Primary Science in Ireland – Seventeen Years On

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Introduction

Our world today faces numerous challenges. The STEM (Science, Technology, Engineering and Mathematics) disciplines are embedded in these and it is essential that STEM subjects at all school levels address the application of STEM subjects in real contexts rather than solely focusing on the concepts within these disciplines (Department of Education and Skills (DES), 2016; Murphy, Smith, & Broderick 2019). With regard to science as one of the STEM disciplines, science plays a central role in our understanding of and responses to the most significant global challenges faced by humanity. It provides fundamental knowledge about the world in which we live and, as a discipline, enables citizens to observe, investigate, measure, analyse, design and advance our physical environment (DES, 2016) taking action to prevent the breakdown of our climate, to tackle the causes of poverty, to address the need for good sanitation and clean water, and to produce clean energy. Furthermore, it is imperative that students leave school as scientifically literate citizens. The Programme for International Student Assessment (PISA) 2015 Assessment and Analytical Framework defines scientific literacy as "*The ability to engage with science-related issues, and with the ideas of science as a reflective citizen ... is willing to engage in reasoned discourse about science and technology*

which requires competencies to: explain phenomena scientifically; evaluate and design scientific enquiry; and interpret data and evidence scientifically" (Organisation for Economic Cooperation and Development (OECD), 2017, p7).

Over the past thirty years, science education has moved from an emphasis on teaching and assessing scientific content towards the development of students' scientific literacy. This development is reflected in science curricula, that emphasise the importance of scientific knowledge that is relevant to students (Murphy et al., 2011; European Commission, 2015).

The current Irish Primary Science Curriculum (PSC) was developed in 1999 and formally implemented in all Irish primary schools in 2003. Seventeen years after the PSC's implementation, the National Council for Curriculum and Assessment (NCCA) is developing a new Primary Curriculum Framework, for publication early in 2021.With the imminent publication and roll-out of this new curriculum framework, it is timely to examine the teaching and learning of primary science in Ireland since the inception of the 1999 PSC. In this article we examine the research literature on primary science across this period and consider the successes and challenges apparent within the teaching and learning of primary science in Ireland. The paper considers possible future developments for science education, as a discrete discipline within STEM education, and, given the necessity of all citizens to be scientifically literate, considers how the re-envisioning of the primary curriculum presents huge opportunities to advance scientific literacy for all students in Ireland.

Primary Science Curriculum Development (1971 - 1999)

Prior to 1971, the Irish education system was perceived as insular, with national needs dominating curriculum texts and teachers' practice (Walsh, 2016). Science education did not

feature in Irish classrooms. Elsewhere, international influence in the form of the 'Sputnik effect' of the 1960s, which saw the United States of America (USA) fall behind the Union of Soviet Socialist Republics (USSR) in the Space Race, spurred policy makers to invest in science education and the development of national science curricula in the USA and across Europe. At a national level, economic prosperity provided impetus for the 1971 curriculum and science became part of Social Environmental and Scientific Education (SESE) (Walsh, 2007; 2016). Analysts acknowledge that curriculum for school science in the 1960s and 1970s were designed, in response to dominant demand, for the preparation of future scientists and engineers (Fensham, 2004; National Science Foundation, 1983; Bodmer, 1985; United Nations Educational, Scientific and Cultural Organisation (UNESCO), 1983). The 1971 curriculum was poorly implemented, with little effect on students' learning of science (Irish National Teachers Organisation (INTO), 1992; NCCA, 1990). This combined with poor international comparative results in tests such as PISA and Trends in International Mathematics and Science Study (TIMSS), followed by a decline of students pursuing science beyond the compulsory years, sparked government concerns (Beaton, Mullis, Gonzalez, Smith, & Kelly, 1997). In pursuit of strategic improvements, several expert groups set about transforming the state of the Irish economy with a focus on science education. The Irish Council for Science and Technology Innovation (ICSTI) called for the introduction of a new primary science curriculum, claiming that the "availability of more people with science training was a prerequisite for the development of an economy capable of maintaining its citizens into the 21st century" (ICSTI, 1998, p.1). Forfás (1999) concurred, highlighting the importance of knowledge and skills for future competitive advantage. An economic-educational discourse was constructed and science was introduced as a subject in its own right in 1999.

The revised PSC is a considerable development of its precursor, Curaclam na Bunscoile (1971), and aims at developing students' scientific content knowledge and skills in working scientifically, from infants to sixth class. The overall aim of the PSC is to support children in learning about the physical and biological aspects of the world, through applying and developing their 'working scientifically' and 'designing and making' skills (DES, 1999b). Social constructivist approaches underpin the PSC and a strong emphasis is placed on supporting children to develop scientific approaches to problem solving. While science is not a core subject in the Irish Primary Curriculum, it is compulsory, and it is recommended that science is allocated 50 minutes per week from infants to second class, and one hour per week from third to sixth class. This equates to approximately 4% of the overall instruction time in Irish primary schools being allocated to science. Reviews of implementation of the PSC were conducted in 2008 (NCCA, 2008; Varley et al., 2008) and again in 2012 by the Department of Education and Skills (DES, 2012). The findings from these national reviews, results from international large-scale studies of achievement, combined with national research in science education, provide some evidence of the status of teaching and learning of primary science in Ireland to date.

The Good News

Research on the teaching and learning of primary science in Ireland presents mixed results. On a positive note there is evidence that student and practising primary school teachers hold positive attitudes towards teaching science (Murphy et al., 2015; Smith, 2014; Waldron et al., 2007) and that student primary school teachers are more confident about teaching science after engaging with their initial teacher education science methodology courses (Murphy & Smith 2012; Waldron et al., 2007). There is also evidence that primary school teachers are affording students with opportunities to engage in hands-on science and that they are integrating digital technologies in their science classes to some extent (DES, 2012; Murphy &

Smith, 2012; Murphy et al., 2012; Smith, 2014). It is also worth noting that a higher proportion of the Fourth-Class children in Ireland who participated in TIMSS (2015), were taught by newly qualified teachers than in previous TIMSS cycles. These newly qualified teachers reported adopting more inquiry-based methodologies for teaching science with more evidence of Inquiry-Based Science Education (IBSE) methodologies being used in primary schools than being used in previous years (Clerkin et al., 2017).

Irish primary school children hold positive attitudes towards learning science, appear to have some experience of engaging with hands-on science in schools, are being provided with opportunities to work collaboratively in school science and are performing above average on international assessments (Clerkin et al., 2016; Eivers, 2013; Murphy et al., 2011; Murphy, 2013; Murphy et al., 2019; Smith, 2014; Varley et al., 2008). Extremely high percentages of Fourth-Class children in Ireland who participated in TIMSS 2015 were positive about their instruction in science class (95%), reported engaging teaching in science (94%) were confident about science (82%) and liked learning science in school (89%) (Mullis et al., 2016).

There is no national assessment of science in Ireland, however TIMSS 2015 reveals positive findings regarding Irish primary students' attainment. In the most recent TIMSS cycle (2015) Fourth Class students in Ireland performed significantly above the TIMSS centre points for both mathematics and science and outperformed students in 37 and 15 TIMSS' countries respectively (Clerkin et al., 2016). Fourth Class students' performance in mathematics and science in Ireland was significantly higher than in 2011 or 1995, however, it is worth noting that there were bigger improvements in mathematics than in science (Clerkin et al., 2016). Interestingly, since 1995 there has been a considerable improvement in the performance of

the lower-achieving Fourth Class students from the Irish cohort in science but a slight dis-improvement amongst higher-achieving students in science (Clerkin et al., 2016). While Fourth Class students' performance in TIMSS 2015 in both science and mathematics has improved significantly since 2011, it could be, as Clerkin et al. (2016) propose, that this is as a result of improved literacy levels amongst students in Ireland which made it easier for them to engage in the standardised science and mathematics tests.

The Not So Good News

On a not so positive note, it is apparent from research that many Irish teachers lack confidence when teaching primary science (Clerkin et al., 2016; Murphy et al., 2015; NCCA, 2008; Smith, 2014). In the most recent TIMSS cycle (2015), Irish teachers reported much lower levels of confidence in teaching science content than they reported for mathematics. They were also found to be less confident about teaching science than teachers in many other participating countries (Clerkin et al., 2016). A further concern was that over half of the Fourth Class students in Ireland were taught by teachers who reported medium or low confidence in improving lower-performing students' understanding of science and/or providing challenging tasks for higher-performing students in science (Clerkin et al., 2016). Inadequate scientific content knowledge, particularly in the physical sciences, is a factor frequently cited by Irish primary school teachers for their lack of confidence in teaching science (DES, 2012; Clerkin, 2013; Eivers & Clerkin, 2013; Murphy et al., 2015; NCCA, 2008; Smith, 2014).

Concerns about scientific content knowledge are also highlighted amongst Irish pre-service teachers (Waldron et al., 2007; Murphy & Smith, 2012). Murphy and Smith's 2012 study, for example, explored the impact an undergraduate curriculum science methodology course had

on student primary teachers' conceptual knowledge of science and on their attitudes towards teaching science. A considerably higher percentage of these student teachers had studied Biology (68%) to Leaving Certificate level than either Chemistry (17%) or Physics (8%). The findings revealed that while there was an increase in students' scientific content knowledge at the end of the module, high percentages of these students still held inaccurate conceptions in Physics, Chemistry and Biology. This was the only compulsory science education module within an initial teacher education degree. A concern was therefore raised as to whether these student teachers would have the requisite conceptual knowledge to effectively implement the science curriculum.

Research indicates that teachers tend to shy away from teaching content about which they do not feel confident and often cope with this lack of specific content knowledge by teaching 'the minimum required … only doing very simple practical work' (Jarvis & Pell, 2004, p.189). Indeed the recent review of the World Around Us (WAU)[1] Curriculum in Northern Ireland revealed that while the vast majority of the responding schools reported that their staff had the requisite skills and knowledge to teach history (94%) and geography (94%), only 67% indicated that they had the requisite knowledge and skills to teach the science and technology strand effectively (Education and Training Inspectorate (ETI), 2014). This review also revealed that only 46% of web-survey schools agreed that their current WAU programme ensures sufficient emphasis is placed on science and technology learning and teaching and only 52% agreed that they have included the progression of the relevant practical and experiential (science and technology) skills within their WAU planning. It could be the case that when

[1] The WAU curriculum (CCEA, 2007) adopts an integrated approach to teaching history, geography and science. In Key Stages 1 and 2, the curriculum supports learning across the strands of interdependence, place, movement and energy, and change over time.

science education is bound to other curricular areas (such as history and geography), the relative lack of science-related Pedagogical Content Knowledge (PCK) places science education in a subordinate position within the grouping, and increases the possibility that the frequency and time allocation of science education may fall. However, further research would be required to explore this.

Research in the Republic of Ireland indicates that primary children appear to be engaging with basic concepts relating to floating and sinking and the properties of magnets considerably more frequently than content from the other strand units within the Energy and Forces Strand (DES, 2012; Murphy et al., 2012; NCCA 2008). It could be the case that teachers are avoiding teaching the other strand units because they have insufficient subject knowledge to support children's learning. A DES inspectorate report (DES, 2012) recommended that additional professional learning to support teachers in teaching content from the Energy and Forces strand was required (DES, 2012). However, no formal national Professional Development (PD) was made available to address this recommendation.

In terms of teaching methodologies, there is strong evidence that teachers in Ireland are still adopting more traditional approaches to teaching science where lessons tend to be more teacher-directed than child-led (DES, 2016, Murphy et al., 2015; Smith, 2014; Varley et al., 2008). Irish children are engaging in hands-on science that tends to involve them carrying out experiments that are more prescriptive, following step-by step instructions given to them by their teachers. This is in contrast to inquiry-based approaches that employ a more child-led approach to scientific inquiry where students are required to apply and develop a range of scientific and problem-solving skills. This tendency to adopt more teacher-directed approaches to science could be related to teachers' lack of confidence in teaching science. It is apparent

from the research that if teachers have good scientific knowledge they are more likely to adopt more inquiry-based approaches to science and are more likely to afford students with opportunities for discussion and reflection in science (DES, 2016; Jarvis & Pell 2004; Murphy et al., 2007 Murphy et al., 2011; Murphy et al., 2015;).

While Irish students are being provided with opportunities to engage with hands-on science, the frequency and nature of this hands-on work is of concern (Varley et al., 2008). It is apparent that while hands-on science is occurring in some classes, for some children these experiences are infrequent and in many classes throughout Ireland, children are experiencing virtually no hands-on science (Murphy et al., 2015; Smith, 2014; Varley et al., 2008). Further concerns relate to the extent to which Irish primary school children are developing their scientific skills and that older primary school children appear to be operating at skill levels similar to those more in line with younger classes (Murphy et al., 2011; Varley et al., 2008; Smith, 2014). It is also apparent that the scientific content with which children engage is not particularly relevant to the children (DES, 2016; Murphy et al., 2011; Murphy et al., 2012; Varley et al., 2008).

Internationally, Irish Fourth Class students are performing above the TIMSS' centre points in both science and mathematics, and we can see that mathematical performance amongst lower and higher-achieving students in Ireland has improved since 2011. However, while there has been an improvement in the performance of lower-achieving students in science since 1995, the performance of higher-achieving students in science in Ireland has not changed since 1995 and is still very low (7%). So, while it is evident that more Fourth-Class students have attained basic levels of scientific understanding than in previous cycles, there has been little change in the percentage of higher performers (Clerkin et al., 2016).

A further challenge regarding primary science in Ireland relates to the time being allocated to the teaching of science (Clerkin et al., 2016; Eivers, 2013; Murphy, 2013; Murphy et al., 2015; Smith, 2014). International research indicates that Irish primary teachers are spending less time teaching science than all OECD countries. The most recent TIMSS cycle revealed that Fourth Class primary teachers in Ireland reported spending less time teaching science than any other of the 57 countries that participated in TIMSS 2015 (32 hours per year in comparison to the TIMSS mean of 76 hours). Even more worryingly, the time allocated to science in Irish Fourth Classes in 2015 has halved from 2011 where the average time Fourth class teachers reported allocating to teaching science was 63 hours per year (Clerkin et al., 2016).

What can be done?

The Primary Curriculum Framework is due to be published in 2021. It is apparent from the research literature and recent TIMSS cycle reports that primary science in Ireland faces challenges; primary school teachers often lack the content and pedagogical knowledge to confidently teach primary science; primary school children are being afforded infrequent opportunities to engage in inquiry-based approaches to science; there appears to be a lack of progression in the development of students' scientific skills as they progress from the junior to senior classes; these is a deficit in the time spent teaching science and engagement with PD in comparison with our OECD counterparts. However, teachers and students are interested in science and hold positive attitudes towards it. Furthermore, Irish primary students are performing above average in international large scale studies of achievement (TIMSS). On the threshold of a new era for primary education in Ireland, it is the ideal time to address these challenges and to work towards progressing the teaching and learning of primary science throughout Ireland to ensure that our young people experience a rich science education that supports them in developing their scientific understanding and skills and in developing positive attitudes and values towards science. The next section

provides an overview of recent educational policy that will influence future developments in primary science education in Ireland.

The Irish STEM Education Policy Statement 2017 - 2026 (DES 2017) was developed with the aim of improving STEM education in the different Irish education sectors. This policy statement outlines a vision for STEM education in Ireland to ensure high-quality STEM education resulting in young people developing the necessary knowledge, skills and dispositions to ensure Ireland has "an engaged society and a highly-skilled workforce in place" (DES, 2017, p.5). The Policy Statement acknowledges that systematic support from the Department and other stakeholders in STEM education is vital to generate a STEM literate society. It highlights the importance of a STEM ecosystem whereby all stakeholders are working collaboratively to promote STEM education and enable and encourage learners to become active and responsible citizens (DES, 2017). In order to achieve the vision of the STEM education Policy Statement, an Implementation Plan 2017-2019 was published. It consists of a number of high-level actions and sub-actions highlighting key areas of development and targets to ensure the ambitions of the STEM policy are met. With specific reference to primary science education the plan (DES, 2017) puts forth a number of objectives to support its future development; it recognises the necessity to provide high-quality STEM related opportunities for teachers to support their own professional learning (Objective 2.3). The policy supports evidence based research to inform STEM education provision, curriculum, pedagogy, professional learning and future policy developments (Objective 1). It also proposes to develop and deliver programmes of PD and high quality curricular materials to support primary curricular change in STEM areas (Objective 1.2).Thus it would seem that the STEM policy and Implementation plan could provide a framework for a coherent development of science education in relation to both teacher education and classroom practice. Also of significance to the future development of primary science

education is the Cosán policy for teacher professional learning published in May 2016 ((Teaching Council of Ireland (TCI), 2016). Despite being in its pilot phase, this policy represents a landmark development in Irish education whereby from 2020, teacher professional learning will be regulated by the TCI and a legislative requirement for all teachers. Cosán is considered a flexible framework which recognises teachers as autonomous professionals responsible for identifying and pursuing relevant learning opportunities. It acknowledges the broad range of learning processes that teachers engage in, with reflection and teacher collaboration at its core (TCI, 2016). Cosán presents a significant opportunity for professional learning in STEM education when the policy is implemented nationally in the near future (Broderick, 2019).

With regard to the STEM implementation policy (DES, 2017) and the Cosán Framework for teacher professional learning (TCI, 2016), and in advance of the new Primary Curriculum Framework, it is crucial that a number of measures are taken to ensure effective teaching and learning in primary science throughout Ireland. Based on the review of literature documenting the current position of primary science education in Ireland, three broad areas are identified: Professional Development; Initial Teacher Education; greater allocation of time for science.

Professional Development

Several studies highlight the positive impact of effective PD on primary teachers' confidence and competence in teaching science (DES, 2016; Guskey 2002; Murphy et al., 2008; Murphy et al., 2015; Smith, 2014; Wellcome Trust, 2014). Research indicates that 'effective' PD addresses subject content knowledge and pedagogies through active engagement over a sustained period of time. Effective PD is hugely successful in developing teachers' confidence and competence in teaching science and has a positive effect on students'

experiences of and learning in science (Murphy et al., 2015; Smith, 2014; Wellcome Trust, 2014). However, PD programmes in primary science in Ireland are often short-term "one-off" courses that ignore individual teacher's PD needs. The literature is highly critical of such approaches as they tend not to lead to significant positive changes in teaching methodologies (DES, 2016; Desimone, 2009; Hamilton, 2018; Smith, 2014).

Prior to the roll out of the revised PSC in 2003, all primary teachers participated in a 2-day in-service programme facilitated by the then Department of Education and Skills. This PD focused on the implementation of the revised PSC, rather than addressing the needs of individual teachers. Follow up support for teaching science was available (when requested) from the Primary Curriculum Support Project (PCSP) and Primary Professional Development Support (PPDS) and currently through the Professional Development Service for Teachers (PDST). However, since the initial 2 days' in-service, no government-led national PD in primary science has been made available for primary teachers. Data gathered from teachers in the latest two TIMSS cycles (2011 and 2015) reveal that the percentage of Fourth-class students in Ireland who were taught by teachers that had recently participated in science education PD was considerably lower than the TIMSS centre points (Clerkin et al., 2017; Murphy, 2013). It is apparent that Irish primary school teachers require further support in developing their competence and confidence in teaching science.

The research literature strongly highlights the instrumental role PD can play in improving teachers' confidence and classroom practice (Darling-Hammond et al. 2017; Desimone 2009; Smith 2014). Revision of the PSC necessitates effective PD in science for primary teachers to ensure that teachers have the requisite confidence and competence to effectively teach science. It is essential however, that this PD avoids a 'one type fits all' type model and adopts a longer

more sustained approach that ensures: continuity; that tasks are clearly defined; collective professional development; a focus on content that is relevant to the teachers; and engagement with active learning methodologies (Coe et al,. 2014; Darling-Hammond et al. 2009; Desimone, 2009; Roesken, 2011; Smith, 2014; Whitehouse, 2011). It is also essential to consider how future PD programmes for primary teachers in science will focus on science as a discipline in itself as well as, separately or otherwise, focusing on science as a discipline in STEM. Recent research from Northern Ireland is informative in this regard. Greenwood (2013), exploring teachers' perceptions of the World Around Us curriculum, found that whilst the majority of teachers in this study supported an Area of Learning featuring science, history and geography, teachers also cited concerns about the loss of science skills and the demotion of science education. Greenwood (2013) identified the need for extensive in-service teacher education to support the development of knowledge, skills and confidence in the delivery of the WAU through cross-curricular planning and teaching. Furthermore, one of the key the recommendations of the WAU review (ETI, 2014) identified the need for more detailed guidance on the development of the discrete concepts, skills and knowledge in the history, geography and science and technology strands to enable schools to plan and evaluate more effectively for continuity and progression in children's learning (ETI, 2014, p. 5). The challenge of ensuring effective PD for discrete science education as well as consolidated approaches to wider curriculum areas must be considered in light of the new primary curriculum framework and revised science curriculum.

PCK represents the intersections between subject knowledge and pedagogical knowledge and was first identified by Shulman in 1986 as a key aspect of teacher knowledge and is now widely accepted. While there are general pedagogical ideas, constructs and practices that are similar across all STEM disciplines, each of these disciplines contains its own specific concepts, processes and epistemologies. If primary teachers are to plan for and effectively

integrate science, mathematics and technology in their teaching it is vital that, in the first instance, they develop robust PCK of the discrete subjects. Research on effective teaching highlights the importance of the domain specificity of PCK (Grossman, Schoenfeld & Lee, 2005). It would therefore seem sensible that future PD in science for primary teachers in Ireland should initially focus on developing teachers' PCK in science to ensure they have the requisite knowledge and skillset to effectively teach science. This could then be followed by PD that would support teachers to effectively integrate the science, technology and mathematics disciplines through STEM education.

There is a plethora of science education research highlighting the importance of IBSE pedagogies in developing students' scientific literacy. It is apparent from the literature that engagement with IBSE methodologies during science class promotes: the development of scientific content knowledge and skills; the development of scientific critical thinking and problem solving skills; collaboration in science; more positive attitudes towards and a greater interest in science (Artique et al., 2012; Harlen, 2012; Murphy et al., 2019; Rocard et al., 2007; Smith, 2015). IBSE is a child-centred methodology that provides 'experiences that enable students to develop an understanding about the scientific aspects of the world around them through the development and use of inquiry skills.' (Harlen & Allende, 2009, p. 11). Harlen (2010) outlines a number of key aspects of inquiry that include: making observations; asking questions; planning and carrying out investigations; interpreting and reporting data. Teachers have a critical role in engaging students in scientific inquiry. However, if teachers are to develop their PCK in inquiry-based science pedagogies it is essential that they are provided with opportunities to experience, understand and value inquiry-based learning. Harlen and Allende (2009) claim 'confidence and understanding play a large part in determining whether teachers provide students with experiences that enable them to develop an understanding of the world around them through inquiry' (p. 17). Future PD should

therefore afford teachers with opportunities to engage with, reflect on and implement a range of IBSE teaching methodologies. These might include, for example, teacher directed and student led scientific investigations; use of digital technologies for collecting and analysing scientific data; design and technology pedagogy; scientific inquiries to support children's scientific problem solving and critical reflection skills.

Initial Teacher Education

In Initial Teacher Education (ITE) programmes in Ireland, students are obliged to take compulsory courses in STEM education pedagogy. These modules vary from degree to degree but essentially, they provide student teachers with opportunities to develop their PCK in STEM. In Ireland, the amount of time and credit allocated to compulsory *science* education pedagogy modules varies from degree to degree, ranging from 2.5 credits to 7 credits of the overall Bachelor of Education (B.Ed.) degree programme, which is approximately 250 credits. While some of the B.Ed. degree programmes offer elective science education specialism modules, these are only offered to less than 10% of the overall cohorts (approximately 25 - 30 students per year).

There are no compulsory modules on any B.Ed. degree programme in Ireland that are explicitly aimed at developing student teachers' conceptual knowledge in science. This is worrying considering the low percentage of students taking Physics and Chemistry to Leaving Certificate levels. In 2017, of all the students in Ireland who sat the Leaving Certificate, only 14% and 17% respectively sat Physics and Chemistry and while these figures show a small increase in uptake since 2012 the numbers are still relatively small. The percentages of B.Ed. students who tend to sit science subjects to Leaving Certificate level are more or less in line with the National averages. In contrast, the percentage of B.Ed. students

who took higher-level mathematics amongst the 2017-2018 and 2018-2019 cohorts were on average 45% and 51% respectively. These percentages were slightly higher than the National average (33.6% in 2017 and 34.9% in 2018).

With such low percentages of primary school teachers taking Physics or Chemistry to Leaving Certificate levels and no compulsory science content modules offered on ITE programmes, one could question whether primary school teachers have the requisite subject knowledge to effectively implement the PSC. If STEM education is now seen as a national priority (DES 2017) it would seem that additional compulsory science content modules should be developed and included on all ITE programmes to support teachers in developing their scientific content knowledge. And what of the content of this provision? In terms of science pedagogy within ITE programmes and taking cognisance of the research that highlights the importance of the domain specificity of PCK (Grossman, Schoenfeld & Lee, 2005) it is essential that students in their early years of their ITE programmes would engage with science as a discipline, laying further foundations for their PCK in science. This provision should focus on developing students' understanding of the epistemology / Nature of Science as well as on different pedagogical approaches to teaching science. Then in the latter part of their ITE programmes, having developed PCK in science, students could then engage with modules that would support them in effectively planning for and teaching science as part of STEM. Mirroring this approach, students should be required to teach science as a discipline in itself during early school placement experiences before being afforded opportunities to plan and teach science as part of STEM towards the latter part of their programme.

More Time for Science

The time allocated for science in the Irish curriculum (at 4% of overall instructional time) is one of the lowest primary curriculum allocations of science worldwide. Recent data gathered from TIMSS (2015) reveal that, in practice, Irish teachers are only teaching 32 hours of science per year, less than half the time reported by Irish teachers in 2011 and the lowest teaching hours of all participating countries. If STEM education is to be seen as a national priority it is essential that the NCCA and the TCI bring in measures to significantly increase the allocation for science on the primary curriculum at the very least to reverse the diminished allocation and preferably to bring Ireland in line with other TIMSS participants. Without this time window, the potential of IBSE cannot be realised and the opportunity to provide all children with the opportunity to extend their scientific literacy will not be met.

Conclusion

Over the last thirty years we have seen a movement towards science education rooted in student-relevant real-world issues and prioritising the development of critical scientific skills and competencies which underpin the process of scientific inquiry. National curricula have somewhat mirrored these transformations, with science education moving from exclusion post-1971, marginalised in the PSC of 1971, before inclusion within the PSC of 1999 as a subject in its own right (albeit on the basis of an economic-educational paradigm), underpinned by social constructivist principles and problem-solving approaches. As we sit at the cusp of curricular reform within the Irish context, it is imperative that the development of a new PSC builds on the successful developments in science education over the past thirty years, whilst also addressing the significant challenges that have been encountered over this time.

Firstly, the successes. Research highlights the success of progressive approaches to science education, including the practice of inquiry-based approaches (particularly from early-career teachers) in classrooms across Ireland. Children in Ireland hold positive attitudes towards science and science education, with some positive developments in attainment recognised in global assessments. This positive evidence provides examples of how progressive science education can work and should guide curricular reform. Furthermore, the Irish Primary Curriculum (DES, 1999a) provided fertile ground for the development of social constructivist approaches to science education, progressive principles which are recognised in the wider literature.

And the challenges. Any new curriculum must continue to promote the transition from traditional science education approaches towards child-led approaches. Whether science education stands alone or sits within a wider grouping of subjects, there is a clear need to ensure opportunities for the development of initial and in-service teacher's scientific PCK as one means of improving teacher confidence to teach science to children of all abilities in primary classrooms. This is all the more imperative considering the gaps in attainment recognised amongst particular groups of children. Whilst this scientific knowledge and science education confidence is being developed, there is a need to ensure that that time allocated for primary science education is extended, at least in line with international norms. Whatever form the curriculum takes, policy makers, researchers and educators must continue to monitor the progression of science education as framed within the curriculum, supported through initial and in-service teacher education, practiced in Irish primary classrooms and as experienced by students. This paper hopes that any development of educational curricula continues to provide students with the opportunities, through science education, to develop

their scientific literacy, engage with real-world issues, and have the opportunity to contribute towards the significant global challenges with which we are faced.

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