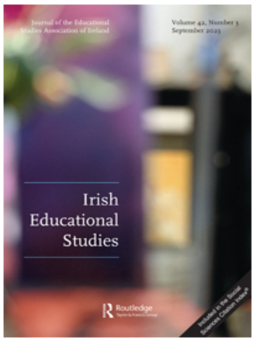

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Exploring different visions of scientific literacy in Irish primary science education: core issues and future directions

Nicola Broderick

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Exploring different visions of scientific literacy in Irish primary science education: core issues and future directions

Nicola Broderick

Institute of Education, Dublin City University Institute of Education, Dublin, Ireland

ABSTRACT
This discussion paper focuses on the purpose of, and vision for, Irish primary science education prior to the redevelopment and publication of the primary science curriculum in 2024. Scientific literacy is broadly accepted as the goal of science education. Despite this, curricular analysis focusing on scientific literacy in Europe is scarce. There is no universally accepted definition of scientific literacy and the divergent perspectives of scientific literacy and its conceptualisation in terms of purpose and competencies warrant discussion. This paper details and critiques both the historical and current position of Irish primary science education against prominent policy documents and research in the field. It presents research informed recommendations required to transform a holistic vision of scientific literacy from curriculum documents into classroom practice. It is hoped that this discussion paper raises important questions for policy makers and educators highlighting the central role of science literacy education to meet the needs of all students in the twenty-first century.

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Introduction

Today, science represents a dominant and pervasive aspect of the lives of individuals and societies (Bencze and Carter 2011). This is exemplified by everyday issues in public discourse, such as climate change, sustainable development, world pandemics and other critical issues, that demand the public's immediate attention. Corresponding to these issues, today's society is awash with information, misinformation and disinformation which is read, interpreted, evaluated, responded to, acted on or indeed ignored. Decisions made can lead to economic, environmental or social chaos (Paul and Elder 2009; Zeidler 1997). It is imperative that all citizens have the science literacy education they need to be able to gather knowledge related to these issues and, subsequently, engage critically and responsibly to offer scientifically informed solutions where social implications appear to exist (Kolstø 2006; Zeidler et al. 2005). Additional arguments for the need for scientific

CONTACT Nicola Broderick Nicola.Broderick@DCU.ie Dublin City University, Institute of Education, C214 St. Patrick's Campus, Drumcondra, Dublin 9, Ireland

literacy have come from the Science, Technology, Engineering and Mathematics (STEM) movement. At a national and international level, expertise in STEM is seen as key to a country's economic success, providing the foundations for future prosperity (Department of Education and Skills (DES), 2016; Kayan-Fadlelmula et al. 2022). In this regard, scientific literacy in the form of skills and knowledge in science education, is deemed necessary to meet the current and future needs of the labour market (Kayan-Fadlelmula et al. 2022). Fostering scientific literacy amongst the population has never been more essential (Siarova, Sternadel, and Szőnyi 2019). With this mind, in an era of Irish primary curricular reform, the purpose and values of science education need to be considered with the ultimate goal of attaining a scientifically literate society.

Scientific literacy is considered by many as the goal of science education (Beernaert et al. 2015; Bybee 2015; National Research Council 2012; Osborne and Dillon 2008; Roberts and Bybee 2014). Holbrook and Rannikmae (2007; 2009) contend that there appear to be a number of divergent points of view when it comes to defining scientific literacy; (a) those that advocate a central role for the knowledge of science, (b) those who see scientific literacy referring to a society usefulness. Indeed, Roberts (2007) suggests that most definitions of scientific literacy fit along a continuum between (a) and (b) above. Contrastingly, Hodson (2010) maintains that scientific literacy should advocate for global citizenship and socio-ecojustice. The divergent views of scientific literacy have a significant impact on policy documents, teachers, teacher educators and students (Sjöström and Eilks 2018). For instance, if the aim of scientific literacy is to promote careers in science or provide an academic background for specialisms in science, then the focus of science education will be on developing profound disciplinary content knowledge and understanding of scientific inquiry (Clegg, Hudson, and Steel 2003; Roberts 2007). Those who propose a focus on socio-ecojustice maintain that a scientific literate individual must prepare for, and engage in, socio-political actions that they believe will make a difference (Hodson 2010; Sjöström and Eilks 2018). While there are synergies between these perspectives of scientific literacy, some such as Dillon (2009) argue that these divergent views of scientific literacy are underpinned by different philosophies and, at their most extreme, reflect competing interests; for instance, fostering scientific literacy for all students or providing a foundation for a more advanced study of science (Chiu and Duit 2011; Dillon 2009; Millar 2009; Sadler 2011). Others such as Donnelly (2006) and Liu (2013) disagree asserting that the visions of scientific literacy are intrinsically linked and to separate them is to create an unnecessary chasm in science learning.

Despite this theoretical debate, scientific literacy is commonly considered the main goal of science education across Europe (Siarova, Sternadel, and Szőnyi 2019). A recent report commissioned by the European Parliament 'Science and Scientific Literacy: An Educational Challenge' (Siarova, Sternadel, and Szőnyi 2019) concluded that whilst most science curricula across Europe have scientific literacy as the main aim with a strong emphasis 'on science for all students' the way it is conceptualised and defined in terms of learning outcomes varies significantly. A number of curriculum documents' learning outcomes have either a significant or an exclusive focus on scientific knowledge and understanding (Siarova, Sternadel, and Szőnyi 2019). Fensham (2016) concludes that it is now common to find new intentions pertaining to scientific literacy listed in the introductory rationale for school science with 'this rhetoric largely ignored in the continued listings of detailed disciplinary content for teaching and learning' (168). Thus, even when curricular aims are holistic and encompass all visions of scientific literacy, the transferal into measureable learning outcomes proves problematic where key dimensions of scientific literacy such as critical thinking and active civic engagement are often sidelined in favour of the acquisition of scientific knowledge and its application (Siarova, Sternadel, and Szőnyi 2019).

Revised Irish primary science education specifications are due to be published in 2024 to align with the new primary curriculum framework published in 2023 (Department of Education (DE), 2022). To various extents, curricula determine the goals, the core content and the expected learning outcomes of science education (Siarova, Sternadel, and Szőnyi 2019). The process of curriculum making is contentious and, as such, is emblematic of the societal values as a whole and more significantly, the economic trends within that (Usher 2020). Gleeson (2020) maintains that human capital has long been considered the dominant rationale for education in Ireland and strongly influences curriculum reform efforts. Looney (2001) asserts that in such a context 'efficient' and 'effective' curriculum become more important than 'good' or 'valuable' curriculum. Beyer and Apple (1998) suggest that curriculum needs to provide greater attention to what should be taught and why rather than how it is organised and evaluated. In terms of curriculum implementation, Looney (2001) highlights the importance of finding new perspectives on curriculum, which could lead for a more philosophical approach to curriculum reform.

This paper considered curriculum as a policy and provides an in-depth exploration of the different conceptions of scientific literacy which underpin it. The historical development of scientific literacy will be presented alongside an analysis of the current state of Irish primary science education. Policymaking and policy interpretation are two different concepts whereby policy texts enter rather than change existing circumstances (Ball 1994). This paper proposes that the future of primary science education should be underpinned by a curriculum which encompasses a holistic vision of science literacy and more importantly considers how this vision can be brought to actualisation. The conclusion will provide recommendations on curriculum implementation and how this can be supported.

Scientific literacy

Scientific literacy is a term that has been used since the late 1950s to emphasise the importance of science in society and that science education should be used to prepare individuals to participate in human and civic affairs (Hurd 1958). Prior to this, science education tended to be centred on textbooks that portrayed science as a body of information, facts and generalisations that required rote memorisation (Smith 2012). International influence in the form of the 'Space Race' of the 1960s, which saw the United States of America fall behind the Union of Soviet Socialist Republic when they launched the world's first artificial satellite into the Earth's orbit, spurred policy makers to invest in science education and the development of national science curricula in the USA and Europe (Bybee and Fuchs 2006). Here, the goal of science education focused on the need to promote science and produce future scientists and engineers (De Jong 2007; Yore 2012). In the 1960s and 1970s economies grew and education changed from that of the privileged to education for the majority (Fensham 1988). The percentage of students remaining at school considerably exceeded the number of students required to meet the demand for future science-based professionals (Fensham 2016). The 'Space Race' was no longer a concern and the technological nature of society, domestic issues and environmental problems ranked high on many national agendas (Smith 2012). It was proposed that science educators should work to support citizens to understand science, to have the ability to seek information pertaining to the positive and negative impacts of science and technology on their lives and to be sympathetic to the work of scientists. However, correspondingly there were concerns that science education was not paying sufficient attention to science as a discipline (DeBoer 2000; Laugksch 2000). In addition, the perceived need to expand the number of potential scientists and engineers was upheld (Smith 2012). Over the last two decades, the mainstream use of the term scientific literacy refers to the acquisition of knowledge and meeting content standards in science education, with a focus on science in social contexts as well (Siarova, Sternadel, and Szőnyi 2019).

Synthesising the above, the most prevalent discussion on the meaning of scientific literacy is the 'science for scientists' versus 'science for all' debate (Siarova, Sternadel, and Szőnyi 2019). On the one hand, it is essential for economic development that young people are interested and engaged in future developments of science and technology (Bybee and Fuchs 2006); on the other, it is crucial that citizens have a basic understanding of science if they are to understand everyday issues and make informed decisions (Chiu and Duit 2011). Roberts (2007) summarised this dichotomy and presented two visions of scientific literacy, referred to as Vision I scientific literacy and Vision II scientific literacy. Vision I scientific literacy focuses on decontextualised science subject knowledge and preparation for careers in science, while Vision II scientific literacy connects science to students' everyday perspectives and develops their ability to make decisions on societal and environmental issues as informed, active citizens (Haglund and Hultén 2017; Osborne 2012; Roberts 2007). In recent years, researchers have proposed an additional vision, Vision III, which moves beyond preparing individuals for participation in society towards a politicised vision of science education aimed at dialogic emancipation, critical global citizenship, and socio-ecojustice in which controversial, relevant issues become the drivers for the curriculum (Hodson, 2003; Sjöström and Eilks 2018).

Building on the above, Liu (2013) suggests that an 'expanded notion' of scientific literacy which encapsulates Vision I, II and III scientific literacy is required. Siarova and colleagues (2019) synthesised this holistic vision of scientific literacy in Table 1 below.

Table 1. Expanded notion of scientific literacy (Siarova, Sternadel, and Szőnyi 2019).

Vision of Scientific literacy	Emphasis	Content	Orientation
Vision I	Scientific content	Knowledge, skills, habit of mind, and disposition	Within science
Vision II	Science-technology societal issues	Knowledge in action, practical problem-solving, attitude, and professionalism	Science in relation to society
Vision III	Scientific engagement – social, cultural, political, and environmental issues	Critical thinking, communication, consensus building	Science within societal

Congruent with other science educators (for example Dillon 2009; Haglund and Hultén 2017; Roberts 2007), this expanded notion emphasises the importance of scientific knowledge and skills and their relevance to particular contexts. A minority of citizens will be producers of scientific knowledge, but all citizens will be consumers of scientific knowledge as they read or hear about science-based knowledge claims or use processes that are based on scientific knowledge (Millar 2009). Science education that promotes Vision I, II and III scientific literacy is crucial to developing students' interest, knowledge and skills in science. Such knowledge includes not only scientific content knowledge but also an understanding of the Nature of Science and consideration of social, cultural, economic and political influences that underpin everyday societal issues (Zeidler and Sadler 2011). Skills such as developing students' inquiry skills are key to scientific literacy (Vision I) but students must also be supported to interpret and evaluate scientific knowledge presented in the media and elsewhere (Vision II and III). The development of critical thinking skills and communication are also necessary if students are to engage in discussion and debate pertaining to societal issues (Vision II and III). Furthermore, students must be provided with opportunities to make informed decisions and take action in response to real-world issues of the twenty-first century (Vision III). Only then will science education be useful for all students, whether or not they are bound for scientific or technical career (Feinstein 2011; Osborne and Dillon 2008; Valladares 2021).

The following section will examine the historical developments of Irish primary science education and explore the different visions of scientific literacy; how they have been conceptualised in curricula and policy documents and what has materialised in terms of classroom practice. Even though much research has been put into discussing and developing the different visions of scientific literacy, these developments seem to have had little impact classroom practice (Fensham 2009; Siarova, Sternadel, and Szőnyi 2019). The evolution of primary science education is a good illustration of how scientific literacy has evolved over time with often competing visions of the purpose of science education. By better understanding the current vision or purpose of primary science education, we can increase our abilities to influence future change in a desired direction (Ball 1994).

Historical developments of the Irish primary science curriculum (1884–1999)

It is clear from its inception that the vision for science education in Ireland has been affected by government preoccupation and priorities prevalent during that time (Walsh 2016). The inclusion of science in Irish primary education dates from 1855 brought about by a political concern that Ireland was lagging behind other countries in terms of industrial development (Vision I priorities). The 'payment by results system' of the 1860s drove a narrowing of the primary curriculum as reading, writing and arithmetic were prioritised with didactic pedagogical approaches dominating classroom practice (Palmer 2001; Walsh 2016). Science was then removed from the curriculum in 1922 for 50 years during a period of nationalist revival whereby government priorities lay in the promotion of Irish language and culture above all else. In 1971, science was reintroduced to the primary curriculum under Social, Environmental and

Science Education. Although this curriculum did incorporate inquiry (Vision I) and connections to the environment (Vision I and II), the 1971 curriculum was poorly implemented, with little effect on students' learning of science due to a lack of resources, limited pre-service science education and in-service teacher professional development opportunities (INTO 1992; Smith 2012; Walsh 2007). Most primary teachers had little to no knowledge of science or experience of science as learners (INTO 1992; Palmer 2001). Thus, it is therefore unsurprising that less than half of primary school teachers taught science (INTO 1992; NCCA 1990). This enduring lack of emphasis on primary science in schools was reflected in the poor comparative results in international tests such as International Assessment of Educational Progress Report (IAEP 1988) and Trends in International Mathematics and Science Study (TIMSS). The IAEP Report revealed that Irish children (aged 9 and 13) performed less well in science activities compared to 12 other countries, including the United States and the United Kingdom. TIMSS (1997) results indicated that Irish girls (age 9) had the lowest proficiency score of any group in the study (Smith 2012). This, along with a decline in the number of students pursuing science beyond the compulsory years, heightened government concerns (Beaton et al. 1997).

During this period (early 1990s), Ireland's economy grew to be one of the most vibrant in Europe (Childs 2002). Its success in attracting high-tech multinational companies in pharmaceuticals, biotechnology and information technology provided a cornerstone for economic success. A well-educated workforce was considered the key to attracting multinational industries to Ireland (Smith 2012). Several expert groups set about transforming the state of the Irish economy with a focus on science education prioritising Vision I goals (Murphy, Broderick, and Mallon 2020). The focus on scientific knowledge and skills necessary for careers in STEM prevailed. For instance, the White Paper on Science Technology and Innovation (Government of Ireland, 1996) highlighted the importance of science education as our most important competitive advantage to continued growth in our economy. Forfás (1999) called for the introduction of a new primary science curriculum, claiming that the availability of more people with science training was a prerequisite for future competitive advantage and the development of an economy capable of maintaining its citizens into the twenty-first century. According to Gleeson (2010) and Walsh (2016), this pattern of economic influence was prevalent in Ireland since the 1980s where curriculum contestation has become more and more influenced by the globalised 'job market'. Thus, an economic-educational discourse consistent with Vision I undertones was constructed and primary science was introduced as a subject in its own right in 1999.

The 1999 primary science curriculum (1999–present)

The current 1999 primary science curriculum aims to develop primary students' scientific content knowledge, working scientifically skills and promote positive attitudes towards science. Learning through hands-on activities and discovery is strongly emphasised as is practical investigation and providing students with opportunities to test and develop their ideas. The term 'scientific literacy' is not explicitly mentioned in the Primary Science Curriculum (DES 1999) though the notion of developing students' scientific literacy is implicitly supported through the aims of the curriculum, for example ‘science education equips children to live in a world that is increasingly scientifically and technologically oriented’ (DES 1999, p. 6). Whilst the curriculum’s aim can be seen to support Vision II scientific literacy, this did not fully materialise in the more specific curriculum objectives where knowledge-based understanding of science dominates and contextualised understanding of science including references to engagement and critical thinking is predominantly absent from the curriculum objectives (DES 1999). Similar de-prioritisation of Vision II competencies when it comes to science learning outcomes have been found in school science curricula throughout Europe (Siarova, Sternadel, and Szőnyi 2019).

At present, there is no internationally recognised scientific literacy measurement tool for primary/elementary school-aged students. Nevertheless, analysis of existing large-scale international assessment data such as TIMSS, national reports such as the Primary Science Review (Varley, Murphy, and Veale 2008) and other national studies (Murphy, Broderick, and Mallon 2020; Murphy, Smith, and Broderick 2021; Smith 2015) provide some initial insights into the scientific literacy of primary students in Ireland. On an international level, TIMSS is the attainment test for fourth-class primary school students (9–10 years old). The TIMSS assessment frameworks specify the scientific content knowledge (life science, physical science, earth science) and cognitive domains (knowing, applying, reasoning) that fourth grade (fourth class, aged 9–10) students are expected to be able to demonstrate. Fensham (2016) and Naganuma (2017) assert that TIMSS’ emphasis on the recall of scientific content knowledge through a multi-itemed questionnaire endorses a Vision I type of science curriculum. Nonetheless, the content knowledge and in particular the cognitive domains give some indication of primary students’ achievements in science education against an international scale. TIMSS 2019 is the most recent cycle of the study with Ireland previously taking part in TIMSS 1995, TIMSS 2011 and TIMSS 2015.

Within Vision I scientific literacy looking at the results of TIMSS 2019, fourth-class students ($n = 5051$) in Ireland achieved a mean score of 528, which was significantly above the TIMSS centrepoint and similar to Ireland’s performance in TIMSS 2015 where a mean score of 529 was reported. Irish fourth-class students performed significantly higher than 33 countries and remained behind 12 countries. Irish fourth-class students displayed a relative strength on earth science topics (much of this content is considered to be part of the geography curriculum in Ireland) and a relative weakness on physical science topics (including physical states and changes in matter, light and sound, electricity and magnetism, and forces and motion) (Perkins and Clerkin 2020). The DES found similar results when they evaluated primary school students’ content knowledge in 2012 with approximately half of the students failing to complete tasks relating to physical sciences (energy, light, sound, heat) (DES 2012). In terms of the cognitive content domains, fourth-class students displayed a relative strength in ‘Knowing’ (including skills such as recalling, recognising information, describing and providing examples) (Perkins and Clerkin 2020). An important aspect of scientific literacy, which intersects Vision I, II and III, is attitudes and habits of mind. Positive findings regarding Irish fourth-class students’ attitudes towards science were also reported, with 89% of students indicating that they like/somewhat like learning science and 83% of students indicating that they are very/somewhat confident in science. Other research concurs that Irish primary school students tend to hold positive attitudes towards learning science in primary school (Murphy 2014;

Murphy, Murphy, and Kilfeather 2011; Murphy, Smith, and Broderick 2021; Smith 2014; Varley, Murphy, and Veale 2008). From a scientific literacy perspective students' positive attitudes towards science are seen to be conducive to promoting engagement in decision-making processes related to science and technology (Vision II and III) (Lee and Kim 2018), as well as a key requirement for students who aspire to a scientific career (Vision I) (Osborne, Simon, and Collins 2003).

There appears to be a strong Vision I focus in terms of students' experience of learning science in Ireland. For instance, while there is evidence to suggest that students enjoy hands-on science and appear to have opportunities to work collaboratively in small groups (DES 2012; Varley, Murphy, and Veale 2008), there are concerns regarding the nature and frequency of the 'hands-on science'. Irish students tend to be involved in more prescriptive, step-by-step, hands-on investigations than the child-led inquiry approach advocated by the curriculum (DES 2016; Murphy et al. 2015; Smith 2014; Varley, Murphy, and Veale 2008). Correspondingly, there are concerns regarding the development and application of students' science skills with older primary students operating at skill levels similar to that of students in the younger classes (DES 2012; Varley, Murphy, and Veale 2008). In order to be able to understand and engage in critical discussions about science-related issues (Vision II and III), scientific knowledge needs to go alongside and in conjunction with scientific inquiry skills where students are able to explain and design scientific inquiries as well as interpret data and evaluate evidence (OECD 2017). Argumentation and socioscientific reasoning, considered key competencies of scientific literacy (Vision I, II and III) (OECD 2013; UNESCO 2016), are not explicit features of the Irish primary science curriculum or classroom practice with TIMSS (2015) data indicating that students have limited opportunities to engage in discussion as part of their science lessons (Clerkin, Perkins, and Chubb 2017). From the above research and assessments, it appears that there are little opportunities for students to develop Vision II and III aspects of scientific literacy. Irish primary school students are generally positive about science, however, national research continuously highlights concerns about the teaching of primary science, the lack of development of students' scientific inquiry skills and the apparent disconnect between school science and the students' everyday lives (Vision II and III) (Murphy, Broderick, and Mallon 2020).

Moving onto Irish post-primary science, it would seem that Vision II and III aspects of scientific literacy are also lacking. While Irish secondary school students are performing above the international average in the international assessment test that measures scientific literacy, PISA 2018, their performance is still behind the highest-performing countries. This is recognised by the Irish government who have set targets to be one of the top-performing countries in PISA by 2030 (DES 2017b). While PISA is considered a scientific literacy test, studies that have analysed PISA test questions concluded that PISA does not fully align with Vision II or III scientific literacy (Burek 2012; Ratcliffe and Millar 2009; Sadler and Zeidler 2009). Sadler and Zeidler (2009) applaud the efforts of PISA to create an assessment that moves beyond traditional approaches to science testing which generally focus on low-level representation of science content knowledge but state that they have serious concerns about the extent to which the PISA assessment supports progressive aims of scientific literacy, namely Vision II and III. They further purport that students' ability to make informed decision-making, apply critical thinking skills, engage in argumentation and reasoning, key characteristics of Vision II and III scientific literacy, are not measured by the test (Sadler and Zeidler 2009). Sjoberg (2018) agrees concluding that important elements of scientific literacy are not measured by PISA although they do feature in PISA's definition for scientific literacy. Others such as Bidegain and Mujika (2020) and Bybee and McCrae (2011) have analysed the relationship between students' self-efficacy, interest in science and participation in science, and scientific literacy score as measured by PISA (2015) and reported a negative correlation; i.e. higher scores in PISA is negatively related to positive attitudes towards science. Furthermore, Sjoberg (2018) and Oliver, McConney, and Woods-McConney (2019) have highlighted the problematic finding that PISA test scores correlate negatively with nearly all aspects of Inquiry Based Science Education (IBSE); IBSE is recommended as pedagogical approach by scientists, science educators and policy documents from a variety of institutions and organisations. Thus, the unintended consequence of striving to climb PISA rankings could be that authentic, context-based and relevant science education pedagogy and content could be sacrificed (Sjoberg 2018).

The Irish STEM education report and implementation plan

Internationally and nationally, science education has emerged as a government priority under the STEM umbrella. The STEM Education in the Irish School System Report (DES 2016) and STEM Education policy documents (DES 2017a; 2017b) instigated the focus on STEM education in Ireland. This section will examine the STEM report and Implementation Plan from a Vision I, II and III scientific literacy lens. The report was commissioned by the DES, driven by Vision I concerns regarding the 'quality and quantity' of STEM graduates (DES 2016, 3). The report explicitly references Ireland's Strategy for Research and Development (DES 2015) which highlights STEM as critical to ensuring the continuous development of a 'pipeline' of talent to support both foreign direct investment and indigenous start-ups. Concurrently, other government reports projected a shortfall of labour-market needs in STEM (Behan et al. 2015; Condon and McNamee 2016; Higher Education Authority (HEA), 2014). According to Osborne, Simon, and Collins (2003) 'there is a clear association between economic performance and the number of engineers and scientists produced by society' (1053). This was further emphasised with the STEM report citing that Ireland would lose its economic competiveness unless 'we secure and sustain a sufficient supply of high-quality scientists, engineers, technologists and mathematicians' (DES 2016, 22). Framed within this Vision I discourse, students' continued success in STEM is increasingly linked to the perceived needs of the economy and international competiveness (Akalu 2014; Cowie and Cisneros-Cohernour 2011; Lynch, Grummell, and Devine 2012; Rizvi and Lingard 2010). Adopting a critical perspective, Carter (2003) argues that 'science education improvement discourses are often more representative of national responses to global economic restructuring and the imperatives of the supranational institutions than they are of quality research into science teaching and learning' (573).

Notwithstanding the economic rhetoric presented above, the principles and vision of the STEM policy documents (DES 2017a; 2017b) allude to Vision II and III scientific literacy, combining the importance of the development of learners' curiosity, scientific skills and knowledge with authentic global and societal issues (DES 2017a). The policy documents highlight the necessity of scientifically-literate citizens 'in order to make well-informed decisions regarding major global issues such as climate change, sustainability, energy, and food security' (DES 2017b, 7). One of the aims of the STEM Policy Statement (DES 2017b) is that young people will gain the skills and aspirations to participate in an increasingly scientific society, and, contribute to a society as active citizens informed of the pivotal role of science and technology in the well-being of society; thereby encapsulating Vision I, Vision II and Vision III scientific literacy. However, when it comes to targeted objectives in the STEM Implementation Plan (DES 2017a), Vision I priorities dominate: Ireland leading STEM in Europe; increasing our ranking in international studies and the importance of attracting a growing number of school leavers into STEM (DES 2017a, 12). Usher (2020) maintains that the focus in these targeted objectives is not on how we can design our education system around the needs of society, but rather how we can design our education system to meet the narrow measurements of standardised testing so we can come out on top of the PISA/TIMSS leader board. Cahill (2015) and Mansfield, Welton, and Grogan (2014) advise that the implicit danger here is that increasing international rankings becomes the goal and focus on students' learning and well-being as engaged citizens of society is lost. Serious questions about the purpose of science education (Vison, I, II and III), its content and emphasis warrant asking (Millar 2009).

This narrowing of the curriculum is not just a science education or STEM phenomenon. Speaking about the Irish primary geography curriculum, Usher (2020) argues that geography is being lost with the continuous narrowing of the primary curriculum and shift to other 'priority' areas. He cites the Numeracy and Literacy Strategy, which was introduced in Ireland after the 2009 PISA shock, as an example of this. This strategy marked a clear statement of intent to elevate literacy and numeracy above all other curricular areas, channelling the focus of teaching and learning towards more specific measurable goals (Usher 2020). Through an analysis of a number of Irish educational policies, including the STEM Education policy, Usher (2020) concludes that focus of these reports is on 'winning' a global competition to be the best education and training system in Europe. Winning at all costs prevails, as long as the limited interpretation of 'success' can measured by standardised tests and the number of STEM graduates. According to Usher (2020), even though the policy documents broadly advocate for the holistic development of children, the narrow focus on 'measurable outcomes' in these documents is counterproductive to the development of children to become active citizens. As such, Usher (2020) is describing an education policy landscape dominated by Vision I priorities of content and specific skills, with less emphasis on broader development of children pertaining to society and the environment. 'Narrowing the curriculum to meet the criteria of global competitiveness, standardised testing and economy-based thinking is a limited conception of what education is all about' (Usher 2020, 430).

Future 'Vision' for primary science education in Ireland

Given the current context of curriculum reform and the impending new era for primary science in Ireland, now is the time to have discussions pertaining to the purpose and future direction of primary science education. Past policy change related to science education in Ireland often had limited effect on classroom practice with teachers accommodating 'new labels, but not new practices, into teacher-led and fact-based teaching of science' (Van Kampen 2021, 405). What will be different this time? How will we progress the teaching and learning of primary science throughout Ireland to ensure that all students develop the vision of scientific literacy they require for active participation in the twenty-first century? Situated within the context of the primary curriculum framework (DE 2022), recommendations regarding the future vision of the primary science curriculum and how this can be achieved in classroom practice will now be discussed.

Irish primary curriculum framework

The primary curriculum framework sets out the proposed purpose, structure and content of the next Irish curriculum for primary schools (DE 2022). It is important to consider the implications of the primary curriculum framework from a science education perspective. The framework aims to 'provide a strong foundation for every child to thrive and flourish, supporting them in realising their full potential as individuals and as members of communities and society during childhood' (DE 2022, 5). This aim requires Vision I, II and III scientific literacies as it highlights the importance of developing skills, knowledge and attitudes children require to live in society both now and in the future. The primary curriculum framework presents seven inextricably linked key competencies, which will be embedded across all curriculum areas and subjects from junior infants to sixth class (DE 2022). A number of these key competencies relate to the goals of scientific literacy particularly Vision II and III. For example, the 'Being an Active Citizen' key competency highlights the importance of developing children's knowledge, skills, concepts and attitudes to empower children to take positive action and live justly in today's society at local and global levels (Vision III) (DE 2022). It could be argued that science is one of the subjects best positioned to prepare students to become active, global citizens (OECD 2018, UNESCO 2016). Through 'Being a Digital Learner', children are empowered to use technology in a responsible, safe and ethical way. Given that the internet is fastest-growing medium, which provides access to scientific information, the critical evaluation of this information, is of upmost importance if members of society are to make informed decisions based on the scientific content they receive online (Vision II and III) (Howell and Brossard 2021). Communicating and using language key competency is significant to developing children's scientific argumentation skills (Vision II) where children engage in discussion and debate in order to participate in wider society, share meaning and develop new knowledge.

The redeveloped curriculum is to be presented in five broad areas with science under 'Science, Technology, Engineering and Mathematics Education'. Northern Ireland followed a similar approach in 2009 where science was amalgamated with geography and history under the single area of learning known as 'The World Around Us'. Similar to the proposed curriculum changes in Ireland, science in Northern Ireland is not a discrete subject with discrete content and discrete teaching time. A number of studies in Northern Ireland revealed that this revision has had a worrying impact on time spent teaching science and content taught. For instance as part of a small-scale study, Johnson reported that over 90% of teachers interviewed ($n = 29$ teachers) revealed that they spend 90% less time teaching science as a result of the World Around Us curriculum with many respondents pointing towards the watering down of science as there is now no statutory obligation to teach science (Johnson 2013). Similarly, Greenwood (2013) reported that science had suffered a serious demotion in the new curriculum with the integrated nature of the curriculum suiting topics related to history and geography rather than science. Greenwood further asserted that extensive in-service teacher education is required to support the development of knowledge, skills and confidence in the delivery of the World Around Us curriculum. Evidence from the Education and Training Inspectorate (ETI) (ETI 2014) also highlighted concerns around the lack of statutory duty to teach science overtly. Murphy and colleagues (2020) suggests that when

> science education is bound to other curricular areas, the relative lack of science-related pedagogical content knowledge 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 (145)

This has significant consequences for all visions of scientific literacy (Vision I, II and III).

Time associated with these broad curriculum areas is also a concern. Ireland already have the lowest time allocated to primary science compared to other countries who participated in TIMSS 2019; Ireland has 34 h per year for science instruction compared to the TIMSS average of 73 h. Evidence from Northern Ireland suggests that an amalgamated curriculum reduces time spent teaching science (Johnson 2013). If a Vision II and III scientific literacy is to be supported, then students must be provided with time and opportunities to gather evidence, engage in reasoning, form opinions, consider multiple perspectives and consider the impact of their decisions on the environment and society as a whole. Thus, additional time must be provided rather than reduced.

Explicit reference to scientific literacy

The term scientific literacy is not an explicit feature of the current Irish primary science curriculum but it is alluded to in the broad curricular aims (DES 1999). Reference to science skills are confined to the processes of science investigations rather than their applications beyond the school context (Vision II and III). The 1999 curriculum does not fully represent the skills or competencies required for active participation in today's society. A science curriculum must go beyond the mere acquisition of scientific knowledge (Siarova, Sternadel, and Szőnyi 2019) and include the ability to apply this knowledge in practice, think scientifically, critically assess information, actively engage in informed discourse, and take informed action using empirical evidence and reasoning skills (Sadler 2011; Siarova, Sternadel, and Szőnyi 2019). This broader vision for science education needs to be coherently integrated into the redeveloped Irish primary science curriculum in 2024.

Past policy documents and curricula have been criticised for failing to clearly define what the basic principles of scientific literacy are or what skills and attributes of a scientific literate citizen should be developed (Day and Bryce 2013; Siarova, Sternadel, and Szőnyi 2019). This needs to be a strong feature of the future science curriculum. Siarova and colleagues (2019) and PISA (OECD 2017) have devised scientific literacy frameworks which should be considered. Siarova and colleagues, (2019) present scientific literacy competencies that are necessary to prepare scientifically literate EU citizens

(Vision I, II and III). Commissioned by the European Parliament's Committee on Culture and Education and built upon academic literature and policy documents, this framework presents five essential components of scientific literacy, which build on and impact each other: fundamental literacy, scientific knowledge, contextual understanding of science, critical thinking and agency (Siarova, Sternadel, and Szőnyi 2019, 15). PISA (OECD 2017) highlights three domain-specific competences in their framework: (i) Explain phenomena scientifically (recognise, offer and evaluate explanations for a range of natural and technological phenomena), (ii) Evaluate and design scientific enquiry (describe and appraise scientific investigations and propose ways of addressing questions scientifically) and (iii) Interpret data and evidence scientifically (analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions) (OECD 2017). While a scientific literacy framework is necessary, these scientific literacy competencies must be entrenched in the learning outcomes of the curriculum if it is to have meaningful impact on classroom practice (Siarova, Sternadel, and Szőnyi 2019). This guidance is already available in practitioner literature in a United States educational context (Zeidler and Kahn 2014) and could be revised/adapted for inclusion in the Irish primary science teacher guidelines to support the redeveloped curriculum. For example, Zeidler and Kahn's (2014) publication provides pedagogical guidance and sample units on how develop competencies such as collaborative learning, argumentation, critical thinking situated within socio-scientific issues relevant to the pupils' lives. In terms of curricula, Hong Kong has a separate subsection, Science Technology Society Environment Connections, which is embedded in each science strand of the Curriculum. The curriculum provides examples that teacher could use to develop students' awareness and understanding of science in their everyday lives (Ling Wong et al. 2011). A similar subsection could be included in the forthcoming redeveloped Irish primary curriculum. Similarly, the Swedish and French curricula present decision-making contexts (personal health as individual and environment protection as collective benefits) where scientific literacy is necessary (Marty, Venturini, and Almqvist 2017). In the recently published Welsh Science and Technology Curriculum (2019), 'Being curious and searching for answers is essential to understanding and predicting phenomena' is one of six 'Statements of What Matters' which underpin the primary curriculum. This statement emphasises that learners need to be able to make informed decisions about issues that affect our environment and well-being.

Increased provision for professional learning

While curriculum is a powerful lever, it in itself is not enough to enact change. It is impossible to predict from policy documents, such as curricula, how they will be taken up or read in context (Ball 1994; 2006). Translating policy into practice is an enormously complex one. The person who interprets the curriculum has to translate policy from written word into mode of action (Bowe, Ball, and Gold 1992). This process of interpretation is a personal, social, cultural and material process which influences how the curriculum will be enacted in practice (Ball 2006). Thus, teachers' role as curriculum policy makers must be acknowledged (Sahlberg 2011; Walsh 2016). Fensham (2016) argues that a disconnection between curriculum development and teachers' professional learning is a prescription for failure for any future direction of science education. Oates (2010) agrees that the curriculum cannot be considered isolated from other vital factors that affect the educational system, namely teachers.

The implementation of the 1999 primary science curriculum is important to consider. After its introduction, teachers were provided with two days of in-service to support its implementation. Follow-up support for teaching science was available (when requested) through the Professional Development Service for Teachers (PDST). Notwithstanding the availability of this support, data gathered from teachers in the latest two TIMSS cycles (2011 and 2015) reveal that the percentage of fourth-class (9–10-year-old students) primary school teachers who had recently participated in science education professional development was considerably lower than the TIMSS centrepoint (Clerkin, Perkins, and Chubb 2017; Murphy 2014). A number of reviews and reports concluded that teachers require support in the form of comprehensive professional development if the aims of the curriculum were to be achieved (DES 2012; Murphy, Smith, and Broderick 2021; Varley, Murphy, and Veale 2008; Smith 2014; 2015). However, these concerns were never addressed and additional government-led professional development opportunities were not provided. According to Gleeson (2020), the NCCA recognise that deep meaningful change is complex and requires more than once-off type launch events (Gleeson 2020).

In an era of curriculum reformation, nationwide professional learning is both promising and necessary. It is crucial to provide professional learning opportunities necessary for teachers to adapt and transform their practices (Osborne and Dillon 2008). Teachers must be provided with opportunities to explore their interpretations of scientific literacy including the visions of scientific literacy, consider their attachment to familiar pedagogical routines, and then reconcile this with the intentions of policymakers (Gleeson 2020). This is particularly critical because, if effective, professional learning can influence teachers' learning, the method and practice of teaching, and student learning (Loucks-Horsley et al. 2003; Murphy et al. 2015; Smith 2014; Wellcome Trust 2014). The NCCA has indicated in the Strategic Plan for 2022–2025 that it intends to 'Support the capacity of schools and settings to develop, introduce and enact change in curriculum and assessment' (17). In 2023, the DES allocated funding from the education budget to support professional development in light of the Senior Cycle reform (second-level education). One would expect similar support when it comes to the primary curriculum reform. Furthermore, the Irish framework for teacher professional learning, Cosán (Teaching Council of Ireland (TCI), 2016) presents a significant opportunity for professional learning in STEM education, at individual and school level, when the policy is implemented nationally (Broderick, 2019). The Cosán framework recognises teacher professional learning and reflection on learning as an integral part of teachers' profession. Cosán is currently in a 'growth phase' where the TCI are collaborating with key stakeholders to support teachers' engagement with Cosán. From a policy perspective, provision of professional learning supports a key aim of the national STEM policy (DES 2017a; 2017b). Speaking about curriculum change in Ireland, van Kampen (2021) asserts that 'teachers must master, be motivated to master, and be given the opportunity to master, new subject material and different approaches to teaching' (404). Continuous opportunities for professional learning, implementation and reflection is key to enhancing the quality of teaching and student learning.

Conclusion

This discussion paper analysed developments in Irish Primary Science Education from inception to current position through a scientific literacy lens. The historical developments of the past reflect a pattern of growing international influence and a concern for economic success mirroring the emerging prioritisation of science education. The threat of a ‘STEM crisis’ initiated the development of the STEM policy with analysis of the policy illustrating prioritisation of Vision I scientific literacy (DES 2017a). However, with the emergence of a new curriculum, there are opportunities for realignment towards a holistic vision of scientific literacy (Vision I, Vision II and Visions III). Van Kampen (2021) argues that 1902 was possibly the only time in Irish history, that the teaching of primary science was deemed to be an essential element of a child’s education for its intrinsic educational value. Over 100 years later, it must become an essential element of every child’s education. Scientific literacy (Vision I, II and III) and associated competencies must be explicitly included in the redeveloped curriculum. Programmes of professional learning aligned with Cosán present huge opportunity to support teachers with the implementation of the new curriculum. This paper calls for the redeveloped primary science curriculum to be orientated toward science education for all students. ‘We need to improve students’ understanding of science as a body of knowledge and of its power and limitations if they are to better understand themselves as human beings and appreciate their place in their world around them’ (Matthews 2007, 89). The next generation of Irish decision-makers needs to be equipped with the practical and analytical skills to effectively address global and local issues. This begins at primary school. The science education scales must therefore be re-balanced so that a holistic vision of scientific literacy can be achieved. Vision II and III scientific literacy is necessary to engage all students in science education and prepare them to become informed, active citizens of the twenty-first century.

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Notes on contributor

Dr Nicola Broderick is an Assistant Professor in Science Education in the School of STEM Education, Innovation and Global Studies, Institute of Education, Dublin City University. Nicola works in the area of Initial Teacher Education and Professional Learning for teachers. She is a member of the Centre for the Advancement of STEM Teaching and Learning (CASTeL), Irish Professional Development Association (IPDA) Ireland and Irish Association for Primary Science Education (IAPSE). Nicola has developed educational resources in science and published in the areas of teaching and learning in primary science, Nature of Science, Socioscientific Issues, Education for Sustainable Development and teacher professional learning.

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