An investigation into the teaching of numeracy in subjects other than Mathematics across the curriculum

Pat Coffeya and Rachael Sharpea

aSchool of Education, University of Lincoln, Lincoln, LN6 7TS, U.K.

acorresponding author - [patcoffey1981@gmail.com](mailto:patcoffey1981@gmail.com)

#### a[rsharpe@lincoln.ac.uk](mailto:rsharpe@lincoln.ac.uk) **,** Orcid ID: 0000-0001-8687-8380

An investigation into the teaching of numeracy in subjects other than Mathematics across the curriculum

**Abstract:**

Ireland’s government placed a renewed focus on the teaching and learning of numeracy with the publication of a national strategy in 2011. Whole-school planning for numeracy was already a requirement for disadvantaged schools also known as Delivering Equality of Opportunity in Schools (DEIS) in Ireland. This single site case study explored how a disadvantaged school was teaching numeracy across the curriculum. It was discovered that teachers were unclear about the difference between numeracy and mathematics. Teachers’ life experiences of mathematics shaped their views towards numeracy. Leadership played a role in shaping teachers’ views of the importance of numeracy. Whilst all teachers could see the relevance of teaching numeracy in their subject area, the majority were unaware of what the school improvement plan for numeracy contained. The findings suggest the need for teachers to understand the concept of numeracy, the need for professional development to address this, in addition to developing teachers’ identities and pedagogical practices in this area. Schools need to consider how leadership can put support in place to enable teacher learning. Policymakers need to consider, and distinguish between mathematics and numeracy, and support schools’ engagement with cross disciplinary, interdisciplinary and transdisciplinary approaches to embedding numeracy across the curriculum.

Keywords: numeracy; mathematics education; teacher education; school improvement; secondary education; leadership

# Introduction

Ireland’s government published a national policy document in 2011 which set out the need for improved literacy and numeracy skills amongst Ireland’s youth (DES, 2011a). Targets for numeracy were set out in this policy document. These targets included each school developing a school improvement plan; an extension of standardised assessments into the secondary sector; increase student uptake of higher level mathematics at both Junior Certificate and Leaving Certificate level; and increase Ireland’s performance in the Programme for International Student Assessment (PISA). PISA is an international assessment of the knowledge and skills of 15-year-old students in the domains of science, reading and mathematics. Each round of PISA takes place every three years. PISA consists of one of the major domains and two of the subdomains being examined. Ireland has participated in all rounds of PISA since 2000. Ireland experienced the second highest drop in mathematics of the participating countries between 2003 and 2009 where Ireland’s score declined by one third of a standard deviation in those six years (Perkins at al., 2013). This was reported in the media with reports suggesting the fall was alarming (Donnelly, 2010; Flynn, 2010). The policy at the time was that all post-primary subject teachers had a role in “developing and consolidating students’ ability to use literacy and numeracy” (DES, 2011a, p.11).

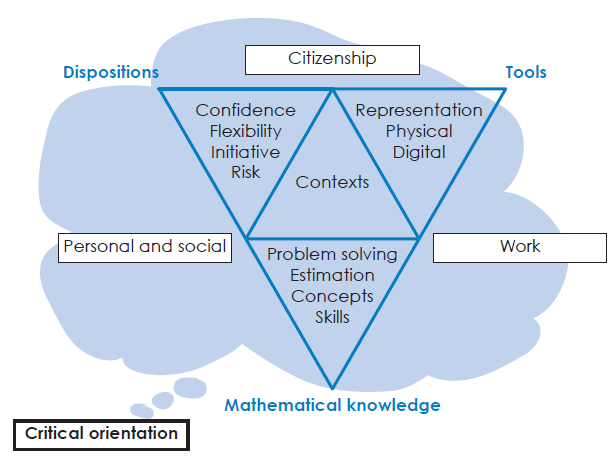
The concept of planning for, and the teaching of numeracy across the curriculum was a concept which was a requirement in DEIS schools in Ireland since 2005 (DES, 2005). In the initiation of DEIS, numeracy was defined as “mathematics for everyday life” (DES, 2005, p. 34). Subsequently, the term evolved somewhat to include contexts, spatial awareness, reasoning skills, problem-solving skills and communication skills (DES, 2011a). More recently, digital skills were added to the definition (DES, 2017a). Steen (2001) made the distinction between mathematics and numeracy; he considered that mathematics “conveys the power of abstraction” (2001, p. 12), whereas numeracy “conveys the power of practicality” (2001, p. 12). This is an important distinction that neither the DEIS policy or the broader national policy documents which encompassed all post-primary schools DEIS and non-DEIS made (DES, 2011a, 2015a, 2015b). Subsequent DEIS inspection evaluations demonstrated teachers having challenges moving the whole-school numeracy away from the mathematics space and that the vast majority of DEIS schools prioritised other areas of DEIS planning above numeracy in the first years of the implementation of DEIS planning (DES, 2011b). This therefore raised the question as to how schools were implementing national policy in relation to the planning for, and the teaching of numeracy. The DEIS school chosen for this project had increased its attainment in the state examinations in mathematics. Although this was an aim of national policy (DES, 2011a, 2017a), this went against the trend nationally (Smyth et al., 2015). The case study school, with the pseudonym of Barrowside Secondary School was worthy of researching to ascertain whether or not the whole-school numeracy practices had a significant role in this increased attainment in mathematics.

**1.1 Numeracy**

This section explores how the concept of numeracy has evolved from its origins to a more sophisticated model of empowering citizens to be critical of the world around them through using their mathematical thinking, skills and dispositions in context. Historically, numeracy had connotations to science and astronomy centuries back, but more recently towards trade and barter (Steen 1997; Madison and Steen, 2008). Researchers are in agreement that the term first appeared in the Crowther Report in 1956 (Withnall, 1995; O’ Donoghue, 2003). In the Crowther Report, (Crowther, 1959) it stated that numeracy was as an important component in understanding problems, and it aided to think quantitatively in situations. Cockcroft (1982) described numeracy as an “at-homeness” (1982, p. 11) with numbers and an “appreciation and understanding” (1982, p. 11) of information which was displayed mathematically. Cumming (1996) suggested that both the Crowther and Cockcroft Reports were written for the exploration of mathematical thinking. Steen (1997, 1999) explained that mathematical literacy was scientific in nature whereas terms such as quantitative literacy or numeracy were contextual. Similarly Goos (2007) explained that the content for numeracy arises from the context in which it is used, and she devised a contemporary model for numeracy.

Goos (2007) devised a model for upskilling teachers in numeracy whereby numeracy is looked upon as a practice (Askew, 2015; Geiger et al., 2015a). This particular model, devised by Goos (2007) in Figure 1 was initially developed “for teachers to plan for, and reflect upon, effective teaching and learning practices in numeracy” (Geiger et al., 2015b, p. 612). The use of contexts was central to Goos’ (2007) understanding of numeracy. Venkat and Winter (2015) found that attention needed to be paid to how numeracy in context is viewed, to ensure numeracy is adequately explained and justified. Askew (2015) explained the need for being interrogative and critical in nature in examining the manner in which numeracy is used to allow us to solve problems in different contexts.

Figure 1. A critical orientation for numeracy (taken from Goos et al., 2012a, p. 4)



Zevenbergen (2004) concluded that since digital tools in workplaces are now ubiquitous; this allowed for more innovative approaches to solving problems. Geiger et al. (2015b) described that tools, including digital tools, help bring about and shape thinking. These tools have helped in allowing tasks to be more critical in nature once teachers were clear on the initial intent of their use. Ireland’s national strategy for literacy and numeracy only referenced the use of digital media and digital literacy in relation to literacy as opposed to numeracy (DES, 2011a). The subsequent interim report did however mention the use of digital technology for students to both develop their understanding and skills of a concept (DES, 2017a). Internationally, the tools specified in the 2018 round of PISA in the assessing students levels of mathematical literacy were a calculator, ruler or a spreadsheet (OECD, 2019) which are a subset of the digital tools included in Goos’s (2007) model, but only two of which would be deemed digital. Goos (2007) model included representational, physical and digital tools.

Geiger et al. (2015b) made reference to the fact that all aspects of the Goos (2007) model are interrelated with contexts being central. The researchers involved in this study believe that the concept of the critical orientation was loose and needed to be more specific. Nevertheless, the researchers accept that Geiger et al. (2015b) were referring to skills such as justification. This critical orientation was subsequently described as using mathematical information to: “make decisions and judgements; add support to arguments; challenge an argument or position” (Bennison et al., 2020, p. 1022). This orientation is consistent with Ireland’s policy which states students whilst engaging with numeracy “engage in problem solving, using investigation and reasoning skills” (DES, 2017a, p. 12), thus demonstrating a shift from the earlier simplistic definition set out by Ireland’s government (DES, 2005). Gravemeijer et al. (2017) pointed out the need to balance the inclusion of contexts in which mathematics in itself is the goal in school. They also explained the need to use experiences outside of school in which tools are used in a meaningful manner to prepare students for a life of work and societal demands when students are finished in school.

## 1.2 Teachers’ identity knowledge and emotions

The teaching of numeracy was the responsibility of all teachers following on from the inception of DEIS planning in 2005 (DES, 2005). This shared responsibility was further corroborated by the national strategy in 2011 (DES, 2011a) and the introduction of school self-evaluation in 2012 (DES, 2012). Considering numeracy context dictates the content for numeracy (Goos, 2007); and the fact numeracy was still seen in the mathematics space by teachers in DEIS schools (DES, 2011b, 2015b); challenges invariably existed if numeracy was to be seen as the responsibility of all teachers. Research in the Irish context has shown that teachers identified themselves as teachers of particular subject areas (Ní Ríordáin et al., 2016), which could have been challenging to them, given the national strategy stated that the teaching of numeracy was now every teachers’ responsibility (DES, 2011a). Bennison (2015a) developed an analytical framework for identity as an embedder of numeracy as seen here in Table 1.

Table 1. Conceptual framework for identity as an embedder of numeracy (taken from Bennison, 2015a, p. 15)

|  |  |
| --- | --- |
| **Domains of Influence** | **Characteristics** |
| Knowledge | Mathematics content knowledge  Pedagogical content knowledge  Curriculum knowledge |
| Affective | Personal conception of numeracy  Attitudes towards mathematics  Perceived preparation to embed numeracy |
| Social | School communities  Professional communities |
| Life history | Past experiences of mathematics  Pre-service programme  Initial teaching experience |
| Context | School Policies  Resources |



Bennison (2015a) considered that there were five domains of concern with regard to a teacher embedding numeracy. An understanding of the concept of numeracy, and what an embedder of numeracy meant, were central to this analytical framework. Thornton and Hogan (2004) defined an embedder of numeracy as a person with the belief that all areas of learning include numeracy which required student understanding. Bennison (2015a) stated that not alone was the use of mathematics important but that justification of their thinking was also required. Kelchtermans (2005) stated that identity can be looked upon as static. Gee (2000) stated that the sort of person a teacher was and the context in which they operated affected their identity. Sfard and Patrick (2005) spoke about the importance of identity when the collective views affect the personal as in the case of Bennison’s (2015a) social domain of influence. Although Bennison (2015a, 2015b) was of the opinion that teacher identity could be used as an analytical lens to develop and support teachers embedding numeracy across the curriculum, the researchers question the categorisation of personal conceptions of numeracy into the affective domain.

McLeod (1992) was of the opinion that emotion was changeable but that it came about from a longer held belief, however, affect did play a significant role in the teaching and learning of mathematics. Ashcraft (2002) has shown that people with higher levels of anxiety towards mathematics tend to avoid its use. Mathematics anxiety resonates with emotions, where in some cases it can be a cause of discomfort whereas in others it can lead to physiological conditions such as shortness of breath ( Jennison and Beswick, 2010; Stoehr, 2017). Although Bennison (2015a) did not explicitly include emotions in the affective domain she did include past experiences of school mathematics. This is in keeping to (Askew et al., 1997) where teachers did report their current emotions as teachers back to their previous experience of school mathematics although this was not always the case. The researchers believe that the lack of emotion in the affective domain by Bennison (2015a) is questionable since emotion was important in shaping beliefs (McLeod, 1992). It would not be surprising if emotions were a factor in teachers’ identifying themselves as embedders of numeracy across the curriculum.

The three aspects of Shulman (1987) that Bennison (2015a) included in her model for teachers’ knowledge, to identify themselves as embedders of numeracy were mathematics content knowledge, pedagogical content knowledge, and curricular knowledge. Shulman explained that “pedagogical content knowledge was the category most likely to distinguish the understanding of the content specialist from that of the pedagogue” (Shulman, 1987, p. 8). Gaffney and Faragher (2010) concluded that teachers’ pedagogy content knowledge, in part, was required to create a vision to improve student learning in the area of numeracy. Askew et al. (1997) believed that school culture played a huge role in shaping effective teachers of numeracy. However, life experiences of teachers themselves also played a role in shaping their views. Many aspects of Bennison (2015a) model are fluid, with little evidence suggesting which domain of influence has more of less impact on shaping teachers’ identities as embedders of numeracy. More heartening though was the fact that research showed improvement in teachers’ concept of numeracy, and pedagogical practices when continuing professional development was afforded to them using Goos’ model (Goos et al., 2011).

***1.3. Models of integration***

In this section the researchers different models of integration are discussed in addition to opportunities that boundary crossings offer for the development of numeracy in science related subjects. Quigley and Herro made a distinction between “cross-disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary” integration (2016, p. 411). Transdisciplinary, which is explained by Quigley and Herro (2016) as using the approaches from many disciplines to form the problem where the problem is to the forefront rather than the discipline. They believe this is preferable to multidisciplinary approaches to integrating numeracy because the multidisciplinary lacks a critical orientation because of the dearth of iteration involving deep questions when multiple subjects are involved. Vasquez et al. (2013) considered that there were varying levels of integration, varying in the level of integration, from solely disciplinary to multidisciplinary to interdisciplinary to transdisciplinary, with the latter being the deepest of the four levels of integration. Geiger et al. (2015a) stated that there were two main forms of teaching numeracy across the curriculum emerging in the literature which included planning for the utilisation of numeracy as it arises in disciplines other than mathematics, and interdisciplinary approaches where two or more subjects or programmes combine to teach a concept. From this analysis, there was a lack of literature emerging on using transdisciplinary approaches for teaching and learning numeracy across the curriculum.

In Ireland emphasis had been placed on the cross-disciplinary approaches to teaching numeracy across the curriculum (DES, 2011a, 2017a). This cross-disciplinary approach was expanded to include interdisciplinary approaches which included mathematics as a subject in the discipline (DES, 2015a). Ireland’s STEM Education Policy Statement 2017-2026 (DES, 2017c) also advocates interdisciplinary approaches with no mention of transdisciplinary in the document. This is despite Collazo Rivera (2020) showing advantages to students learning mathematics in context through problem based approaches. Although Rupnik and Avsec (2020) suggested that students need good knowledge and skills for transdisciplinary learning, the approach affords an opportunity for students’ learning to go beyond the curriculum.

Mathematics is seen as abstract (Steen, 2001) with numeracy being more contextual (Goos, 2007). The abstract aspects of mathematics have been shown as useful in helping prepare students for the societal demands that numeracy places on them (Gravemeijer et al., 2017). The researchers believe that this challenges the need to explore how the integration of mathematics and other subjects can be developed, most notable subjects with a high level of mathematical content as advocated by Ireland’s policy makers (DES, 2015a). However, since many of these subjects with a higher mathematical content are known as STEM (science, technology engineering and mathematics) then it is worrying when (Maass et al., 2019) stated that there was no widely accepted agreement on whether STEM education aimed to promote new knowledge within individual subjects or whether it aims to promote an interdisciplinary approach to its teaching. Furthermore, English (2016) argued that there are different interpretations about what constitutes STEM education and STEM integration.

Interdisciplinary approaches (Ní Ríordáin et al., 2016; Wang et al., 2020) have shown inflexible curricula, standardised tests, time and leadership as challenges. However the use of real life problems were common place across many studies (Wang et al., 2020). These real life contexts are seen as central to STEM education (Maass et al., 2019). Ireland’s recent policy initiatives in the junior cycle aspect of education for 12-15 year olds allows for more flexibility (DES, 2015c) which Johnston et al. (2020) pointed out will allow for more boundary crossing. Conversely though, given the fact that Ireland’s current policy in STEM education states that “all STEM learning activities are underpinned by mathematics” (DES, 2017c, p. 5) there is a need to investigate the possibilities of integrative approaches. Walshe et al. (2020) pointed out science is only mentioned once in Ireland’s current junior cycle mathematics specification despite the fact that it was published after Ireland’s STEM strategy (DES, 2017c) which would call into question the consistency of emphasis on various approaches of integration across both policy and individual subject specifications at a national level in Ireland.

Boundary crossing is a central feature of STEM integrated perspectives (English, 2016); although the definitions and interpretations of the same concept vary widely. “A boundary crossing can be seen as a socio-cultural difference leading to discontinuity in action or interaction” (Akkerman and Bakker, 2011, p.133). They expanded on this to explain that although there were commonalities between boundaries that two or more differing sites were in some way related. Hobbs (2013) suggested that where teachers were teaching a subject they were not necessarily qualified in; there were opportunities for professional growth. Akkerman and Bakker (2011) suggested that this form of development could lead to a change in teacher identity. Ní Ríordáin et al. (2016) found that teacher perspective, their knowledge of the other ‘subject’, their content knowledge and pedagogical content knowledge and levels of collaboration and support all play a role in successful integration of mathematics into science. Johnston et al. (2020) explained that boundary crossing is not a single act, and might not even be transformative unless time is given for teacher to engage with, reflect upon, discuss and make meaning of the boundary crossing. Venkat and Winter (2015) pointed out the importance of being explicit to students about what perspective one takes on a particular issue or aspect being taught at a boundary crossing in order to avoid ambiguity.

* 1. ***School improvement in numeracy***

In this section, the researchers compare the current method of promoting numeracy across the curriculum in South Africa to the methods ongoing in both Ireland and Australia. The promotion of numeracy across the curriculum has been approached differently in different jurisdictions. In South Africa for example, numeracy is taught as a stand-alone subject known as mathematical literacy (Geiger et al., 2015a). North (2017) believed that how mathematical literacy is taught in South Africa is unique the world over. It is a subject which is compulsory for students who do not study traditional mathematics in grades 10-12. One of the aims of mathematics literacy is: “Learners must be exposed to both mathematical content and real-life contexts to develop these competencies. Mathematical content is needed to make sense of real-life contexts; on the other hand, contexts determine the content that is needed” (Department of Basic Education, 2011, p.8). North (2017) claimed that the curricular aims of mathematical literacy (Department of Basic Education, 2011) are not being met because mathematical literacy is being used as a substitute for children who were unable to cope with mathematics as a traditional core subject. Additionally, the content is being assessed as competency in mathematics as opposed to preparedness for life as espoused in its aims. Forgasz and Hall (2019) concluded that it is recognised that the aims of the South African mathematical literacy programme have not worked out well for their learners. Bansilal et al. (2015) stated that the programme is compulsory only for those students in South Africa who cannot cope with mathematics as a subject.

Unlike the South African stand-alone mathematical literacy, or numeracy classes, Australia and Ireland have followed the same policy path in looking at opportunities to teach numeracy across the curriculum with all subject teachers sharing responsibility. Goos et al. (2012b) explained the potential of exploiting the numeracy demands throughout the middle years of the Australian curriculum by exploiting the ubiquitous nature of numeracy in the enacted curriculum. A fundamental understanding of the term numeracy, and the difference between mathematics and numeracy was a common theme running through many studies irrespective of whether they were pre-service teacher studies (Forgasz and Hall, 2019) or studies involving the development professional capital in the area (Callingham et al., 2015). Professional development programmes developed teachers both in-career teachers (Goos et al., 2011) and pre-service teachers’ confidence (Forgasz et al., 2017) in their understanding of the term and subsequently in their confidence in addressing the numeracy demands of their own subjects (Goos et al., 2012b). Components which were deemed important to teachers in Australian schools when they engaged in the Goos (2007) model for professional development in the are included time, openness with colleagues, and accountability (Goos et al., 2011). Teachers’ capacity to develop rich tasks for conceptual understanding of numeracy to be enabled at classroom level is seen as an area for development (Geiger et al., 2015b) through the use of online tools. Whole school pedagogies where effective methodologies for the teaching of mathematics were discussed coupled with a high level of school leadership which included teacher leaders, have been found to help with improved student outcomes in numeracy (Gaffney and Faragher, 2010).

All secondary schools in Ireland, both DEIS and non-DEIS schools are expected to use the process of school self-evaluation to create their own action plan for the teaching of numeracy across the curriculum (DES, 2011a, 2012, 2016). This was seen by some researchers as a political motive rather than a pedagogical one (Ó Breacháin and O’ Toole, 2013). In a study commissioned by the Department of Education and Skills in Ireland to ascertain the effectiveness of DEIS it was found that although there was a slight, albeit significant gap between DEIS and non-DEIS schools in narrowing the attainment gap in Junior Certificate English between 2003 and 2011, no such improvement was in evidence in Mathematics (Smyth et al., 2015). This was further reinforced with results in PISA across all domains including mathematics (Perkins et al., 2013), a trend which is also evident across all OECD countries (OECD, 2014). The DES interim report on the national strategy (DES, 2017a), and in a DEIS Action Plan launched by the government (DES, 2017b) set out specific targets for DEIS schools to decrease the attainment gap between DEIS and non-DEIS schools. McNamara and O’ Hara (2006) showed that there was a lack of the use of evidence based data in terms of student attainment as a form of self-evaluation. However, the policy in the initial strategy (DES, 2011a) saying that all teachers had a responsibility for teaching numeracy did not take into account the levels of mathematical skills and reasoning associated with the various subjects.

Ireland’s policy makers were expecting schools to close attainment gaps nationally by implementing by and large “cross-curricular approaches” (DES, 2015a, p. 4). A hybridity of leadership has been seen to be effective in the teaching of and improvement of mathematics outcomes between senior leadership and teacher leadership (Higgins and Bonne, 2011). However, the promotion of numeracy requires whole-school cross-curricular direction which requires a coordinated approach in a school (DES, 2015a). The ubiquitous nature of numeracy means that there are multiple opportunities for its teaching (Steen, 1999; DES, 2015a); the deeper models of integration which have also shown benefits to learners through teacher collaboration (English, 2016; Collazo Rivera, 2020; Johnston et al., 2020) should not be marginalised by either senior leadership or teacher leadership within schools.

The principal was seen as pivotal in providing adequate support to the teacher leaders by collaborating with them to ensure the instructional needs of the students are shared with the staff (Sun and Leithwood, 2015), and also by protecting them from any negativity that may arise from colleagues (Pankake and Moller, 2007). Sahlberg (2013) made the point that “leadership is closely tied to teaching” (Sahlberg, 2013, p. 38). Ferme (2014) in the Australian context suggested that the promotion of whole-school numeracy practices was the responsibility of the mathematics department. This view is not shared by Ireland’s policy makers or by other researchers because although good mathematical pedagogies underlie good numeracy practices (DES, 2015a); Steen (1999) believed that all teachers had that responsibility to move into this space, a view echoed by Goos et al. (2012b) in terms of the opportunities to promote and teach numeracy across the curriculum. The researchers believe that the varying models of integration need to be examined at school-level to investigate the full potential of national policy in the area (DES, 2011a).

**2. Methodology**

***2.1. Research questions and theoretical framework***

The researchers set about ascertaining how national policy (DES, 2011a, 2016, 2017a, 2017b) was being implemented in a single site DEIS school which was going against the trend of other DEIS schools in terms of improving attainment in mathematics (Smyth et al., 2015).The researchers believe that Barrowside Secondary School offered a unique case to see what practices were in place outside of the mathematics classrooms, and also to gather evidence as to whether or not whole-school numeracy practices were a factor in this school’s successes in increasing mathematical attainment. This single site case study explores how a disadvantaged school was teaching numeracy across the curriculum. In examining this, the researchers aligned sub-questions to each of the first four levels of Guskey (2002) The questions comprise of teachers’ feelings to both numeracy, and the teaching of numeracy; what they knew about the teaching of numeracy; how were teachers learning from each other, if at all, and what role, if any, did school leadership play in the planning for numeracy and finally; what numeracy was being taught. The research methods in collecting the data are also shown in the Table 2. Guskey’s (2002) model was broadly based on Kirkpatric’s (1959) model for evaluating effective training in the corporate world. However, as King (2014) stated, Guskey added level 3 to incorporate the school organisation. The researchers were interested in ascertaining the numeracy being taught across the curriculum as espoused by Government policy (DES, 2011a) through examining how a school was engaging with the implementation of their own school improvement plan. The five levels of the Guskey model (2002) are as follows:

1. Participants’ reactions,

2. Participants’ learning,

3. Organisation support and change,

4. Participants’ use of new knowledge and skills,

5. Students’ learning outcomes

Table 2. Questions and methods for the research project aligned to Guskey’s (2002) theoretical framework (taken from Coffey, 2018, p. 49)

|  |  |  |
| --- | --- | --- |
| **Guskey (2002) Levels of Impact** | **Research Questions** | **Method** |
| Level 1  Teachers’ feelings | How do teachers feel about numeracy?  How do teachers feel about the teaching of numeracy in their subject area? | Teacher interview |
| Level 2  Teachers’ Knowledge | What do teachers know about the teaching of numeracy in their subject area? | Teacher interview |
| Level 3  Organisational Support and Change | Were subject teachers across the curriculum learning from each other; and if they were, how was this learning organised and facilitated?  What role, if any, did senior management and teacher leaders have in this planning? | Teacher interview  School Leader interview  School documentation |
| Level 4  Teachers’ use of new knowledge and skills | Is numeracy being taught in individual subject areas across the curriculum? | Classroom observations  Field notes |

Level 1 facilitated the researcher in ascertaining how teachers felt about the teaching of numeracy. Level 2 was used to find out what teachers’ knowledge was of teaching numeracy in their own subject areas. Level 3 enabled the researchers to ascertain the role of leadership in facilitating this learning and also to probe how teachers’ learned from each. Level 4 supported the researchers in collecting data on how numeracy was taught in various subject areas across the curriculum. Although each level of Guskey (2002) is not strictly linear (Abrahams et al., 2014; King, 2014), success at one level is usually dependent on the previous level and evidence can be built at each level. Level 5 was not used for the purpose of this research because this was outside the scope of the project. The researchers agree with Abrahams et al. (2014), where they said that it was difficult to ascertain whether or not the results were directly linked to the intervention or not, in this case, the school improvement plan for numeracy.

***2.2. Conceptual framework for observing numeracy***

The researchers chose aspects the Goos (2007) model for conceptualising numeracy in this project as opposed to the definition set out in the Ireland’s national strategy (DES, 2011a) because of the similarities between the two concepts of numeracy set out in both. The concept of numeracy for this study comprised of: mathematical content, contexts, mathematical skills including the use of criticality within these, and the use of tools. However, a more quantifiable method of ascertaining what mathematical content was being taught; the skills being observed and the critical orientation of these skills was required. Therefore, a modified version of Goos (2007) model was developed. In line with Goos (2007) and Geiger et al., (2015a), contexts were to the forefront. The mathematical concepts observed were quantified based on four of the five strands of Ireland’s Junior Certificate Project Maths curriculum (NCCA, 2013).

The skills observed in this study were a combination of skills from the Primary School Mathematics Curriculum (NCCA, 1999) and from those used by the Organisation for Economic Co-operation and Development (OECD). There were eighteen skills in total included for the purposes of observation. These skills, to incorporate the critical orientation which is important in any understanding of a modern definition of numeracy (Askew, 2015) were categorised using Bloom (1956) classification. This classification came about after a peer review process where two colleagues of the primary researcher, in the Professional Development Service for Teachers, classified them separately before agreeing on the classification. The six levels of skills observed comprised of: knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, 1956). The eighteen skills, and their classification are made explicit in Table 3. The tools for the purposes of this project are the same as those included in the Goos (2007) model. These included: “the use of materials (models, measuring instruments), representational (symbol systems, graphs, maps, diagrams, drawings, tables) and digital (computers, software, calculators, internet) tools to mediate and shape thinking” (Geiger et al., 2015a, p. 542).

Table 3. Analytical framework for numeracy used in the research project

(Coffey, 2018, pp. 62-63)

|  |  |  |
| --- | --- | --- |
| **Bloom’s Levels (1956)** | **Bloom’s Definitions** | **Subskills**  **(NCCA, 1999; OECD, 2014)** |
| 1. Knowledge | “Knowledge as defined here included those behaviours and test situations which emphasise the remembering, either by recognition or recall” (Bloom, 1956, p. 62) | * Recall numerical facts * Recall procedural processes * Recall definitions * Identifying mathematical operations |
| 2.C Comprehension | “When students are confronted with a communication, they are expected to know what is being communicated and to be able to make use of the material or ideas contained in it” (Bloom, 1956, p. 89). | * Reading, decoding and interpreting statements and tasks or objects (OECD) * Record the results of mathematical tasks * Present and explain solutions to problems/findings * Classify objects into categories/patterns |
| Application | “An application is where a student uses an abstraction when “no mode of solution is specified” (Bloom, 1956, p. 120). | * Carrying out a mathematical procedure * using appropriate manipulatives to carry out a mathematical task * Estimating |
| 4.A Analysis | “Analysis emphasises the breakdown of the materials into its constituent parts and detection of the relationships of the parts and on the way they are organised. It may also be directed at the techniques and devices to convey the meaning and to establish the conclusion of a communication” (Bloom, 1956, p. 144). | * Relating the numeracy being taught to that of the mathematics curriculum * Connecting the various strands of the mathematics curriculum |
| 5. S Synthesis | “Synthesis here is defined as the putting together of elements as parts so as to form a whole” (Bloom, 1956, p. 162). Creative behaviour is expected here. | * Devise a strategy * Implement a strategy to complete the task * Interpret the findings of answers |
| Evaluation | “Evaluation is defined as the making of judgements about the value, for some purpose, of ideas, works, solutions, methods materials etc.” (Bloom, 1956, p. 185). | * Check justification of answers/solutions provided * Provide justifications |

***2.3. Case study research***

Barrowside Secondary School offered the research project, as what Yin (2014) described as an unusual case because research had shown (Smyth et al., 2015) that the attainment gap between DEIS and non-DEIS schools in Junior Certificate mathematics had not decreased. Therefore, this school was worth investigating, to see what numeracy practices were taking place across the curriculum. A phenomenological stance was adopted for the study. The reason for this was that phenomenology is concerned with an “individual’s experience of the world” (Savin-Baden and Howell Major, 2013, p. 61). Consequently, the individual views and practices of the teachers would give a collective view of the whole school. As seen in Table 2, the method of data collection is outlined for each of the 4 levels of Guskey (2002) used for this project. The lessons to be observed followed what Gray (2014) referred to as a stratified technique where lessons were observed, from each of the six year groups in the school. Twenty-one lessons in total were observed. Table 4 shows the subjects observed in each of the year groups:

Table 4. Subjects observed from the different year groups (adapted from Coffey, 2018, p. 57)

|  |  |
| --- | --- |
| Year Group | Subject(s) observed |
| First Year | art, business, English, French, technical graphics |
| Second Year | civic social and political education (CSPE), music, physical education (PE), woodwork |
| Third Year | geography, home economics, Irish |
| Transition Year | history |
| Fifth Year | construction studies, metalwork, physics and chemistry, agricultural science, design and communication graphics (DCG) |
| Sixth Year | biology, English, Leaving Certificate Vocational Programme (LCVP) |



The sampling of the teachers for the semi-structured interviews was based on the analysis of the lessons observed. In total, eight teachers were interviewed, the numeracy co-ordinator, and seven non-mathematics teachers. A list of the teachers, which again are pseudonyms, and the subject they teach are to be seen in Table 5 here:

Table 5. Non-mathematics teachers interviewed and the subjects they taught (adapted from (Coffey, 2018, p. 58)

|  |  |
| --- | --- |
| **Teacher’s name** | **Subjects taught** |
| Mr Shannon | woodwork and construction studies |
| Ms Lee | English and history |
| Ms Blackwater | religion, CSPE, resource |
| Ms Boyne | Irish and German |
| Ms Witham | music and geography |
| Mr Barrow | English, history and Leaving Certificate Vocational Programme(LCVP) |
| Mr Brosna | metalwork, technical graphics, DCG, engineering |

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

All transcripts from the interviews were read a number of times for the purpose of what Hyncer (1985) explained was to get a good overview. Secondly, they were coded using codes which Saldaña (2015) referred to as content. These codes were then made into themes; statements were consequently made out of what Creswell (2012) referred to as the essence of the themes. School documentation was analysed similar to both lesson observations using the conceptual framework set out in Tables 3 and 4 above. Validity and reliability were ensured by peer reviewing the critical analysis of the skills observed in Table 3, and by carrying out a pilot of the observational template.

**3. Results**

In order to be able to discuss the results to the questions it is important that the researchers analyse the school improvement plan at Barrowside Secondary School. This plan is indicative of how the school implemented national policy (DES, 2011a, 2012, 2016) in a school context. The school improvement plan was a six page document. The document was for a three-year period. The plan included a list of strengths and weaknesses for the school context regarding the teaching and learning of numeracy. To address these identified areas, and in keeping with national policy (DES, 2012, 2016); the plan contained five targets in relation to numeracy with multiple actions associated with each target. The terms “maths” and “numeracy” were used interchangeably throughout the document. No distinction was made in the plan between the terms numeracy and mathematics. The term “maths” was referenced in the plan 51 times as opposed to the term numeracy which was referenced 17 times which amounts to a ratio of 3:1.

A list of the five targets from the school improvement plan are documented below in Table 6. There were multiple actions associated with each target. The third column in Table 6 below shows the people responsible for the actions for each target. Targets 4 and 5 were what policy makers (DES, 2012) referred to as SMART targets. Smart targets are defined as: “specific, measureable, attainable, realistic and time bound” (DES, 2012, p. 19). That said, the values associated with Target 4 were not made available to the researchers. Targets 1, 2 and 3 did not meet this criterion. Target 2 was the only one that explicitly mentioned the term “numeracy”. Also, noteworthy, was that the specific targets set out did match the areas identified by the school as areas for priority except for one instance where it was stated that “teachers needed to liaise with the maths department on methods used to teach mathematical concepts”. Targets 1, 2 and 3 were not specific to learner outcomes as advised by policy makers (DES, 2012), and also there was no reference to progress made on previously identified targets. Each target in the school plan had a number of associated actions. Out of a total of twenty-six actions, the mathematics department were solely responsible for eleven of these. This placed over forty per cent of the responsibility of whole-school planning for numeracy on the mathematics department.

Table 6. Analysis of Numeracy Plan for Barrowside Secondary School

|  |  |  |
| --- | --- | --- |
| Target | Specific targets | Personnel responsible for the actions associated with each target |
| Target 1 | Staff will develop a whole school plan for explicit teaching of mathematical language across all subjects | -Maths department  -All students and all teachers |
| Target 2 | Improved awareness of the use of numeracy in other subjects | -Maths department  -All teachers  -All teachers and students |
| Target 3 | Use of Learning Goals as an assessment for learning measure | -All teachers and students |
| Target 4 | To improve learner outcomes in State examinations and increase the uptake of students taking maths at higher level | -Maths department o  -School Completion Programme  -Maths department and senior management |
| Target 5 | Maintain and increase the proportion of students who  say they like mathematics from 45% to 60% over 3 years | -Maths department  -Junior Certificate School Programme (JCSP) co-ordinator, -Maths department and the English department |



Emphasis was placed on a cross-curricular approach to numeracy in Barrowside’s school improvement plan. This was in keeping with both Ireland’s policy (DES, 2011a) where it stated that all subject teachers were responsible for developing and consolidating students’ numeracy skills. Geiger et al. (2015a) considered this one of the two approaches which were found in the literature in relation to the promotion of numeracy across the curriculum. However, the other approach, an interdisciplinary approach, which according to Geiger et al. (2015a) was showing great potential was absent from the planning. There were no references made transdisciplinary approaches either to the teaching of numeracy in the plan. Neither was there a definition of numeracy or a distinction made between the terms numeracy or mathematics. The approaches mentioned, and the lack of distinctions made between the terms were also absent from the national policy at the time (DES, 2011a).

***3.2. Guskey level 1: How do teachers feel about numeracy?***

The results are discussed according to each level of the Guskey (2002) model, ranging from level 1 to level 4 inclusive. Although the school improvement plan was the intervention, the questions asked, and subsequent discussions, centre round how the school implemented national policy through the implementation of its own plan at school level. The question ‘how do you feel about numeracy?’ was asked of all seven non-mathematics teachers interviewed. Seven non-mathematics teachers were asked this question in the process of a semi-structured interview. Six out of the seven teachers were unclear whether the term was the same as mathematics or whether it was different. Four out of the seven teachers referenced their own experience of mathematics. Ms Blackwater, who is a parent, brought her own experience of helping her daughter with school mathematics into her response. Ms Boyne, a language teacher, also referenced her aptitude in school mathematics when she was asked. Two teachers both of whom are considered carrier subjects of numeracy (DES, 2015a) responded similarly. Mr Shannon answered by saying: “In school, I would not have been strong at maths at all. I did ordinary level maths, and I found it a struggle when I went to college”. Mr Brosna also said he was “not natural” at mathematics. Mr Barrow, a teacher of history, English and LCVP, brought school mathematics into his answer when he said “I suppose as an English teacher, I quite liked maths at school. I wasn’t bad at it”. Ms Lee asserted that mathematics was not her favourite subject at school when she was asked the question. Ms Witham, the music and geography teacher was the only teacher who did not relate her feelings of numeracy towards mathematics. Instead she said she thought it was a great concept how numeracy was now across the board.

The fact that six out of seven teachers were unsure about the difference between mathematics and numeracy is indicative of a lack of professional development on this topic within the school. Studies (Forgasz et al., 2017; Forgasz and Hall, 2019) have shown with pre-service teachers, distinguishing between the two terms is a fundamental step in ensuring that student teachers developed more confidence in its teaching similar to Ireland across all subject areas. This is also a factor with building capacity within schools (Callingham et al., 2015). It was evident that teachers were identifying themselves with both the life history, and affective domains of the Bennison (2015a) model for embedding numeracy. Teachers were bringing the emotions they experienced from school mathematics into their professional judgements on the teaching of numeracy across the curriculum due to the fact that they were not distinguishing between numeracy and mathematics. The lack of distinction in national policy (DES, 2011) between the terms: mathematics, numeracy and mathematical literacy could also have caused this ambiguity in teachers’ perception of the term numeracy.

***3.2.1. Guskey level 1: How do teachers feel about the teaching of numeracy in their subject area?***

Teachers did not allow their own views of numeracy affect the importance they placed on its teaching. School leadership played a role in shaping teachers’ views in relation to this. Mr Shannon for instance, who stated he was not “strong at maths”, was aware that the school senior management team had placed a “huge emphasis” on the teaching of numeracy. Mr Shannon and Mr Brosna also used the term “vital” in referencing how important they saw numeracy. Two of the language teachers interviewed, Ms Lee and Mr Barrow, associated their identity more with literacy than numeracy. However, Mr Barrow’s identity was changing due to the fact that the more he heard about numeracy in school, the more he could see the relevance of it in his teaching. Ms Lee separated her own lack of passion for school mathematics with the relevance of numeracy. Furthermore, she did think it was more applicable to history than to her second teaching subject which was English. Conversely, Ms Boyne, a teacher of languages displayed indifference when commenting about how she felt about its teaching in her subject areas when she said “I don’t have any problem with it. Mathematics would not be my strongest point, but I do not mind you know”. Again the lack of clarity between numeracy and mathematics as a discipline can be seen in her response. Ms Blackwater felt that numeracy was important, especially for girls. She referenced how she was “embarrassed” helping her own child with her mathematics homework. Ms Blackwater’s child was in fourth class in primary school. Fourth class is the sixth year of primary school education in Ireland. Typically the average age would be 10 years of age. Therefore, Ms Blackwater’s personal life was influencing her feelings towards numeracy. Ms Witham, the only teacher who did not reference mathematics as a subject or a discipline thought it was refreshing. However, she did say she had not changed the way she taught anything which would suggest that the planning for numeracy both in subjects and at whole-school level had not impacted upon her teaching.

There was evidence to suggest that although teachers were uncertain about the difference between the two terms that the school culture and school leadership were shaping their views on its importance. Askew et al. (1997) stated that school culture is an important aspect in changing teachers’ beliefs as could be evidently seen by the answers given by Mr Barrow in response to how he was feeling. Equally too, the fact that senior management placed emphasis on the teaching of numeracy highlighted its importance to one teacher. Gaffney and Faragher (2010) stated that the focus of senior managers in addition to teacher leaders developing pedagogical practices were important in maintaining school improvement in the area. Interestingly, teachers did not talk about any areas of knowledge identified under Bennison (2015a) categorisation. Shulman (1987) singled out pedagogical content knowledge as being the most important aspect to enable teachers to meet the learning needs of students. However, instead of mentioning these, teachers were more focussed on their own ability in mathematics either through their own perception of their ability of school mathematics or through their life experiences as a parent. Studies (Goos et al., 2011; Geiger et al., 2015b) have shown that multiple iterations, time, and the use of the Goos (2007) model had a positive effect on teachers’ confidence in addressing the numeracy demands of their subjects but only when an understanding of the term also occurs. This common understanding was not in evidence in Barrowside Secondary School.

***3.3. Guskey level 2: What do teachers know about the teaching of numeracy in their subject area?***

All seven non-mathematics teachers were given the opportunity to describe how they taught numeracy in their subject areas. All teachers were capable of giving many different contextual examples. The number strand (NCCA, 2013) was the strand from which all teachers gave examples of how they taught numeracy. The researchers, in their analysis of the findings grouped Mr Shannon and Mr Brosna together due to the fact they were teachers of technical subjects. However, they were unclear of the difference between mathematics and numeracy. Although Mr Brosna referred to numeracy as “basic maths”, he did have skills from level 4, analysis and level 5, synthesis of Bloom. He had collaborated with the mathematics department on the teaching of constructions to first year students. This however, was a once off, and did not continue. Nevertheless, the initiative benefited both himself and the mathematics department according to Mr Brosna because he experienced first-hand the pedagogies used in the mathematics class for teaching a common topic. Unlike Mr Brosna, Mr Shannon did not have any skills mentioned in relation to level 4, analysis. This meant there was a lack of relating the numeracy being taught in his subjects to the mathematics curriculum. Mr Shannon said that he did not collaborate on pedagogy with the mathematics department. His knowledge from this came from the students rather than the teachers because students would tell him they had done something in mathematics.

Mr Trent, the school principal mentioned that much work had taken place on pedagogical practices within the mathematics department but that this was yet to be disseminated beyond that individual department. However, the school improvement plan stated that folders of common practices would be made available to all teachers which were used in the teaching of first year mathematics. In her interview, the numeracy co-ordinator confirmed that this had taken place, in terms of information disseminated and folders given out but it did not appear that the approaches to teaching mathematical content were explored at staff level. With the exception of Mr Brosna, Ms Witham was the only other teacher who mentioned skills from level 4, analysis of Bloom (1956) in her interview as can be seen in Table 7 below. Ms Witham was, however, very anxious about her own ability with numeracy. For one of the agreed approaches mentioned in the whole-school plan to return test scores to students as a fraction and ask them to convert it to a percentage, Ms Witham said “I do not know how to do this. I would not teach them (the students) how to do it”. She said she had not upskilled in the new approaches to mathematics (i.e. Project Maths) and would be “nervous” about teaching it. She did however say that the mathematics department and the music department had collaborated but that she would be “afraid” of how to teach new approaches. In spite of this, she was capable of giving examples of how she taught numeracy across all four strands of mathematical content (NCCA, 2013), all six components of Bloom (1956) as seen in Table 7, and also give examples of the use of tools across all three of Goos (2007) categories as seen in Table 8.

Mr Barrow and Ms Lee both taught the same subjects with the exception of the LCVP programme. Both of these teachers demonstrated a wide range of skills, and the same use of tools but contrasted in their views because Mr Barrow had a broader understanding of a whole-school approaches to teaching from his experience as the literacy co-ordinator. Ms Lee considered cross-curricular approaches as “box ticking” but, interestingly, she considered numeracy to be more applicable to history than to English. She claimed that for English that she was “so focused on literacy issues that is why I do not consider numeracy”. However, she said “Well it never occurred to me, I never thought about students doing patterns in mathematics” indicating a lack of collaboration with the mathematics department.

Ms Boyne and Ms Blackwater both lacked a critical orientation of numeracy as can be seen in Table 7. Ms Boyne viewed numeracy as a “building block” for languages but more for the process of acquiring new vocabulary as opposed to a critical stance, hence the lack of the use of tools as seen in Table 8. Ms Blackwater, on the other hand was fearful of exposing her own perceived inadequacies in relation to numeracy when she said “I’d be terrified that anybody would discover just how bad I am”. She mentioned that the planning for numeracy for the religious education department was “casual”. She explained that she regularly collaborated with the mathematics department informally because as she said “I am so needy in that area”.

Table 7. Breakdown of the categorisation of skills mentioned in interviews.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Teacher | Categorisation of Skills | | | | | |
|  | knowledge | comp-rehension | application | analysis | synthesis | evaluation |
| Mr Shannon | √ | √ | √ |  | √ |  |
| Mr Brosna | √ | √ | √ | √ | √ |  |
| Ms Lee | √ | √ | √ |  | √ | √ |
| Mr Barrow | √ | √ | √ |  | √ | √ |
| Ms Boyne | √ | √ | √ |  |  |  |
| Ms Blackwater | √ | √ | √ |  |  |  |
| Ms Witham | √ | √ | √ | √ | √ | √ |

It was evident from the responses given by teachers that their understanding of numeracy lacked consistency and also lacked the critical orientation that was associated with the term by researchers (Goos 2007; Askew, 2015; Geiger et al., 2015a). The only model of integration that was in evidence with six teachers was second onVasquez et al. (2013) list which was cross-disciplinary insofar as teachers were capable of giving examples of where numeracy was taught in their subjects but separately within disciplines. Although, Ms Witham mentioned skills which demonstrated aligning what was being taught to that of the mathematics department, her levels of anxiety which as McLeod (1992) suggested comes from a longer held belief, in this case, a perceived lack of ability to carry out an agreed whole-school pedagogy. The teacher’s lack of confidence would have prohibited her to realise the goal of what Vasquez et al. (2013) says is to deepen students’ knowledge and skills in the area.

One teacher, Mr Brosna did engage in interdisciplinary integration with the use of closely linked knowledge and skills between the mathematics department and his teaching of technical graphics. This however, appeared to be a practice in isolation amongst two teachers as opposed to across the school. Other teachers, despite seeing the importance of teaching numeracy in their subject area, were unaware of the critical orientation involved which would suggest a possible lack of exploration of the concept of numeracy in the whole-school planning.. Furthermore, the fact that five out of the seven teachers interviewed did not align the numeracy they taught to the mathematics curriculum was evident that teachers were not implementing all of the knowledge which was disseminated to them by the numeracy co-ordinator, Ms Nore. Interestingly, one of the two teachers who did, Mr Brosna, had engaged in interdisciplinary integration with the mathematics department which has been shown as a deeper form of integration than cross disciplinary approaches (Vasquez et al., 2013; English, 2016). That said, other factors, including teachers’ attitudes towards mathematics as opposed to numeracy; the associated emotions and experiences they had from school; and other life experiences all shaped their views of numeracy in the absence of an agreed understanding of the term at whole-school or subject department level.

***3.4. Guskey Level 3: Were subject teachers across the curriculum learning from each other; and if they were, how was this learning organised and facilitated?*** Numeracy was discussed both formally and informally amongst the staff. The numeracy co-ordinator, Ms Nore, had made subject folders containing a scheme of work for first year mathematics and methods on how the mathematics department taught various mathematical topics available to other subject areas. This action was explicitly mentioned in the school improvement plan, and it was followed through on by Ms Nore. Approaches on how to teach mathematical concepts were discussed within the mathematics department and shared formally through the folders for areas of first year. Additionally, the mathematics department were happy to discuss pedagogies with non-mathematics teachers informally. The principal had requested that all subject departments would have a numeracy section incorporated into them. Subject departments had incorporated a numeracy section into most plans. Access was given to eight subject plans; two of the plans, the mathematics and home economics plan made reference to the targets set out in the whole-school plan for numeracy. However, the other six plans did not reference the targets set out in the school improvement plan. Out of the seven non-mathematics subject plans critiqued, four of the schemes detailed areas where numeracy was taught. The plans that exemplified where numeracy was taught were (history for junior cycle only, engineering, metalwork and music). Considering Mr Brosna was a teacher of metalwork and engineering, and Ms Witham was a teacher of music, it was evident that their understanding of the teaching of numeracy in their subject areas had been influenced by collaboration with the mathematics department as specified in their interviews.

***3.4.1. Guskey Level 3: What role, if any, did senior management and teacher leaders have in this planning?***

Although five out of the seven mathematics teachers were uncertain of what the school improvement plan for numeracy contained, they all knew that senior management took the teaching of numeracy seriously, and that there was a requirement of them to have a numeracy section in their own subject department plans. Mr Shannon explicitly mentioned there was a “drive” for school improvement for numeracy coming from senior management. The school principal, Mr Trent gave the autonomy to subject departments on how they taught numeracy; he believed it was subject department led. Mr Trent was of the opinion it was the responsibility of all subject departments to teach numeracy but that it was the responsibility of the mathematics department to lead the process. This was seen in the school improvement plan where the mathematics department were solely responsible for eleven out of the twenty-six actions. However, Mr Trent also noted that pedagogical practices in the area had not expanded beyond the mathematics department.

Ms Nore, the numeracy co-ordinator had given all subject departments folders outlining the sequencing of mathematical content taught in first year, common approaches taken to teaching these topics, and common language used. These folders were taken by the teachers. However, it did not appear, from interviews, that these methodologies were explained at whole-staff level. The conversations around pedagogical practices were informal in nature with two teachers, Mr Shannon and Mr Barrow saying they never discussed pedagogies. However, Ms Lee, a teacher of both history and English similar to Mr Barrow, said that methodologies were discussed in subject departments but she also said that numeracy was spoken about in an informal manner with the mathematics department.

The evidence suggested that numeracy in Barrowside Secondary School was seen by teachers as being important due to the fact that there was a perception that it was senior management led by four out of the seven teachers interviewed. Gaffney and Faragher (2010) explained that the leadership in school is seen as very important in improving student learning. Much work had been done by the numeracy coordinator, Ms Nore, in providing teachers with folders which contained the three aspects of Shulman’s (1987) knowledge base for learning which were included in Bennison’s (2015a). However, the majority of teachers interviewed did not reference these approaches. Additionally, there was no mention of reflection time given to teachers to deepen their understanding of numeracy. Furthermore, the fact that five out of the seven teachers were unsure of what the plan contained illustrates a certain apathy on their behalf, and this also demonstrates the fact that the professional development of the plan needs to be an iterative process of reflection where adequate time is given to it at whole-school planning level as shown by research (Goos et al., 2011; Callingham et al., 2015). There was however, reference made to the interdisciplinary nature of mathematics and engineering and also a reference to the other STEM subjects by virtue of mentioning the importance of subject departments working closely together. English (2016) considered interdisciplinary integration a deeper approach than cross-curricular. However, no further exploration beyond this point was developed in the plans either at whole-school or subject planning level.

***3.5. Guskey Level 4: Is numeracy being taught in individual subject areas across the curriculum?***

Twenty-one lessons in total were observed. Numeracy was being taught by all teachers, but it must be stressed to varying degrees, and not necessarily in the way that was envisioned by either the school improvement plan or government policy (DES, 2011a). One example from the probability and statistics strands was observed, eight lessons contained geometry and trigonometry with six lessons having algebra. All twenty-one lessons contained number. Only four lessons showed evidence of the skills set in level 4, analysis of Bloom (1956). Two out of the four teachers who demonstrated this were mathematics teachers. Many lessons lacked a critical orientation associated with a modern definition of numeracy (Askew, 2015). Only one third of lessons observed had examples from level 5, synthesis or level 6, evaluation of Bloom (1956). The majority of lessons which had examples of skills from level 3, application of Bloom (1956) were mathematical based subjects (DES, 2015a) as can be seen in Table 8. The use of tools in the lessons observed can be seen in Table 9. Tools were used in thirteen out of the twenty-one lessons observed. In the thirteen lessons, in which tools were used, only six of these had skills observed from either level 5, synthesis or level 6, evaluation or both. This indicated that the tools used in the majority of cases were not aiding a critical orientation to the teaching of numeracy and ultimately improving students’ problem solving skills.

Table 8. A breakdown of the categorisation of skills observed in terms of the six levels of Bloom (1956) (taken from Coffey, 2018, p. 160)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Bloom (1956) levels | | | | | | Subject | Year group |
| Knowledge | comprehension | Application | analysis | synthesis | evaluation |  |  |
| √ | √ | √ |  | √ |  | art | 1 |
| √ | √ | √ |  |  |  | business | 1 |
|  | √ |  |  |  |  | English | 1 |
| √ | √ | √ |  |  |  | French | 1 |
| √ | √ | √ |  | √ |  | tech. graphics | 1 |
|  | √ |  |  |  |  | CSPE | 2 |
| √ | √ |  |  | √ | √ | music | 2 |
|  | √ |  |  |  |  | PE | 2 |
| √ | √ | √ |  | √ |  | woodwork | 2 |
| √ | √ | √ | √ |  | √ | geography | 3 |
| √ | √ | √ | √ |  |  | home ec. | 3 |
|  | √ |  |  |  |  | Irish | 3 |
|  | √ |  |  |  |  | history | 4 |
| √ | √ | √ |  | √ | √ | construction | 5 |
|  | √ | √ |  |  |  | metalwork | 5 |
| √ | √ | √ | √ |  |  | Phys/chem. | 5 |
|  | √ |  |  |  |  | ag. science | 5 |
| √ | √ | √ |  |  |  | DCG | 5 |
| √ | √ |  | √ |  |  | biology | 6 |
|  | √ |  |  |  | √ | English | 6 |
|  | √ |  |  |  |  | LCVP | 6 |

Table 9. A breakdown of the category of tools as categorised by Geiger et al. (2015a) in each of the lessons observed (taken from Coffey, 2018, p. 161)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Tools (Goos et al., 2012a) | | | Subject | Year group |
| Representational | Physical | Digital |  |  |
| √ | √ |  | art | 1 |
| √ |  | √ | business | 1 |
|  |  |  | English | 1 |
| √ |  |  | French | 1 |
| √ | √ |  | tech. graphics | 1 |
|  |  |  | CSPE | 2 |
| √ |  |  | music | 2 |
|  |  |  | PE | 2 |
|  | √ |  | woodwork | 2 |
| √ | √ |  | geography | 3 |
| √ |  |  | home economics | 3 |
|  |  |  | Irish | 3 |
|  |  |  | history | 4 |
| √ |  |  | construction | 5 |
| √ | √ |  | metalwork | 5 |
|  |  | √ | Phys/chem. | 5 |
|  |  |  | ag. science | 5 |
| √ | √ |  | DCG | 5 |
| √ |  |  | biology | 6 |
|  |  |  | English | 6 |
|  |  |  | LCVP | 6 |

The findings from level 4 of Guskey (2002) raise the fundamental question as to whether or not the teaching witnessed by the researchers across the curriculum could be attributable to the rise in attainment in the school in mathematics. Since only four teachers linked the numeracy being taught in their lessons to that of the mathematics classes, and the fact that there were higher order skills only visible in a minority of lessons it is unlikely that this was the case. The limited development of skills beyond levels 1-3 of Bloom (1956) demonstrated a lack of critical orientation which envelopes Goos (2007) model for numeracy. It also was indicative of teaching which did not realise the fundamental goal set out by government policy which aimed to create students who could “encompasses the ability to use mathematical understanding and skills to solve problems and meet the demands of day-to-day living in complex social settings” (DES, 2011a, p. 8). The emphasis on the skills from comprehension and the number stand enforced the views of some of the teachers when they referred to numeracy as “basic mathematics”. The limited use of tools in lessons indicated a lack of emphasis was placed on how rich tasks could be taught throughout the curriculum which have been shown to develop students’ numeracy skills and their understanding of mathematical concepts (Geiger et al., 2015b). Planning was not reflective in nature, it did not develop a whole-school understanding of the term numeracy, or facilitate the necessary changes to allow teachers to evolve their identities into what Bennison (2015a) described as embedders of numeracy.

**4. Discussion and Implications**

The lack of clarity amongst the teaching staff of the difference between mathematics and numeracy was very evident in this study. Although numeracy was defined in the national strategy (2011a) and further developed in the interim report (DES, 2017a), no distinction was made in these documents between mathematics and numeracy. This was further compounded by using test scores in mathematical literacy in PISA as a target in national policies (DES, 2011a. 2017a) because it introduced a third term, mathematical literacy. The use of these three terms in national policy, and the lack of distinction made between them has contributed to confusion amongst teachers. Steen (2001) made an important distinction between the terms mathematics and numeracy. However, this study shows that a clear distinction of the terms are needed at a national level to ensure that there is no ambiguity at school level in implementing a school improvement plan. A lack of understanding in the key concepts contributed to a lack of shared ownership and knowledge of the school improvement plan. The lack of a distinction between the terms allowed teachers’ own life experiences of school mathematics shape their own views towards numeracy. Goos et al. (2011) demonstrated that professional development using the Goos (2007) model has had a significant impact in developing teachers’ understanding of the term numeracy. Professional development for teachers is essential for them to come to a shared understanding of the concept of numeracy. Teachers require a means to work through their own experiences, identities and emotions in order for them to feel comfortable and confident in being empowered to implement the pedagogical practices associated with school improvement in numeracy.

The national strategy (DES, 2011a) in Ireland was introduced after Ireland experienced the second highest drop in mathematics in PISA of participating countries between 2003 and 2009 (Perkins et al., 2013). The tension between numeracy as a quantifiable targeted area in terms of mathematical literacy in PISA and the State exams in Mathematics (DES, 2011a, 2017a, 2017b), and numeracy as a skill embedded in subject areas across the curriculum is a challenge for schools. The fact that the whole-school policy in Barrowside Secondary School had forty per cent of the responsibility placed on one subject department indicated that increased attainment in mathematics was central to the aims of the school policy. Although this is consistent with the quantifiable measures of national policy (DES, 2011a, 2017a), it did pose the challenge as to whether all teachers across all subjects had the same responsibility for the improvement in numeracy. Although there had been success in Barrowside Secondary School in terms of increasing the uptake of higher level mathematics; the evidence from this study would not suggest that a cross-curricular approach to numeracy was attributable to this increase in attainment.

Policy in Ireland with regard to numeracy at secondary level has changed in recent years. The policy in this area is shifting from an almost equal responsibility across the curriculum (DES, 2011a) to a recognition that mathematical reasoning and thinking are of paramount importance in certain subjects (DES, 2015a; 2017c). However, as Walshe et al. (2020) pointed out, there needs to be consistency between national policy with regard mathematics education and subject specific specifications especially when teachers in Ireland have traditionally been identified as subject teachers (Ní Ríordáin et al., 2016). Teachers themselves, as with the case in Barrowside Secondary School see the differing relevance of numeracy to their subjects. The researchers believe that although there are numeracy demands in all subjects, emphasis needs to be placed on pedagogical content knowledge which involves the use of teacher pedagogical tools (Geiger et al., 2015b) and resources to deepen teachers’ understandings of concepts which will further the learning for everyone through meaningful collaboration.

The emphasis in Barrowside Secondary School was on a cross-curricular approach to the teaching of numeracy where both curricular knowledge and mathematics content knowledge were prioritised. Although Geiger et al. (2015a) stated that internationally that either cross-disciplinary approaches or interdisciplinary approaches have been adopted, the researchers are of the belief that there is scope to further investigate the use of interdisciplinary approaches and also to investigate transdisciplinary approaches. Interdisciplinary approaches although not without their challenges (Ní Ríordáin at al., 2016; Wang et al., 2020), lead to changes in teacher identity and teacher professional development (Hobbs, 2013). The form of collaboration required for such an approach is challenging due to the curricula in individual subjects (Walshe et al., 2020); however, the researchers believe that further exploration in this area is required to deepen teachers’ understanding of numeracy and to develop their pedagogical content knowledge in the area. They also believe that transdisciplinary approaches should be investigated to deepen student learning in the area of numeracy through adopting problem based approaches to the integration.

School leadership played an important role in demonstrating the importance placed on a particular area in the school. It also placed importance on the relevance of the teaching of numeracy across the curriculum which is significant considering that teachers’ feelings are at Level 1 of Guskey (2002) evaluation of professional development. Researchers (Abrahams et al., 2014; King, 2014) believe that success at one level is usually dependent on the levels beneath. There was evidence of a hybridity of leadership (Bonne and Higgins, 2011) between the numeracy coordinator, the principal and the teachers within the mathematics department but this fell short in the enactment of the school improvement plan across the curriculum. The majority of teachers knew that senior leadership in the school placed an important emphasis on numeracy. Subsequently, although teachers were limited in their knowledge of the school plan, they could all see the relevance of numeracy to their subject area despite their own past and in some cases present experience of mathematics. However, there is a need for both the senior leadership, and teacher leaders to facilitate a more reflective form of teacher professional development (Goos et al., 2011) which aims at coming to a shared understanding of numeracy to build professional capital in the school (Callingham et al., 2015).

In summary, further research is required into exploring how school’s develop an understanding of numeracy across the curriculum and then how they enact national policy at whole-school level. Additionally, there is scope to further explore the various factors that impinge on teachers’ identifying themselves as embedders of numeracy. An examination of how different forms of integration (Vasquez et al., 2013; English, 2016), particularly within STEM education (Maass et al., 2019), and also incorporating other mathematical based subjects (DES, 2015a) is required to ascertain the full potential of a deep exploration of the teaching of numeracy across the curriculum. Whilst not negating responsibility and the opportunities presented to all teachers pertaining to numeracy (Steen, 1999), the recognition that the teaching of numeracy, by virtue of the level of mathematical reasoning and thinking associated with the term (Callingham et al., 2015) is more relevant to some subjects than others is a salient point which was not included in Ireland’s initial national strategy in the area (DES, 2011a).

**Disclosure Statement**

No potential conflict of interest was reported by the authors.

**References**

Abrahams, I., Reiss, M.J. and Sharpe, R. (2014) The impact of the ‘Getting Practical: Improving Practical Work in Science’ continuing professional development programme on teachers’ ideas and practice in science practical work. *Research in Science and Technological Education*, 32(3), 263-280.

Akkerman, S. F. and Bakker, A. (2011) Boundary crossing and boundary objects. *Review of Educational Research,* 81(2), 132-169.

Ashcraft MH. (2002) Math Anxiety: Personal, Educational, and Cognitive Consequences. *Current Directions in Psychological Science*, 11(5), 181-185.

Askew, M., Brown, M., Rhodes, V., Johnson, D. and Wiliam, D. (1997) *Effective teachers of numeracy.* London: Kings College.

Askew, M. (2015) Numeracy for the 21st century: a commentary. *ZDM - The International Journal on Mathematics Education,* 47(4), 707-712.

Bansilal, S., Webb, L. and James, A. (2015) Teacher Training for Mathematical Literacy: A Case Study Taking the Past into the Future.  *South African Journal of Education*, 35(1), 1-10.

Bennison, A. (2015a) Developing an analytic lens for investigating identity as an embedder-of-numeracy. *Mathematics Education Research Journal,* 27(1), 1-19.

Bennison, A. (2015b) Supporting teachers to embed numeracy across the curriculum: A sociocultural approach. *ZDM - The International Journal on Mathematics Education,* 47(4), 561-573.

Bennison, A., Goos, M. and Geiger, V. (2020) Utilising a Research-Informed Instructional Design Approach to Develop an Online Resource to Support Teacher Professional Learning on Embedding Numeracy across the Curriculum.  *ZDM: The International Journal on Mathematics Education*, 52(5), 1017–1031.

Bloom, B.S. (1956) *Taxonomy of educational objectives: The classification of educational goals. Handbook 1 cognitive domain.* London*:* Longman Group Ltd.

Breacháin, A. Ó. and O’Toole, L. (2013) Pedagogy or Politics?: Cyclical Trends in Literacy and Numeracy in Ireland and Beyond. *Irish Educational Studies*, 32(4), 401–419.

Callingham, R., Beswick, K. and Ferme, E. (2015) An initial exploration of teachers' numeracy in the context of professional capital. *ZDM - The International Journal on Mathematics Education,* 47(4), 549-560.

Cockcroft, W.H. (1982) *Report of the Committee of Inquiry into the teaching of mathematics in schools.* London: HMSO.

Coffey, T.P. (2018) *An investigation into the teaching of numeracy in subjects other than Mathematics across the curriculum: A case study of a post-primary disadvantaged school in Ireland.* Unpublished PhD (Professional) Thesis. University of Lincoln.

Collazo Rivera, G. L. (2020) The Impact of Project Creation on Learning Mathematics in a Transdisciplinary Setting. *International Journal of Educational Methodology*, 6(2), 405–421.

Creswell, J.W. (2012) *Qualitative inquiry and research design: Choosing among five approaches.* London: Sage publications.

Crowther, G. (1959) *A report of the Central Advisory Council for Education.* London: Her Majesty’s Stationary Office*.*

Cumming, J. (1996) Adult numeracy policy and research in Australia: The present context and future directions. *ERIC*.

Department of Basic Education. South Africa (2011). *Curriculum and Assessment Policy Statement: Grades 10–12, Mathematical Literacy*. Pretoria: Department of Basic Education.

Department of Education and Science (DES) (2005) *DEIS (Delivering Equality of Opportunity in Schools) An action plan for educational inclusion*. Dublin. Available from <https://www.education.ie/en/Publications/Policy-Reports/deis_action_plan_on_educational_inclusion.pdf> [Accessed 16 February 2021].

Department of Education and Skills (DES) (2011a) *Literacy and numeracy for learning and life: The national strategy to improve literacy and numeracy among children and young people 2011-2020*. Dublin. Available from <https://www.education.ie/en/Publications/Policy-Reports/lit_num_strategy_full.pdf> [Accessed 16 February 2021].

Department of Education and Skills (DES) (2011b) *An evaluation of planning processes in DEIS post-primary schools*. Dublin. Available from <https://www.education.ie/en/Publications/Inspection-Reports-Publications/Evaluation-Reports-Guidelines/insp_deis_post_primary_2011.pdf> [Accessed 16 February 2021].

Department of Education and Skills (DES) (2012) *School self-evaluation guidelines for post-primary schools.* Dublin.

Department of Education and Skills (DES) (2015a) *A joint report by the Education and Training Inspectorate and the Department of Education and Skills Inspectorate on promoting and improving numeracy in post-primary schools*. Available from <https://www.education.ie/en/Publications/Education-Reports/Best-Practice-Guidelines-in-Numeracy-Provision-at-Post-Primary-Level.pdf> [Accessed 16 February 2021].

Department of Education and Skills (DES) (2015b) *Looking at action planning for improvement in DEIS post-primary schools: Inspectorate valuation Studies*. Dublin.

Department of Education and Skills (DES) (2015c) *Framework for Junior Cycle 2015*. Dublin. Available from <https://www.education.ie/en/Publications/Policy-reports/Framework-for-Junior-Cycle-2015.pdf> [Accessed 16 February 2021].

Department of Education and Skills (DES) (2016) *School self-evaluation guidelines 2016-2020 post-primary.* Dublin. Available from <https://www.education.ie/en/Publications/Inspection-Reports-Publications/Evaluation-Reports-Guidelines/School-Self-Evaluation-Guidelines-2016-2020-Post-Primary.pdf> [Accessed 16 February 2021].

Department of Education and Skills (DES) (2017a) *National strategy: Literacy and numeracy for earning and life 2011-2020 interim review: 2011-2016 new targets: 2017-2020*. Dublin. Available from <https://www.education.ie/en/Publications/Education-Reports/pub_ed_interim_review_literacy_numeracy_2011_2020.PDF> [Accessed 16 February 2021].

Department of Education and Skills (DES) (2017b) *DEIS action plan 2017 delivering equality of opportunity in schools.* Dublin. Available from <https://www.education.ie/en/Publications/Policy-Reports/DEIS-Plan-2017.pdf> [Accessed 16 February 2021].

Department of Education and Skills (DES) (2017c) Stem Education Policy Statement 2017-2026. Dublin. Available from <https://www.education.ie/en/The-Education-System/STEM-Education-Policy/stem-education-policy-statement-2017-2026-.pdf> [Accessed 16 February 2021].

Donnelly, K. (2010) Reading, maths skills of students shows alarming fall. *Irish Independent.* 8 December. Available from <https://www.independent.ie/life/family/learning/reading-maths-skills-of-irish-students-show-alarming-fall-26604509.html> [Accessed 16 February 2021].

English, L.D. (2016) STEM education K-12: perspectives on integration. International Journal of STEM Education, 3(3), 1-8.

Ferme, E. (2014) What can other areas teach us about numeracy? *Australian Mathematics Teacher,* 70(4), 28-34.

Flynn, S. (2010) Ireland drops in literacy rankings. *The Irish Times*. 7 December. Available from <http://www.irishtimes.com/news/ireland-drops-in-literacy-rankings-1.868428> [Accessed 16 February 2021].

Forgasz, H.J., Leder, G. and Hall, J. (2017) Numeracy across the curriculum in Australian schools: Teacher education students’ and practicing teachers’ views and understandings of numeracy. *Numeracy* 10(2), 1-20.

Forgasz, H. J. and Hall, J. (2019) Learning about Numeracy: The Impact of a Compulsory Unit on Pre-Service Teachers’ Understandings and Beliefs.  *Australian Journal of Teacher Education*, 44(2), 15–33.

Gaffney, M. and Faragher, R. (2010) Sustaining improvement in numeracy: Developing pedagogical content knowledge and leadership capabilities in tandem. *Mathematics Teacher Education and Development,* 12(2), 72-83.

Gee, J.P. (2000) Chapter 3: Identity as an analytic lens for research in education. *Review of Research in Education,* 25(1), 99-125.

Geiger, V., Forgasz, H. and Goos, M. (2015a) A rich interpretation of numeracy for the 21st century: A survey of the state of the field. *ZDM- International Journal on Mathematics Education,* 47(4), 531-548.

Geiger, V., Forgasz, H. and Goos, M. (2015b) A critical orientation to numeracy across the curriculum. *ZDM - The International Journal on Mathematics Education,* 47(4), 611-624.

Goos, M. (2007) *New tools, new learners … new numeracies?* In: Keynote address delivered at the South Australian Literacy and Numeracy Expo, Adelaide.

Goos, M., Dole, S. and Geiger, V. (2011) Improving numeracy education in rural schools: A professional development approach. *Mathematics Education Research Journal,* 23(2), 129-148.

Goos, M., Dole, S. and Geiger, V. (2012a) Numeracy across the curriculum. *Australian Mathematics Teacher,* 68(1), 3-8.

Goos, M., Geiger, V. and Dole, S. (2012b) Auditing the numeracy demands of the middle years curriculum. *PNA,* 6(4), 147-158.

Gravemeijer, K., Stephan, M., Julie, C., Lin, F.-L. and Ohtani, M. (2017). What Mathematics Education May Prepare Students for the Society of the Future? *International Journal of Science and Mathematics Education*, 15, 105–123.

Gray, D.E. (2014) *Doing research in the real world.* 3rd Edition*.* London, Thousand Oaks, California: SAGE.

Guskey, T.R. (2002) Does it make a difference. *Educational Leadership,* 59(6), 45-51.

Higgins, J. and Bonne, L. (2011) Configurations of instructional leadership enactments that promote the teaching and learning of mathematics in a New Zealand elementary school. *Educational Administration Quarterly,* 47(5), 794-825.

Hobbs, L. (2013) Teaching “Out-of-Field” as a Boundary-Crossing Event: Factors Shaping Teacher Identity. *International Journal of Science and Mathematics Education*, 11(2), 271–297.

Hycner, R.H. (1985) Some guidelines for the phenomenological analysis of interview data. *Human Studies,* 8(3), 279-303.

Jennison, M. and Beswick, K. (2010) Student attitude, student understanding and mathematics anxiety. In: Shaping the future of mathematics education. *Proceedings of the annual conference of the mathematics education research group of Australasia*, Freemantle, Western Australia, Australia, 3-7 July. Adelaide, Australia: ERIC, 280-288.

Johnston, J., Walshe, G. and Ríordáin, M. N. (2020) Supporting Key Aspects of Practice in Making Mathematics Explicit in Science Lessons. *International Journal of Science and Mathematics Education*, 18(7), 1399–1417.

Kelchtermans, G. (2005) Teachers’ emotions in educational reforms: Self-understanding, vulnerable commitment and micropolitical literacy. *Teaching and Teacher Education,* 21(8), 995-1006.

King, F. (2014) Evaluating the impact of teacher professional development: An evidence-based framework. *Professional Development in Education,* 40(1), 89-111.

Kirkpatric, D. (1959) Techniques for evaluating training programmes. *Journal of ASTD,* 13(11), 1-13.

Maass, K., Geiger, V., Ariza, M. R. and Goos, M. (2019) The Role of Mathematics in Interdisciplinary STEM Education. *ZDM: The International Journal on Mathematics Education*, 51(6), 869–884.

Madison, B.L. and Steen, L.A. (2008) Evolution of numeracy and the National Numeracy Network. *Numeracy,* 1(1), 1-18.

McLeod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics,* 575–596. Macmillan Publishing Co, Inc.

McNamara, G. and O’Hara, J. (2006) Workable compromise or pointless exercise? school-based evaluation in the Irish context. *Educational Management Administration and Leadership,* 34(4), 564-582.

National Council for Curriculum and Assessment (NCCA) (1999) *Primary School Curriculum: Mathematics.* [online] Dublin: Government of Ireland. Available from <http://www.curriculumonline.ie/getmedia/9df5f3c5-257b-471e-8d0f-f2cf059af941/PSEC02_Mathematics_Curriculum.pdf> [Accessed 01 August 2019].

National Council for Curriculum and Assessment (NCCA) (2013) *Junior Certificate Mathematics Syllabus Foundation, Ordinary and Higher Level.* Dublin: NCCA*.*

Ní Ríordáin, M., Johnston, J. and Walshe, G. (2016) Making mathematics and science integration happen: key aspects of practice. *International Journal of Mathematical Education in Science and Technology*, 47(2), 233-255.

North, M. (2017) In Pursuit of an Orientation for Life-Preparation: A Case Study of the Subject Mathematical Literacy in South Africa. *African Journal of Research in Mathematics, Science and Technology Education*, 21(3), 234–244.

O’Donoghue, J., (2003) Mathematics or numeracy: Does it really matter. *Adults Learning Maths Newsletter,*18, 1-4.

Organisation for Economic Co-operation and Development (OECD) (2019) *PISA 2018 Results (Volume I): What Students Know and Can Do*. PISA: OECD Publishing, Paris. Available from <https://www.oecd-ilibrary.org/docserver/5f07c754-en.pdf?expires=1613696359&id=id&accname=guest&checksum=DC8F14945CC5FF64BC5C5732F5129504> [Accessed 19 February 2021].

Organisation for Economic Co-operation and Development (OECD) (2014) *PISA 2012 results: What students know and can do-student performance in mathematics, reading and science volume 1* (revised edition, February 2014*)*. PISA: OECD Publishing. Available from <https://www.oecd.org/pisa/keyfindings/pisa-2012-results-volume-I.pdf> [Accessed 16 February 2021].

Pankake, A. and Moller, G. (2007) What the teacher leader needs from the principal. *Journal of Staff Development*, 28(1), 32-34.

Perkins, R., Shiel, G., Merriman, B., Cosgrove, J. and Moran, G. (2013) *Learning for ‎life: The achievements of 15-year-olds in Ireland on mathematics, reading ‎literacy and science in PISA 2012.* Dublin: Educational Research Centre.

Quigley, C.F. and Herro, D. (2016) Finding the joy in the unknown: Implementation of STEAM teaching practices in middle school science and math classrooms. *Journal of Science Education and Technology,* 25(3), 410-426.

Rupnik, D. and Avsec, S. (2020) Effects of a Transdisciplinary Educational Approach on Students’ Technological Literacy.  *Journal of Baltic Science Education*, 19(1), 121–141.

Sahlberg, P. (2013) Teachers as leaders in Finland. *Educational Leadership,*7(2), 36-41.

Saldaña, J. (2015) *The coding manual for qualitative researchers.* 3rd Edition*.* Los Angeles, CA: Sage.

Savin-Baden, M. and Howell Major, C. (2013) *Qualitative research: The essential guide to theory and practice.* London: Routledge.

Sfard, A. and Prusak, A. (2005) Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational Researcher,* 34(4), 14-22.

Shulman, L. (1987) Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review,* 57(1), 1-23.

Smyth, E., McCoy, S. and Kingston, G. (2015) *Learning from the evaluation of DEIS*. Dublin: The Economic and Social Research Institute.

Steen, L.A. (1997) *Why numbers count: Quantitative literacy for tomorrow's America*. New York: College Entrance Examination Board.

Steen, L.A. (1999) Numeracy: The new literacy for a data-drenched society. *Educational Leadership,* 57(2), 8-13.

Steen, L.A. (2001) Mathematics and numeracy: Two literacies, one language. *The mathematics educator,*6(1), 10-16.

Stoehr, K.J. (2017) Mathematics anxiety one size does not fit all. *Journal of Teacher Education*, 68(1), 69-84.

Sun, J. and Leithwood, K. (2015) Direction-setting school leadership practices: A meta-analytical review of evidence about their influence. *School Effectiveness and School Improvement,* 26(4), 499-523.

Thornton, S. and Hogan, J. (2004) Orientations to numeracy: Teachers’ confidence and disposition to use mathematics across the curriculum. In: M.J. Hoines and A. B. Fuglestad (eds), *Proceedings of the 28th Conference of the International Group for the Psychology of Mathematics Education*, Bergen Norway,14-18 July. Norway: University College, 4, 313-320.

Vasquez, J., Sneider, C. and Comer, M. (2013). *STEM lesson essentials, grades 3–8: integrating science, technology, engineering, and mathematics*. Portsmouth, NH: Heinemann.

Venkat, H. and Winter, M. (2015) Boundary objects and boundary crossing for numeracy teaching. *ZDM - The International Journal on Mathematics Education,* 47(4), 575-587.

Walshe, G., Johnston, J. and Goos, M. (2020). Promoting 21st century skills through STEM integration: A comparative analysis of national curricula. In: L. **Leite, E. Oldham, A.S. Afonso, F. Viseu, L. Dourado and M. H. Martinho. (**Eds) Science and mathematics education for 21st century citizens: challenges and ways forward. (Chapter 13) Nova publishers.

Wang, H.-H., Charoenmuang, M., Knobloch, N. A. and Tormoehlen, R. L. (2020). Defining Interdisciplinary Collaboration Based on High School Teachers’ Beliefs and Practices of STEM Integration Using a Complex Designed System. *International Journal of STEM Education*, 7(3), 1-17.

Withnall, A. (1995) Towards a definition of numeracy. Adults learning mathematics-a research forum, and ALM. In: Diana Coben (Ed.), *Proceedings of the inaugural conference of adults learning maths-a research forum,* Fircroft College, Birmingham, UK, *22-24 July 1994*. Goldsmith's College: University of London, 1995.

Yin, R.K. (2014) *Case study research: Design and methods.* 5th edition*.* Thousand Oaks, CA: SAGE.

Zevenbergen, R. (2004) Technologizing numeracy: Intergenerational differences in working mathematically in new times. *Educational Studies in Mathematics,* 56(1), 97–117.