data from institutions of higher education (IHEs) to local education agencies (LEAs). Therefore, it is crucial to prepare and develop STEM-ready school leaders to promote STEM activities in schools. In this study, STEM Leadership has been conceptualized with four main domains. Domain 1 "STEM PARTNERSHIP, RESOURCES, AND NETWORK SYSTEM. This domain focuses on identifying the professional development needs of educators to use the key STEM resources and to establish collaborative efforts and networks to support systemic STEM improvement. Domain 2 is "STEM CURRICULUM, INSTRUCTION, AND PROFESSIONAL DEVELOPMENT. This domain focuses on identifying the professional development needs of educators to promote an integrated curriculum and professional development that empower educators to promote student STEM education.

Domain 3 is listed as "LEADERSHIP & ADVOCACY FOR STEM CULTURE". This domain focuses on identifying the professional development needs of educators to establish a robust infrastructure and leadership system to continuously improve and advocate for all students. The last domain was "DIGITAL AGE LEADERSHIP AND STEM LEARNING". This domain focuses on identifying the professional development needs of teachers to use appropriate technologies, and digital-age learning tools to provide a rigorous, relevant, and engaging STEM education for all students. Aligned with these leadership domains, the study highlights the complex interaction of professional development, educational leadership, and collaborative efforts in establishing innovative STEM programs in schools.

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ID: 142
Research Paper
Keywords: STEAM, alternative education, Youthreach, framework, competences

Towards a Framework for STEAM Education in Youthreach in Ireland: Building on stakeholder perspectives

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STEAM education is a pedagogical approach that merges science, technology, engineering, arts and mathematics and aims to develop learner knowledge, skills/life skills and attitudes, while promoting engagement. It can be particularly relevant in alternative education provision settings, such as the Youthreach programme for early school leavers, in Ireland. This research is based on the implementation of a two-year project "Full STEAM ahead: A partnership approach to STEAM in Youthreach". This paper presents the approach adopted to design a Framework for STEAM Education in Youthreach, developed in light of current literature and through co-creation between researchers and stakeholders, over the first year of the project. Stakeholder viewpoints were gathered through interviews, then analysed through qualitative content analysis. This involved comparing interview transcripts to a pre-determined coding frame based on the Framework for STEAM Education in Youthreach. The Framework identifies STEAM; STEAM learning outcomes; STEAM session supports; and STEAM assessment. The proposed Framework is informed by the innovative and emerging field of literature in STEAM education and the important role that STEAM education can play within Youthreach alternative education provision in Ireland.

Friday, 24/June/2022 11:50am - 12:10pm
ID: 143 / PS-3A: 2
Research Paper
Keywords: Computer Science education, transversal skills, student partnership, interactive oral assessment

Integrating transversal skills in Computer Science education - it really does make sense

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Computer Science (CS) is a very technical area and requires knowledge of programming and other topics. The general image of computer scientists is someone, often male, working on their own in front of a computer. While computer scientists sometimes work individually, a lot of the time they work with others as part of a team. Modern computer systems are large and complex and require a group of people to work together for their successful design and development. Computer science students need to learn how to work successfully with others and be comfortable with communicating with a range of people from both technical and non-technical backgrounds.

Transversal skills or 21st century skills (Voogt & Roblin, 2010) include innovation, creativity, entrepreneurial agility, analytical skills, business acumen, teamwork and communication skills. CS students generally have good analytical and problem solving skills, but sometimes lack teamwork and communication skills. Even though they are uncomfortable skills for CS students to learn, it is important to give them the opportunity to cultivate and improve their communication skills. CS students often fall into the category of reluctant learners (Salacore, 2007).

This paper outlines how the learning of transversal skills were woven into a communications module for computer science students. The module has a Student Partnership approach (Mercer-Mapstone et al., 2017) and this aligns with a more global approach to Student Partnership in the School (Ward et al., 2022). There is a scaffolded approach to assessment and there are elements of peer review and feedback in the module which integrates educational technologies into the module delivery (Ward & Costello, 2016). There is an innovative approach to assessment with the use of Interactive Oral assessment (Sotiriadou et al., 2020) as part of the module. This scenario-based, genuine conversation approach integrates several transversal skills and emulates real-world scenarios for the computer science students. The feedback from the students has been positive with many, although not all, citing the group work and group research as their favourite part of the module. This module is delivered immediately before the students go out on work placement and as the focus of the module is on real-world, relevant, practical skills, the students understand why they are taking this module and know that the skills they learn will be of benefit to them in the world of work.

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Friday, 24/June/2022 11:30am - 11:50am
ID: 144 / PS-3A: 1
Research Paper
Keywords: Concepts, Cognition, Chemistry. Teacher Education.

Identification and linking of concepts within the Leaving Certificate Chemistry Curriculum

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According to Capper (1996), one powerful way of organizing knowledge is through the use of concepts. Concepts play a crucial role in guiding the production of knowledge and meaningful learning (Novak, 1977). However, it is useful to establish procedures for how central concepts can be identified within a curriculum and how, having identified these concepts, can they be linked to aid learning. Identification of central concepts which link topics plays a role in '*chunking of information*' which results in a reduction of cognitive overload for students. Miller (1956) first used the word 'chunking' to refer to the skill of bringing ideas together so that the working memory saw them as one, thus reducing pressure on limited working memory capacity. By chunking of information, the demand on the working memory can be reduced (Reid and Amanat Ali, 2020). There still exists a gap in the literature in relation to the kinds of ways teachers can assist learners in chunking (Reid, 2020)

In this paper, we discuss how the central concepts in the LC Chemistry curriculum were identified by a group of pre-service chemistry teachers; through a methodology module, the pre-service teachers were focused on linking central ideas and hence developed their own understanding and thinking around these concepts. Qualitative data was collected throughout the methodology module which included pre-service generated material, and visual and audio recordings of workshops. Implications for development of future chemistry curricula are discussed.

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Friday, 24/June/2022 3:10pm - 3:20pm
ID: 145 / PS- 9: 4
Pre-recorded Lightning Talk
Keywords: gender, unconcious bias, STEM education, teacher education, pedagogy

EDI in STEM: Look See What I Can Be

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This initiative is informed by our original 2019 project "Girls in DEIS Schools: Changing Attitudes / Impacting Futures in STEM" https://www.ucd.ie/research/impact/casestudies/girlsinstemchangingattitudesandincreasingdiversity/

Research tells us that for young women to pursue a career in STEM, they must believe in the importance of STEM and in their ability to succeed in the field (Accenture, 2014). Our findings, as suggest that teachers and boys should also be included in any initiative that wishes to address the negative impacts gender stereotypes and gender bias hinder girls' engagement in STEM.

In this project primary and post-primary children investigate their heroines in STEM the impact these women have had on society and on the students' own lived experience. Storytelling underpinned by Philosophy for Children (P4C) is used as the methodology for this project in order to assess the experiences, characteristics, and impact of diverse leaders of STEAM (Simmons, 2019). P4C is an ideal pedagogy for this kind of project as it provides a context in which pupils can pose questions, express concerns, suggest reasons for particular phenomena, such as the low representation of women in STEM historically and why female STEM leaders matter.

Teachers access classroom resources through our website www.edistem.ie and have engaged in a programme of professional development on how to introduce pupils to diverse role models in STEM through a story- telling methodology, underpinned by a Philosophy for Children (P4C) pedagogy. A series of online workshops for teachers explored the role gender bias plays in the creation of negative stereotypes that act as barriers to the progression of girls and minority groups in STEM. Thus teachers are empowered to decide what their role should be in addressing equity, diversity, and inclusion in STEM and what practical steps can be taken to address implicit bias in their classroom and in their schools.

This ongoing sustained support for teachers was further enhanced by each primary school being allocated an associate from the PDST primary STEM team and each post-primary school being allocated a link person from the School of Education in UCD.

The current project culminated in a shared learning day in June 2022 where 700 children presented their project work on the contributions of women in STEM and the impact of gender bias on girls and women engaging with STEM.

In summary the project's outputs are:

- Targeted interventions to raise awareness of STEM-related careers and the role STEM plays in our communities and society while addressing the stereotypes that can act as a barrier into STEM careers for women and minority groups.
- Increase girls' exposure to and engagement with digital technologies such as coding, robotics, and virtual reality.
- A programme of professional development for teachers in the use of innovative pedagogies that will develop their capacity and skills as STEM educators and that will develop an increased understanding of the implications of stereotypes and gender bias in society and the classroom and how to address this.
- Shared learning days and the development of our website www.edistem.ie to celebrate the work of teachers and students and where the artefacts and findings of this project can be disseminated.

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Friday, 24/June/2022 3:10pm - 3:30pm
ID: 146 / PS- 7: 3
Research Paper
Keywords: Policy, Practice, Digital Strategy for Schools

The Digital Strategy for Schools (2015-2020) – What was learned and where to from here?

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In for the successor Digital Strategy for Schools (2015-2020), the need to reflect on the changes that are taking place within schools and in the world outside school raised questions about what a quality curriculum in a technological era should look like, and the equally challenging issues about how to achieve the necessary changes in schooling in order for such a curriculum to be realised (Twining et al. 2020). However, before considering the question “where to from here”? there was need to stand back and examine what was happening in schools in Ireland ‘Before Covid’, (BC) and ‘During Covid’ (DC) in order to prepare for ‘After Covid’ (AC). Against this backdrop, the authors carried out a review of the implementation and effectiveness of the Digital Strategy for Schools (2015-2021), drawing on a range of sources including (i) Department of Education (DE) Digital Strategy Actions Plans (2017-2019) and the draft Action Plan (2020), (ii) Department of Education’s (DE) Inspectorate report, the Digital Learning Framework longitudinal study (Frederick et al. (2021) and the literature documenting the experiences of schools in Ireland during the school closures brought about by the Covid-19 pandemic and (iii) findings from the public consultation carried out by the DE. This led to a final set of conclusions that served both to highlight the progress that has been made across the four themes of the DSS (2015-2020) (Teaching, Learning and Assessment using ICT; Teacher Professional Learning; Leadership, Research and Policy and ICT Infrastructure) as well as to identify a number of aspects of each theme that requires further attention and development. Using this findings, a range of issues and recommendations that need to be considered in the next iteration of the Digital Strategy for Irish schools were made.