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The Current State of Scientific Literacy in Wales

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The Current State of Scientific Literacy in Wales

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Abstract

Education leaders and political leaders worldwide are increasingly placing greater emphasis on developing scientific literacy in response to OECD's PISA testing. This is also the case in Wales where the results of the 2009 and 2012 scientific literacy tests were significantly lower than the rest of the United Kingdom.

This thesis considers interpretations of the term scientific literacy in Wales, including confusion over what the term actually means and an exploration of the potential of renaming it 'scientific competency' in order to minimise issues regarding current definition. An alternative definition is considered, in addition to an exploration of the current methods of measuring and improving it within the country. A post-positivist approach was adopted in the research. Data were collected through questionnaires, semi-structured interviews and a case study. The analysis of data revealed that Welsh science teachers often had inadequate skills and understanding regarding scientific literacy and this impacted directly upon their ability to measure and improve it within their lessons. This was due to teachers' perception of a lack of guidance and training.

Although there was substantial consensus about the importance of science and scientific literacy to pupils, this was not adequately translated into scientific literacy practices within schools. Large scale educational reform has led to an emphasis on literacy and numeracy skills, but there has been limited focus on science education. In addition, the Welsh education system and its lack of standardised testing may have produced a lack of rigor within science, leading to a decrease in attainment.

The study has implications for the professional development of Welsh science teachers and the general teaching of Science within the country and beyond.

Key Words: scientific literacy, Wales, OECD, PISA

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Abbreviations and Specialist Terms

There are a number of specialist terms used throughout this thesis and these are outlined in Table 1.

Table 1: Specialist educational terms and abbreviations used throughout this thesis.

Term	Further Information
DfES	The Department for Education and Skills (DfES) (Yr Adran Addysg a Sgiliau) is a Welsh Government department that is responsible for education, training and children's services in Wales. This responsibility comes from powers devolved from the Department for Children, Schools and Families of the UK government under Schedule 5 of the Government of Wales Act 2006. It is headed by the Minister for Education and Skills, who at the time of writing was Leighton Andrews until 25 June 2013, before being replaced by Huw Lewis (Welsh Government, 2014a).
Key Stage 3 and 4	The terms Key Stage 3 and Key Stage 4 refer to stages of schooling within the school system of Wales, and encompass ages 11-14 and 14-16 respectively. The school years within these Key Stages are referred to as Year 7, 8 and 9 in Key Stage 3, and Years 10 and 11 in Key Stage 4. Year 1 to Y6 (KS1 and KS2) is considered as primary education, and Y12 and Y13 (KS5) is post-compulsory education (National Foundation for Educational Research, 2010).
STEM	STEM subjects are those in the domain of Science, Technology, Engineering and Mathematics. It is a Welsh government target to increase uptake of STEM subjects in schools, especially in girls (Chwarae Teg, 2014).
The National Curriculum	The National Curriculum is a document which outlines what is to be taught in schools. It was first introduced in 1988 by the Government, though it has been regularly revised. In Wales, a new revision is currently underway, ready for implementation in 2015 (Jones, 2015).
Estyn	Estyn is the Welsh equivalent of Ofsted and is the education and training inspectorate for the country. Its name is derived from the Welsh verb meaning "to extend". Its role is the provision of independent inspections and advice on the quality of education within Wales (Power, 2015).
National Reading and Numeracy tests	The National Reading and Numeracy tests were statutorily implemented in May 2013 for all Years 2 to 9 pupils. Previously, most schools used commercially produced reading and numeracy tests so the introduction of

Term	Further Information
	the National Reading and Numeracy tests provided standardisation. The tests complement the National Literacy and Numeracy Framework (LNF) and designed to track the progress of reading and numeracy skills from Year 2 (i.e. the end of the Foundation Phase) through to Year 9 (the end of Key Stage 3). The standardisation of the tests fit a normal distribution with a mean of 100 and a standard deviation of 15, thus meaning 68% of pupils will achieve a score of between 85 and 115 (Welsh Government, 2013).
WJEC	The Welsh Joint Education Committee (WJEC) is an examination board that will be the only provider of external assessments in Wales from 2015 (Welsh Government, 2014d).
GwE	The Gwasanaeth Effeithiolrwydd a Gwella Ysgolion Gogledd Cymru or North Wales School Effectiveness and Improvement Service works alongside Local Authorities in North Wales to develop excellent schools across the region.

1 Background to the Study

This chapter explores the rationale behind the research and how it came to be conducted, the potential significance of the study and the research questions. It also includes information about the researcher background, key terminology and a brief overview of the chapters.

1.1 Overview

Over the past few years, the idea of scientific literacy and its importance to technologically advanced societies has been a focus of a great amount of research (Bybee, 2015). The Organization for Economic Cooperation (OECD) offers a comprehensive definition of scientific literacy as:

"The ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person, therefore, is willing to engage in reasoned discourse about science and technology which requires the competencies to: explain phenomena scientifically; evaluate and design scientific enquiry and interpret data and evidence scientifically" (OECD, 2013).

Other literature suggests that to be scientifically literate is having the ability to apply both scientific content and process skills to personal, local, national and global issues, and an informed responsibility when making decisions that affect these (Bauer, 1994, Bybee et al., 2009, Eijck and Roth, 2013, Galbraith et al., 1997, Hodson, 2005, Holbrook and Rannikmae, 2009, Kelly, 2007, Laugksch, 2000). A more detailed consideration of the definition of scientific literacy is given in section 3.3, but all research is broad in its agreement of the importance of scientific literacy. Individually, there are intellectual and moral benefits achieved by people when they become scientifically literate (Hodson, 2008), whereas on a larger societal scale, it is important for all citizens to be scientifically literate in order to be able to understand and contribute to any scientific issues that may arise (Jenkins, 1999), thus improving the economic wellbeing of a nation (Hodson, 2008).

1.2 Significance of the Study

Alongside numeracy and reading, Scientific Literacy is tested on a global scale by the OECD's PISA tests (OECD, 2006). These take place on a three-year cycle with a rotation of which strand is the major focus. The most recent tests took place in 2012, where Wales' performance in science was placed at joint 36th, a drop of six places from the 2009 tests. Wales' score was significantly below the OECD average (Wheater et al., 2013), with the mean pupil score decreasing since PISA 2009 (Wheater et al., 2013). In addition, there was no significant difference between the mean scores of England, Scotland and Northern Ireland in 2012, but Wales again scored significantly lower (Wheater et al., 2013).

The disappointing results of the PISA assessments may suggest that Welsh pupils lack the skills and competencies required to address the personal and economic development strategies of the country. As a result, the 2009 and 2012 OECD PISA test results were a major factor in promoting change in the education system of Wales and have been the trigger of numerous new initiatives such as the National Literacy and Numeracy Framework (LNF), a school banding system and a complete overhaul of the National Curriculum. This education overhaul has placed greater emphasis on literacy and numeracy skills. However, despite scientific literacy also being a strand of the PISA tests, there has been less emphasis in this area, perhaps due to the ease in which literacy and numeracy can be targeted in *all* subjects.

With the introduction of the new Welsh National Curriculum and the examination body reform (Donaldson, 2015), an opportunity arises to explore the potential of intentionally developing teaching techniques focussed on the development of scientific literacy, and whether the current emphasis on scientific content is necessary in producing scientifically literate pupils. The advent of the revised Welsh education system puts Science teachers in a position where they can influence teaching strategies, and it is important that any changes are informed by current research. If the significance of scientific literacy is fully appreciated, future Science students will be advantaged, with the associated knock-on economic contributions (Hodson, 2005). Across the world, there seems to be consistent agreement that producing scientifically literate youngsters is important (Bybee, 2015, Kolstø, 2001, Laugksch, 2000, Thomas and Durant, 1987), and with the current educational reforms that Wales is undergoing (Welsh Government, 2014d), the country is in an ideal position to try and improve this.

This research attempts to provide background information that may be used as a reference to develop an effective science curriculum that facilitates an improvement in scientific literacy levels, thus allowing Wales to become a major competitor in the OECD PISA tests.

1.3 Researcher Background and Motivation for the Study

This study is motivated by my interest and involvement in science education. I have taught science at the secondary level for seven years initially as a teacher of Biology and Physics and latterly as Head of Biology in my current position. I have taught the full age and ability range in a number of different courses and have been the science representative on the literacy and ICT working parties within my school. These experiences have been instrumental in exposing me to issues involving scientific literacy within Wales.

As a result of the 2009 and 2012 PISA results (Bradshaw et al., 2010, Wheater et al., 2013), Wales has seen some of the biggest changes in its educational history, but relatively little in terms of direct intervention in the development of science education. Instead, the initial focus has largely been on literacy and numeracy through the development of the National Literacy and Numeracy Framework (LNF) (Welsh Government, 2013), a statutory initiative designed to help teachers embed literacy and numeracy into all subjects. Currently, there has been little focus on scientific literacy, although this may be implemented once the LNF is fully embedded.

The teaching of English language literacy in secondary schools has traditionally been seen as the role of the English teacher, and not part of a Science teacher's job description (Alvermann et al., 2011) but there is now a requirement for literacy to be a part of every secondary lesson. However, this is *not* the same as scientific literacy, and this is where the issue lies. Despite being a science teacher and working with a number of different individuals across a wide range of schools, during meetings, I felt that there was often confusion surrounding the term 'scientific literacy'. This confusion seemed to be widespread, including both older and newer teachers, different subject specialisms and different workplaces. Prior to starting my research, I suspected that my colleagues were teaching literacy through the medium of science - rather than scientific literacy - in order to fulfil school and government level expectations for the LNF. Alongside other subjects, science lessons must incorporate both literacy and numeracy teaching (Welsh Government, 2013). Interactions with colleagues in both my own school and in other Welsh schools when attending training sessions suggested that this problem might be common throughout the country. When first considering an area for my research, a detailed search showed that there was a shortage of guidance and resources for the development of scientific literacy within Wales. As a science teacher, I am passionate about improving the delivery of my subject and enthusing pupils to be as passionate as myself. Therefore, this research was triggered by my belief that educators should be improving the scientific literacy of their pupils, especially when considering Wales' PISA results, but I felt that there was both a lack of understanding and support regarding scientific literacy to be able to do this.

1.4 Research Questions

The research explores three linked questions, which are central to an evaluation of the current status of scientific literacy within Welsh schools.

Research Question 1

What are teachers' interpretations and perceptions of scientific literacy in Wales?

Research Question 2

What methods are used for measuring and improving scientific literacy in Wales?

Research Question 3

What factors support or hinder the development of scientific literacy in Wales?

I spent a long time in considering these questions, but the wording and focus of them was developed relatively quickly. The most time-consuming aspect of the process was ensuring that the questions could be answered within an appropriate timeframe and with the resources I had available.

The questions themselves developed from my desire to understand how other teachers and education professionals consider scientific literacy. From a professional point of view, I was interested in whether the issues I was facing in my lessons were being faced elsewhere. I was also curious about how scientific literacy is being measured and improved within Wales. I wanted to learn about good practice, and see if there were areas where scientific literacy was being improved to a high standard. After speaking with members of my department, it was obvious that my colleagues also wanted to improve their own teaching and the learning of their pupils, but felt that there was a lack of guidance. We were having departmental meetings where we were sharing "good practice", but none of us knew if what we were sharing *was* actually good practice. Working in a school can be a very insular experience, so an exploration of what happens elsewhere in the country could only ever be advantageous.

Finally, in light of the development of the LNF and the recent focus on literacy and numeracy throughout schools, I felt that scientific literacy should be considered at the same level as literacy and numeracy. After all, they are equal strands within the PISA tests, so I was curious as to how this strand could be further be developed within the country, potentially providing some valuable information to policy makers involved in any future scientific literacy work. The process of developing these questions is discussed in further detail in section 4.2.

1.5 Overview of the Thesis

Chapter 2 of this thesis consists of a literature review that informed the research design, implementation, and final interpretation of the research. Part one outlines the history of science education. Part two discusses the term scientific literacy and its rationales and potential barriers to its successful implementation. Part three outlines the background to the UK education system, making comparisons with the differences found in Wales. Part four considers the OECD PISA tests and potential flaws behind its implementation.

In Chapter 3, I describe the research design of this thesis, presenting the theoretical model underpinning the research and outlining the methods used to collect and analyse data, including questionnaires, semi-structured interviews and reinterviews where the interviewed participants were reinterviewed a year after the original interview.

Chapter 4 comprises the results of the study. The results reported here include the qualitative and quantitative analysis of the questionnaires, semi-structured questionnaires and reinterviews.

Chapter 5 consists of the discussion, which considers the analysed data with reference to the three original research questions. Aspects of the research design intervention are summarised and developing theoretical perspectives from the research are also summarised. A discussion of the results in relation to the literature review is made, and developing themes are discussed, in addition to problems identified during the research process.

Finally, Chapter 6 outlines the conclusions of the thesis and discusses the limitations and implications of this work for teaching science in Wales. Issues arising from the research are discussed and areas for further research are identified.

1.6 Summary

The purpose of this chapter has been to introduce the reader to the research, a consideration of my professional background and my motivation for the study, before outlining the research questions and the structure of the thesis.

2 Review of Literature

2.1 Introduction

The literature review is broadly split into fourteen separate sections.

The first section will consider the general history of science education in the UK, before the second places particular focus is placed on the definition of the term 'scientific literacy'. The third section considers the importance of scientific literacy to science education and the rationales behind its delivery, with the fourth considering the potential barriers to this process.

The fifth section outlines the structure of the UK education system, with particular focus being placed on the educational reforms in Wales. This is expanded upon in section six with an explanation of the current literacy levels in Wales.

The educational reforms mentioned in section five is largely in response to Wales' poor PISA results. Consequently, section seven explains the history and rationale of OECD's PISA testing, with particular focus on the scientific literacy subsection of the PISA tests. Shortcomings of the PISA tests are outlined in section eight and the Welsh PISA scientific results are explained in section nine, with potential reasons for those results being suggested in section ten.

Section eleven looks at current literacy policies within the Welsh education system, and the impact of PISA on these. Section twelve outlines the role of science teachers in delivery scientific literacy and how professional development is used to improve this. Section thirteen considers a more general explanation of how scientific literacy is currently being improved, and how this process could be developed. Finally, section fourteen summarises the findings on the literature review.

2.2 History of Science Education

Prior to 1500, any scientific understanding was based on the philosophical workings of Thales of Miletus and Aristotle (Lloyd, 2012). This relied on trying to find naturalistic explanations for phenomena, rather than relying on mythology (Toplis, 2010, p.35). The sixteenth century is considered to be the dawn of modern science in Western civilisation (Restivo, 1988), with the period of time between 1500 and 1800 being deemed a "scientific revolution" (Hall, 1954).

William Sharp has the accolade of being the first public school science teacher (Williams, 2012). A physician and homeopath by trade (Sharp, 1856), his sons attended Rugby School. In 1847, he persuaded the Headmaster that Science should be taught to the boys attending the school and was offered the post until his resignation in 1850.

It was not until 1867 and the publication of *On the best means for Promoting Scientific Education in Schools* by the General Committee of the British Association for the Advancement of Science (BAAS) that any consideration was given to teaching Science to the “industrial classes” (Betts, 1998). The BAAS was established in 1831 with the aim to increase understanding of the importance of Science (Withers et al., 2006). However, despite the efforts of the BAAS and a campaign by the Clarendon Royal Commission (Shrosbree, 1988, p.64), the 1868 Parliamentary Select Committee opposed Science teaching in schools (Baron, 2003).

Until 1902 and the arrival of the Education Act (Eaglesham, 1962), any teaching of Science in schools was largely “chaotic” (Timmons, 2001, p.110). Problems included a lack of understanding about what should be taught, a shortage of specialist teachers (Williams, 2012) and scarcity of resources (Timmons, 2001). The 1902 Education Act implemented Local Education Authorities and sought to build up an organised system of national education (Jenkins, 1978). This was consolidated by the 1904 Secondary Regulations which created the introduction of a standardised academic curriculum (White, 2009) that included Science.

Science became a core part of school education in 1989 with the advent of the National Curriculum (House of Commons, 2002). Despite a few revisions of the National Curriculum, science education is now an integral part of the British education system (Holbrook and Rannikmae, 2007), and is considered a ‘core subject’ alongside Mathematics and English (Ruthven et al., 2004).

2.3 Definition of Scientific Literacy

The term 'scientific literacy' has become increasingly prominent when discussing the aims and purposes of school science education (Millar, 2006) and is perhaps the most popular one used when describing the preferred outcomes of science education in schools (Linder et al., 2010). The attainment of scientific literacy for all pupils is one of the main goals of the recent reform in science teaching (van Eijck, 2010). Nevertheless, there is no standardised definition of scientific literacy (Meichtry, 1999, Dawson and Venville, 2009) and educators often disagree over exactly what it is (Eijck and Roth, 2013). This is despite its recent increase in popularity (Linder et al., 2010) and its status as a "key theme" across the world (Erduran and Wong, 2013).

Scientific literacy has been defined in many different ways (Bybee, 1997) since the term was first used in the late 1950s (Dillon). One of the earliest cited examples of scientific literacy was in Paul Hurd's 'Science Literacy: Its Meaning for American Schools' (Hurd, 1998). However, earlier examples of the term have been found, such as Meister (1949, p.9), Carleton (1951, p.104) and Boell (1952, p.139) meaning that it has been considered an integral part of science education for much longer than first anticipated. Nevertheless, these early pioneers of the scientific literacy movement never provided a definition for the term (Laugksch, 2000, Dillon, 2009). Some authors have started to consider 'scientific literacy' to be an educational slogan or a metaphor (Bybee, 1997) whereas DeBoer (2000) notes that "to speak of scientific literacy is simply to speak of science education itself". Nevertheless, any definitions of scientific literacy are often not mutually exclusive (van Eijck, 2010) to such an extent that the term is often "ill-defined and diffuse" (Laugksch, 2000, p.71). Scientific literacy has been variously considered as being: knowledgeable about science (Mayer, 1997); understanding science (DeBoer, 2000); or simply being able to read and write about science (Glynn and Muth, 1994). The National Research Council (1996) describes scientific literacy as an individual being able to use their scientific knowledge and evidence to infer, allowing them to process information. Uno and Bybee (1994) neatly described four strands of scientific literacy:

- *nominal*, where individuals understand scientific terms;
- *functional*, where individuals can apply known scientific terms to various phenomena;
- *structural*, where individuals are capable of undertaking scientific enquiry due to an understanding of scientific concepts; and finally,
- *multidimensional*, where individuals are capable of making scientifically informed decisions.

In the 1950s, more emphasis was placed on the importance of scientific knowledge to society. Those individuals who were well versed in science would have a greater likelihood of being successful in a time where there was accelerated technological development. This new emphasis was coined as "scientific literacy" and considered to be the new purpose of science education (Laugksch, 2000). In the late 1960s, this new role of science education began to become diluted as science teachers started to consider scientific literacy as the knowledge of science content (DeBoer, 2000). Over this period of time, there was still no clear definition for the term.

During the 1970s, the prominence of teaching science content was starting to affect school science. There was increasing concern that the emphasis on teaching science content was affecting the original goal of scientific literacy (DeBoer, 2000). In the 1980s, the *Science-Technology-Society* curriculum was developed in the USA (Dillon, 2009) with the aim of promoting how science and technology interacted with general society. Any current scientific social issues such as the environment or areas of public health were to be at the forefront of the curriculum development. However, this was badly received by science teachers in the classroom, as they had the belief that science content should form the basis of classroom teaching. This discord fuelled the US science education reform in the 1990s (DeBoer, 2000)

Some came to view scientific literacy as being the ability of individuals to be taught and understand the nature of science, in addition to the scientific content. This is summarised as the *"education through science"* model outlined by Holbrook (2010) and focuses on relating science to the requirements of society. This involves aspects of learning such as problem solving, creativity, perseverance and team working in addition to scientific knowledge. As Norris and Phillips (2003) commented, students need knowledge to intelligently participate in any scientific social issues.

In 2000, the Organisation for Economic Co-operation and Development (OECD) ran their first worldwide Programme for International Student Assessment (PISA) tests with scientific literacy being one of the three core domains being tested, alongside reading and mathematics. These tests are discussed in more detail within section 3.8. The original OECD definition of scientific literacy is: *the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and make decisions about the natural world and the changes made to it through human activity"* (OECD, 2000).

This definition was then expanded upon in the later tests that took place during 2006 and 2009. "*The capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity"* (UNESCO Institute for Statistics and OECD, 2003, p.21, OECD, 1998). This definition has been criticised in some quarters due to it being used as validation for an internationally recognised test, although Holbrook and Rannikmae (2009) do go on to say It is appropriate for school science education. However, according to DeBoer, scientific literacy should not be restricted to a basic understanding of scientific principles, but should also encompass an appreciation of science. Essentially, scientific literacy should be "*synonymous with the public's understanding of science"* (DeBoer, 2000, p.594).

In 2013, the draft framework for the 2015 PISA tests was published, recognising the issues surrounding a definition for scientific literacy. OECD's new 2015 definition of scientific literacy is: "*the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen"* (OECD, 2013), the definition now seemingly distancing itself from any specific mentioning of science content and knowledge. This is a change from an internal understanding of scientific processes, to a more external one (Lederman and Abell, 2015).

Norris and Phillips (2003) went even further and considered scientific literacy to have core facets: *"(a) knowledge of the substantive content of science and the ability to distinguish science from non-science; (b) understanding science and its applications; (c) knowledge of what counts as science; (d) independence in learning science; (e) ability to think scientifically; (f) ability to use scientific knowledge in problem solving; (g) knowledge needed for intelligent participation in science-based social issues; (h) understanding the nature of science, including its relationship with culture; (i) appreciation of and comfort with science, including its wonder and curiosity; (j) knowledge of the risks and benefits of science; and/or (k) ability to think critically about science and to deal with scientific expertise"* (p. 225).

In response to more recent technological advancements, Holbrook (2010) mentions that science education should reflect the role that science has in technology. He suggests an entirely new term: '*scientific and technological literacy'* that focuses on important technological and societal developments, rather than placing an emphasis on scientific content.

There is one very different understanding of scientific literacy, as outlined by Yore, et al. (2003). Their focus is on language usage in science, saying *"language is an integral part of science and scientific literacy"* (p.691). They consider language as an implicit part of science as it allows individuals to be able to do, understand and communicate science. All students of science will be required to use written and spoken language to communicate and understand ideas. This view of scientific literacy has been coined explicit literacy or 'disciplinary literacy' (Freebody et al., 2008). This disciplinary literacy approach has an expectation that science teachers explicitly teach literacy within the subject, providing pupils with literacy strategies that improve their ability to speak, read and write scientifically.

Murcia (2009) suggested a metaphorical, hierarchical system of scientific literacy development. Individuals must start with a basic knowledge of science and its associated concepts, before progressing on to the nature of science and then understanding how science has an impact on society. Taking these three hierarchies of scientific literacy, plus an emphasis on literacy within science as mentioned by Yore, et al. (2003) could potentially allow pupils to develop both the knowledge and relevant communication skills necessary to act as responsible citizens (Holbrook and Rannikmae, 2009).

All of these definitions allow the term to be broadly considered in two ways. The first is a fundamental sense where pupils can read and write scientifically (Millar, 2006). However, this is more than the ability to simply read and write about science and technology (Miller, 1998) and should involve pupils being able to comprehend, interpret, analyse and critique, meaning that literacy in the fundamental sense is central to scientific literacy as a whole (Norris and Phillips, 2003). The second form of scientific literacy is a derived sense where pupils are knowledgeable about scientific matters (Norris and Phillips, 2003, Fang, 2005, Millar, 2006, Yore et al., 2007). This includes understanding of the nature of science, scientific inquiry and unifying concepts of science (Hand et al., 2003). Many current ideals of science literacy often focus on the derived sense of scientific literacy while ignoring the fundamental sense (Fang, 2005). However, Yore (2007) determines that there is a clear link between the fundamental and derived senses. Each sense stimulates the other, with the fundamental sense being dependent upon the derived sense (Kelly, 2007): "*Reading and writing when the content is science [is] the fundamental sense of scientific literacy, and being knowledgeable, learned, and educated in science [is] the derived sense of scientific literacy"* (Norris and Phillips, 2003, p.224)

It is clear that there are huge differences in the level of understanding of the term scientific literacy, and yet it is still well used. DeBoer (2000) fully understood the controversy surrounding the contentious term of scientific literacy and so omitted the term from the goals of science education. Instead, he outlined nine main goals of science education (pp. 591-593), omitting scientific literacy. It is apparent that the term is almost misleading, giving the impression that it is relatively simple but the fundamental concepts are so numerous and complex, with multiple interpretations, that it is a far more multi-faceted idea than may be expected. It was even placed on the same level as the terms "justice" and "liberty" by Laugksch (2000) due to its controversial complexity.

2.3.1 Wales-specific definition of scientific literacy

In 2014, the Welsh Government published a guide to Scientific Literacy, in preparation for the 2015 PISA tests. This document outlined that Scientific Literacy "requires core knowledge of the concepts and theories of science. It also requires knowledge of the common procedures and practices associated with scientific enquiry, and how these enable science to advance" (Welsh Government, 2014c). This has simply been taken from the PISA documentation (OECD, 2013), rather than being a Wales-specific interpretation of Scientific Literacy.

Currently, Key Stage 3 Science in Wales largely follows a similar model to the one outlined by Holbrook (2010), despite the former being implemented prior to the publishing of Holbrook's paper. This is outlined in further detail during section 3.6.1.1. Briefly, the KS3 Welsh curriculum is currently skills based and there is less emphasis on content and more focus on particular skills. It is more education through science, rather than science through education. However, Key Stage 4 is more content driven due to the expectations of the GCSE and A Level exams.

2.4 Rationales for Scientific Literacy

As a subject, Science is an indubitable part of the curriculum in most countries, and has been part of the UK National Curriculum since its advent in 1989 (House of Commons, 2002). The importance of Science has been repeated by scientists themselves, but also politicians and educationalists. The central theme of these arguments has been the economic importance of the subject. To ensure the scientific infrastructure on which the country depends and guarantee national security and economic success (Millar, 2011), an education system should support the development of scientifically literate students who can enter the scientific community. The National Curriculum offers a standardised programme that provides early training in Science that is intended to fulfil that need.

However, is this an effective methodology? Is it a good idea to make every 15-16 year old study the same Science curricula when not all will fully benefit? Is it possible to develop students into scientists by all individuals following the same science curriculum? As Ogborn notes, “A central fact about science is that it is actually done by a very small fraction of the population. The total of all scientists and engineers with graduate level qualifications is only a few percent of the whole population of an industrialised country. Thus the primary goal of a general science education cannot be to train this minority who will actually do science” (Ogborn, 2004, p.70).

Thomas and Durant (1987) identified a range of rationales for scientific literacy that can be considered broadly at individualistic and societal levels. Individually, there are a number of reasons that focus on the intellectual and moral benefits achieved by people when they become scientifically literate (Hodson, 2008). This results in people that are well skilled and knowledgeable who have greater access to a wide range of career prospects (Hodson, 2005), especially as many economies are becoming more knowledge-based (Laugksch, 2000). Scientifically literate individuals are also better able to cope in a technological society (DeBoer, 2000), can respond effectively to any scientific arguments they are presented with (Miller, 1998) and are well equipped to make important decisions about many aspects of their lives (Laugksch, 2000).

Within society, there is a belief that it is important for all citizens to be scientifically literate in order to be able to understand and contribute to any scientific issues that may arise (Jenkins, 1999). This was termed “scientific literacy in the wild” by Eijick and Roth (2013). It allows individuals to possess the skills that enable them to distinguish evidence from propaganda, observation from inference and knowledge from opinion (Boujaoude, 2002) and allows them to become involved in public decisions (Sadler and Zeidler, 2009). Individuals that live in a scientifically literate society have a disposition to think critically (Norris and Phillips, 2003) in addition to the ability to challenge the direction of scientific innovation (Hodson, 1994) and there is a distinct and pervasive economic argument regarding the necessity of a scientifically literate population (DeBoer, 2000). Hodson (2008) regards scientific literacy as a "form of human capital that sustains and develops the economic wellbeing of a nation" (p.8). Examination boards are responding to this need of having 'scientifically literate' individuals and market particular GCSE science courses accordingly. For example, Oxford, Cambridge and RSA Examinations' (OCR) Twenty First Century Science course states that "most people are unlikely ever to be producers of new scientific knowledge. But we all need to be informed users and consumers of scientific knowledge. For this we need to understand [both] ideas about science which show how science works [in addition to] science explanations which help us to make sense of our lives" (Nuffield Foundation, 2015).

There is also a belief that scientific literacy enriches the cultural and intellectual life of the nation (Laugksch, 2000) and has the capacity to enhance democracy and encourage responsible citizenship (Kolstø, 2001). For example, some authors believe that an improvement in the scientific literacy of individuals can lead to more ethical behaviour in the wider community (Shortland, 1988) as science is often the logical application of respected human values such as integrity, fairness, curiosity and imagination (AAAS, 1989, p.201).

2.5 Potential Barriers to Development of Scientific Literacy

2.5.1 Language in Science

International surveys have shown that worldwide, approximately 90% of school children learn science using some form of text (Peacock and Gates, 2000). Therefore, It is clear that one of the important features of science is the plethora of the words and terms it uses (Wellington and Osborne, 2001) and the learning of science has been compared to learning a new language (Henderson and Wellington, 1998). However, this wide range of vocabulary can often be a major barrier to pupil achievement (Wellington and Osborne, 2001), especially as children often lack the conceptual knowledge required for the comprehension of scientific terms (Best et al., 2006). In addition, scientific literature bears little resemblance to normal literary form and has developed its own semantics (Lemke, 1990). Verbs or entire sequences of events can be replaced with nouns, for example 'evaporation', and nouns can be used as adjectives (Koba and Mitchell, 2011). Research on the comprehension of the technical text found in science often discovers that a lack of comprehension by pupils is due to individuals being unable to amend their own knowledge to comprehend the new information being presented (Van Dijk, 2011).

Science has created a wealth of terms that are now in common usage and are commonly used by pupils and the general public (Gilbert et al., 1982) and many words regularly used in science have 'dual definitions' whereby a word has one meaning in a scientific setting and another everyday meaning (Prain, 2006). Some words are simply synonyms for common words that are already familiar to pupils (Brown and Spang, 2008), such as trachea rather than windpipe, or saliva in place of spit. Therefore, a part of learning and understanding science involves giving familiar objects new names. However, sometimes pupils are required to learn names of objects which they may have never seen, either through physical impossibility or through simple unfamiliarity. Other words such as 'distillation' and 'photosynthesis' denote processes that happen in science (Wellington, 2002). These are abstract terms and so are understood more easily than others by pupils if they are able to be demonstrated by the teacher. These allow such ideas to be more firmly understood as they can be *seen*. Finally, concept words such as *work, evolution and temperature* are gradually understood in more depth by pupils as they explore and discuss the scientific theories surrounding them (Lynch and Dick, 1980). The wide range of vocabulary and specialist terms regularly used in science can make language one of the biggest barriers to learner understanding and without this, pupils can experience difficulty and a lack of enthusiasm towards the entire subject (Young, 2005).

When accessing any scientific text, such as when using a textbook, learners have to process text, images, schematic drawing, photographs and underlying concepts at the same time (Peacock, 2001). Thus, any illustrative sections are not just supportive of the written text, but can sometimes contain most of the information. Science texts for British children exists in a wide range of forms, including story books, workbooks, expository text, comic books and packaged schemes which incorporate and combine text with images in complex ways (Peacock and Gates, 2000). Therefore pupils must use an integrative approach when accessing any multi-modal text (O'Halloran, 2006). Pupils are also faced with the differences in scientific literature within school and outside of school. The authors of textbooks are scientists that have to write for different audiences and the terminology utilised within textbooks and publications designed for the scientific community are often dissimilar (Hand and Prain, 2006). In addition, being literate in Science also requires a firm understanding of many mathematical principles (Hodson, 2008). For example, pupils need to be familiar with algebraic equations or be able to interpret graphical data or statistical information in order to fully understand the topic they are studying (Norris and Phillips, 2003).

How pupils 'position' themselves in relation to the scientific text that they are accessing also affects their ability to understand it. Norris and Phillips (2003) considered two different scenarios here. Firstly was an individual taking a 'dominant stance' towards the information? In this situation, the individual allows their previous knowledge to shield the information being given. Secondly, a 'deferential stance' can be taken. This results in an individual having an acceptance of whatever is written in the text, even if it opposes their previous knowledge. This latter situation is often the case within science lessons, where the teacher and textbook are considered to be 'right' and the pupil is unable to challenge this (Kalantzis and Cope, 2012). Furthermore, if a pupil has been attending science lessons where there is a lack of focus on scientific literacy, then students will be unable to challenge the information being presented.

2.5.2 Constraints of Science Lessons

The content of science lessons is dictated by the National Curriculum (DCELLS, 2008). Many authors have argued that the current National Curriculum is not conducive to effective Scientific Literacy (Oates, 2011, Millar, 2011, Donnelly, 2001) as it is too prescriptive and can limit many teachers. In the 1999 revision of the National Curriculum, bureaucracy forced the content of the Key Stage 4 science curriculum to fit onto two sides of A4 paper, so it would correspond with other subjects (Millar, 2011). This produced a vague document that is largely too broad to adequately direct educators or exam boards in what should be taught and assessed. There is a competitive element to exam boards as schools can opt to move from one to another, in an effort to improve examination results due to the differences in syllabus specifications (Pollitt and Crisp, 2004). As early as 2002, the issues with the National Curriculum, in particular at Key Stage 4 were being noted by Dr Ian Gibson, chair of the House of Commons Committee on Science and Technology. He commented that:

"Science should be the most exciting subject on the school curriculum: scientific controversies and breakthroughs hit the headlines every day. But school science can be so boring it puts young people off science for life. GCSE science students have to cram in so many facts that they have no time to explore interesting ideas, and slog through practical exercises which are completely pointless".

These admissions of lacklustre science lessons within British schools are not conducive to effective improvement of scientific literacy. Nevertheless, although the National Curriculum is prescriptive to what is required to be taught, teachers should have the necessary skills to inspire, enthuse and motivate their students. If pupils are not inspired, then they will not engage within the lesson, leading to lower attainment. Motivating and enthusiastic teaching is therefore key to ensure success.

Textbooks may also be problematic. Publishers work closely with exam boards to produce 'endorsed' textbooks that can be as limiting as the National Curriculum they are guided by. Most topics are restricted to a 'double page spread', often at the publisher's request and therefore there is a limitation to the depth of knowledge that can be included. Key Stage 3 textbooks in particular have diverged away from content matter and now focus on facilitating tasks and activities. This is true of the most common school Science textbooks, despite it only being Wales that has a skills-based curriculum.

2.5.3 The Impact of Gender

In terms of general literacy, it has been well documented that boys perform at a lower level than girls on literacy tests (Watson et al., 2010). However, in Science, up until the age of 16, boys and girls reach similar levels of attainment in science and mathematics, although girls tend to outperform boys in other subjects. However, in the 2009 PISA tests, boys outperformed girls in Science in all regions of the UK, but this only became significant in Wales (Bradshaw et al., 2010). This also occurred during the 2012 PISA tests, where boys performed significantly better than girls by an average of 11 score points (Wheater et al., 2013).

Girls being less scientifically literate has been attributed to many different factors, such as girls having less peer support for their scientific interests than boys, which can consequently affect their motivation (Stake and Nickens, 2005). Crowley *et. al.* (2001) also found that parents were three times more likely to explain scientific concepts to sons than to daughters, thus meaning girls may lack vocabulary and understanding. Liebham (2013) found that early years boys had higher levels of interest in Science than girls, and also noted that boys did better on physical science questions and girls performed better on life science questions.

Interestingly, in terms of general literacy, in the 2014 Welsh National Literacy and Numeracy tests, girls outperformed boys in the National Reading Test with more girls than boys achieving a standardised score greater than 115. At the lower end of the scale, more boys than girls achieved a standardised score less than 85 in both versions of the National Reading Test (Hughes, 2014b).

2.5.4 Issues with Teaching

There has been some research on the impact of *teacher* misconceptions and their impact on science lessons (Concannon et al., 2013), and some studies have suggested that teachers demonstrate the very same misconceptions that their students have (Valanides, 2000). Teachers who lack subject knowledge are more likely to provide sub-standard answers to pupil questions and therefore, further misconceptions can develop when pupils are interacting with teachers (Gilbert and Zylbersztajn∗, 1985). This is particularly true when a specific science topic is being taught by a non-specialist (Childs and McNicholl, 2007).

2.6 The UK Education System

Across the UK there are five broad phases of education: early years, primary, secondary, Further Education (FE) and Higher Education (HE). Until the age of 16, education is compulsory. Further Education is not compulsory, but young people are expected to be in some form of training, education or employment until they are 18. Higher education is considered as studying beyond A levels and normally occurs in universities.

Nevertheless, there are slight differences between the education provision of the four UK member countries which are currently diverging even further after recent policy changes. The Welsh education system is explained in section 3.6.1. This is in large detail due to the immense changes that have occurred within the past few years in response to the 2009 and 2012 PISA results outlined in section 3.10.1.

2.6.1 The Welsh Education System

Since the devolution of Wales from England, the Welsh education system has diverged to promote its own distinctive education policy (Reynolds, 2008). Within Wales, there has been a particular emphasis on community-led comprehensive schooling. This has resulted in no academies, free schools or state grammar schools being established. Although there are a nominal number of foundation schools (schools which are state-funded but outside of local education authority control), the Welsh Government introduced new legislation to prevent further schools from changing their status to foundation status.

The school curriculum for ages 3-19 was introduced in September 2008 and was designed to be a flexible and learner-focused, with a specific emphasis on skills rather than subject content. Pupils aged between 3 and 7 follow the Foundation Phase, a largely Scandinavian-influenced curriculum that encourages experiential learning over more traditional, formal instruction (Maynard, 2013).

Wales do not administer the Key Stage 2 or 3 National Curriculum Tests (Standard Attainment Tests or SATs), although statutory teacher assessments are administered at the end of Key Stage 2 and Key Stage 3 (Hall and Sheehy, 2006). In contrast to England, Wales does not produce school league tables (Goldstein and Leckie, 2008). However, the Welsh Government have recently introduced a banding system that utilises a range of data to place schools into one of five broad bands (Burge and Lenkeit, 2015). Schools placed in Band 1 are considered to be good, showing progress, whereas those in Band 5 are considered to show the weakest performance and progress.

Until recently, Wales offered the same qualifications as England, but at the time of writing, Wales' assessment and qualification policies were beginning to diverge. To overview these changes, a new national body called Qualifications Wales was implemented to develop, regulate and award qualifications. From 2015, qualifications are being standardised and all schools in Wales will only be able to offer Welsh

Joint Education Committee/Cyd-Bwyllgor Addysg Cymru (WJEC/CBAC) courses at GCSE and GCE level. Wales also offers its own national qualification, called the Welsh Baccalaureate. Again, this is a heavily skills-based qualification that is studied during GCSEs and A-Levels. This qualification is currently also under review, ready for first awarding in 2015 (Dauncey, 2015).

Wales also has its own education inspection system called Estyn and is led by Her Majesty's Chief Inspector of Education and Training in Wales (Murphy, 2014). Inspections occur every six years (Estyn, 2015). Nevertheless, new regulations are being implemented that is making it increasingly difficult to determine when a school will next have an inspection (Estyn, 2015).

Since 2011, education in Wales has had a direct focus on a "rapid response" to the PISA results, including an attempt to improve literacy and numeracy standards (ASE, 2014). In 2012, the National Literacy and Numeracy Framework (LNF) was introduced throughout the country, which ensures that basic literacy and numeracy skills are embedded throughout the curriculum, regardless of subject. This Framework is discussed further in section 3.12.1.

These recent education reforms led to a reduction in specific subject support (i.e. subject advisors) and now rely more heavily on schools supporting each other (ASE, 2014). From 2015 to 2016, changes to the curriculum and the associated assessment will be implemented, which is planned to have a greater focus on literacy, numeracy and wider skills such as Problem Solving (Welsh Government, 2014d).

2.6.1.1 The Welsh Science Curriculum

A general overview of the Foundation Phase to Key Stage 4 science curriculum is outlined in Table 2.

Table 2: An overview of the required skills and knowledge that pupils in Wales are required to have in Science (taken from (DCELLS, 2008))

Key Stage	Progression in science
Foundation Phase	Children should experience the familiar world through enquiry, investigating the indoor and outdoor environment in a safe and systematic way. They should be given experiences that help them to increase their curiosity about the world around them.
Key Stage 2	Pupils should develop their skills through the range of Interdependence of organisms, The sustainable Earth and How things work. Learners should be taught to relate their scientific skills, knowledge and understanding to applications of science in everyday life, including current issues. They should be taught to recognise that scientific ideas can be evaluated by means of information gathered from observations and measurements.
Key Stage 3	Pupils should develop their skills through the range of Interdependence of organisms, The sustainable Earth and How things work. Learners should be taught to apply their scientific skills, knowledge and understanding to design strategies, solve problems and offer explanations, relating scientific ideas to the information about them, including current issues. They should be given opportunities to study the work of scientists and to recognise the role of experimental data, creative thinking and values in their work and in developing scientific ideas.
Key Stage 4	Pupils should learn about the way that science and scientists work within society. They consider the relationship between data, evidence, theories and explanations and develop their practical, problem-solving and enquiry skills, working individually and in groups. They evaluate enquiry methods and conclusions both qualitatively and quantitatively, and communicate their ideas with clarity and precision. Learners develop their ability to relate their understanding of science to their own and others, decisions about lifestyles, and to scientific and technological developments in society.

2.6.1.1.1 Foundation Phase, Key Stage 2 and Key Stage 3

In 2008, the new Welsh science curriculum marked a revolutionary change in the way teachers planned and delivered science in primary schools (DCELLS, 2008). It was at the forefront of an increasingly pupil-focused methodology of teaching and was supportive of the new initiatives of improving pupil thinking skills. The 2008 curriculum changed Science to a non-statutory subject in the Foundation Phase, also removing the requirement to report on progress here. It was renamed as Knowledge and Understanding of the World in the Foundation Phase, or essentially the idea of “embracing science” as a reflection of these changes. It significantly reduced the amount of specific science content knowledge in Key Stage 2 and 3, in addition to also increasing the focus on science ‘skills’ and their assessment (DCELLS, 2008).

In 2013, Estyn completed a review of the standard of Key Stage 2 and 3 science teaching in Wales. Generally, the standard of teaching and learning was considered good, but it did have some concerns. These included more able and talented (MAT) pupils not being challenged enough and a reduction in the number of pupils achieving more than a level 5. They found that there was often insufficient support from education authorities or regional consortia. Regional consortia were developed in 2012 and stopped the control of individual local authorities' over school standards. Their mission is to improve attainment, and drive improvement (Halliwell et al., 2015). Estyn also found that schools often lacked a vision for Science as a subject. At primary school level, there was concern over the assessment of Science, particularly in relation to the reliability and validity of the teacher assessments. Both the lack of verification from external bodies, but also ambiguous assessment criteria were deemed to be problematic. They noted that many primary schools were not allocating sufficient time to teaching Science. In some cases, pupils were only getting one hour of Science teaching a week (Estyn, 2013).

2.6.1.1.2 Key Stage 4

Currently, pupils in Years 10 and 11 have a number of different science education routes they can take. These are outlined in Figure 1.

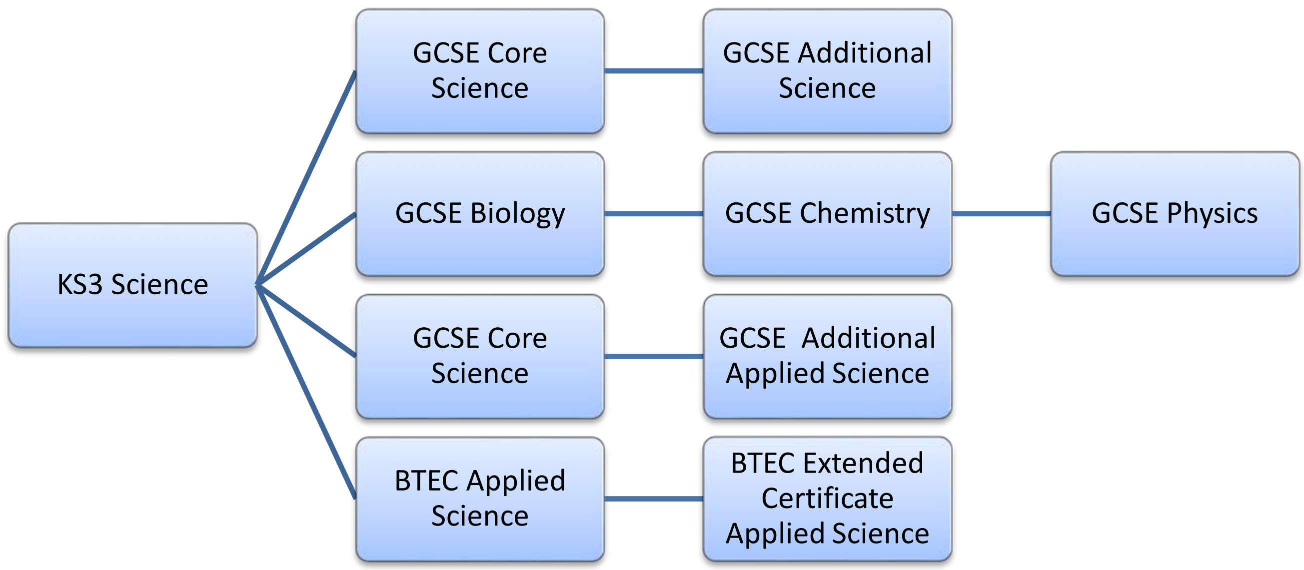

Figure 1: The different Key Stage 4 science education pathways that can be taken by 15-16 year olds in Wales

In 2008, Estyn completed a review of the standard of Key Stage 4 science teaching in Wales. Attainment in Science at Key Stage 4 is generally comparable to Mathematics but was significantly lower than English. They found that the proportion of pupils gaining a good GCSE pass (grades A* to C) is increasing in science, but at a slower rate than in Mathematics or English.

However, the future of Science at Key Stage 4 is currently being considered in preparation for change in 2016. The Welsh Government have indicated that GCSEs will be the only science-based qualifications that will be counted in any school performance measures (Qualifications Wales, 2015). The Welsh Government believe that GCSEs are widely understood and in particular, they are valued (Qualifications Wales, 2015). Therefore, if a pupil is capable of working towards a Level 2 qualification, then that qualification should be a GCSE. This is especially important as completing BTEC qualifications severely restricts pupils in any future choices they may make with regards to their science education (Donnelly, 2009). The full details of the 2016 science qualification changes are currently unknown.

2.6.1.1.3 Key Stage 5

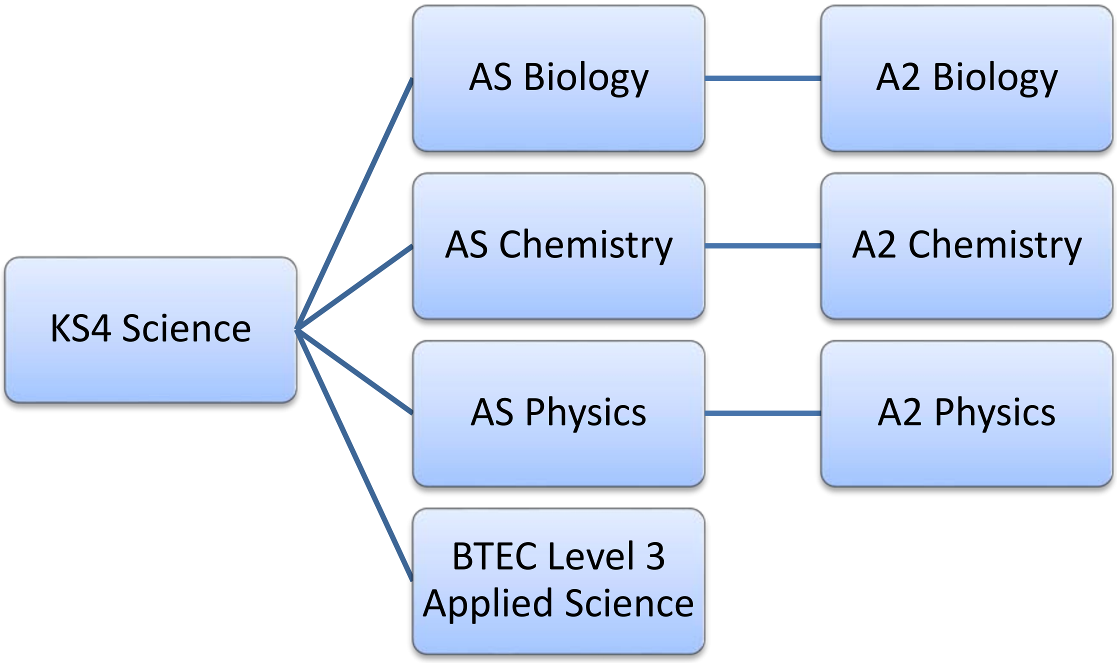

Figure 2: The different Key Stage 5 science education pathways that can be taken by 16-19 year olds in Wales.

Currently, students in Wales can study all three sciences at AS and A2 Level, or a Level 3 BTEC in Applied Science (Figure 2). However, after the Review of Qualifications for 14 to 19-year-olds in Wales was published in November 2012, these are being overhauled (Welsh Government, 2014d). From 2015, WJEC/CBAC will be the only organisation awarding the new A-Levels in Wales. After consultation, it has been decided that both AS and A2 will be retained as coupled qualifications, continuing the current procedure of an AS qualification counting towards the A2 qualification, although there will be a revised weighting of 40% instead of the current 50% (Qualifications Wales, 2015). All assessments will take place in the summer and a candidate will only be allowed to resit a unit once, again continuing current practice (Welsh Government, 2014d).

In the WJEC Science A-Levels, there will be greater emphasis placed on Mathematical skills (in the examinations, a minimum of 10% in Biology, 20% in Chemistry and 30% in Physics of questions will be numeracy based). Furthermore, there will be a statutory obligation to complete more practical work in each subject, with the introduction of student lab books and practical examinations (Welsh Government, 2014d).

2.7 Current Literacy Levels within Welsh Schools

Estyn's 2011 annual report on the standards and performance across education and training in Wales. found that in Wales, 40% of pupils arriving at secondary school have a reading age below their chronological age. Twenty percent have a reading age below nine years and six months, the functional literacy age, or the reading ability to be able to operate in society. A further 20% have reading ages that are between six and 18 months below their chronological age. (Estyn, 2011). This was in comparison to England, where the most recent data shows that only 13% of pupils have a lower than average chronological reading age (Parliamentary Office of Science and Technology, 2009). This disparity has been attributed to many factors, such as differences in pupil funding from the Government (Evans, 2011) and child poverty (Kellett and Dar, 2007).

Since 1998, England has historically had specific national strategies to improve literacy (Smith et al., 2004), but this is not the case in Wales. Teachers in Wales have had relative autonomy over their choice of teaching methods, but local authorities use different reading tests and these are implemented at different stages. Although Estyn collects the results, this produces data which is therefore not comparable.

2.7.1 National Literacy and Numeracy Framework and Tests

The National Literacy Numeracy Framework (LNF) was implemented by the Welsh Government in order to improve literacy and numeracy standards in Wales (Welsh Government, 2013). The LNF was first proposed by the Minister for Education and Skills in 2011 (Andrews, 2011) and became a statutory curriculum requirement from September 2013, with assessment against the LNF also becoming a statutory requirement from September 2014. As part of the LNF, pupils aged between 7 and 14 sit annual reading and numeracy tests, which are designed to help identify the most appropriate way to challenge and support learners in developing literacy and numeracy skills. As a result of these tests, each pupil receives an individual report at the end of the summer term (Welsh Government, 2013). The tests are designed as an assurance that the LNF is working in raising standards, although “whilst developed with careful reference to the expectations of the Literacy and Numeracy Framework, are tests of the National Curriculum and assess skills which learners should already be acquiring as part of that Curriculum. As such, they are independent of, but complimentary to, the LNF” (Dauncey, 2013).

2.7.1.1 Development of the National Literacy and Numeracy Framework

The National Literacy and Numeracy Framework is based on research into effective teaching, assessment, recording and reporting practice, and the success of similar international systems. The LNF is based on a system that is used in “parts of Canada” and was developed in partnership with an Association of Directors of Education in Wales (ADEW) advisory panel that consists of local authority literacy and numeracy advisers (Welsh Government, 2013). Nevertheless, there was no science specialist on the development team (Edwards, 2012).

2.7.2 Results from the LNF Tests

The first National Reading Tests took place in 2013, where 14.1% of Welsh pupils scored less than 85 as a standardised score. 15.5% scored above 115. Scores of less than 85 were regarded as being below the national average range, while scores greater than 115 are regarded as being above the national average range. A year after the implementation of a year's LNF, there was slight improvement, with 13.4% of pupils scoring less than 85 and 16.5% scoring above 115 (Table 3). In 2015, two years after implementation, there was only an improvement in the 85-115 scores.

Table 3: National Reading Test results for all pupils in Wales, taken from *Hughes (2013), **Hughes (2014b) and ***Hughes (2015)

		Standardised scores (% of pupils)		
Year	**Absent or disapplied**	**Less than 85**	**85 to 115**	**Greater than 115**
2013*	3.4	14.1	67.1	15.5
2014**	3.5	13.4	66.7	16.5
2015***	3.1	13.5	67.1	16.3

2.8 Program for International Student Assessment (PISA)

2.8.1 The History of the OECD

In 1948, the Organisation for European Economic Co-operation (OEEC) was created for the administration of American aid in the rebuilding of Europe after the Second World War. By the 1950s, the majority of reconstruction had been completed, and many countries felt that the OEEC was no longer required in its original state (Woodward, 2009). Instead, there was a suggestion that it could be used at a more global level to deal with economic issues (Godin, 2004).

In 1961, the original twenty founding members of the OEEC signed a convention to found a new organisation whose focus would be the development of economic policy (Schuler, 2010). The Organisation for Economic Co-operation and Development (OECD) was born. Over the next few years, the OECD expanded, leading to an organisation that currently has 34 member countries (OECD, 2014).

Table 4: The OECD member and partner countries. Countries in bold are the original founding countries of the 1961 OECD Convention.

OECD Member countries			OECD partner countries and economies		
Australia	**Austria**	**Belgium**	Albania	Argentina	Azerbaijan
Canada	Chile	Czech Republic	Brazil	Bulgaria	Chinese Taipei
Denmark	Estonia	Finland	Colombia	Croatia	Dubai (UAE)
France	**Germany**	**Greece**	Hong Kong (China)	Indonesia	Jordan
Hungary	**Iceland**	**Ireland**	Kazakstan	Kyrgyz Republic	Latvia
Israel	**Italy**	Japan	Liechtenstein	Lithuania	Macao-China
Korea	**Luxembourg**	Mexico	Panama	Peru	Qatar
Netherlands	New Zealand	**Norway**	Republic of Montenegro	Republic of Serbia	Romania
Norway	Poland	**Portugal**	Russian Federation	Shanghai (China)	Singapore
Slovak Republic	Slovenia	**Spain**	Thailand	Trinidad and Tobago	Tunisia
Sweden	**Switzerland**	**Turkey**			
United Kingdom	**United States**				

Article 1 of the OECD Convention defines the Organisation's mission as being to (OECD, 1960):

- support economic growth
- boost employment
- raise living standards
- maintain financial stability
- assist other countries' economic development
- contribute to growth in world trade

However, education is becoming increasingly important within the OECD's mandate, as it is considered central to economic competitiveness (Kallo, 2009). The OECD's role in global education is outlined in section 3.8.2.

2.8.2 PISA

In response to the desirability of a 'knowledge economy', the OECD created the Programme for International Student Assessment (PISA) in 1997. This is a collaboration between both OECD member and partnership countries to monitor student achievement (Bybee et al., 2009). PISA is designed to focus upon testing the knowledge and skills required for societal participation, assessing the extent to which students can apply the skills they gain or are taught in school in everyday adult life. It is testing more than the student's capability to merely learn a school curriculum (Schleicher, 2006).

The PISA assessments take place every three years and involve testing 15 year olds in three domains: Reading, Mathematical Literacy and Scientific Literacy. In each year of testing, the main focus is on one domain. The other domains are assessed but using a smaller number of questions.

2.8.2.1 Organisation of PISA tests

Schools are randomly selected by the OECD, and thirty learners in the appropriate age group are then again randomly selected to take part. The survey takes place in school at a mutually convenient time and the selected sample students take the tests which last approximately two hours. PISA tests include multiple choice and open questions on mathematical literacy, scientific literacy and reading. Further to this, there is also an attitudinal questionnaire for pupils that considers their values and experiences of learning. Finally, there is also a questionnaire that is completed by the school (Welsh Government, 2012a).

2.8.2.2 PISA Questions

PISA relies heavily on the concept of metacognition (Welsh Government, 2012a) that involves high-level literacy skills. This links with Donaldson's vision for the future of education, whereby pupils take control of their own learning (Donaldson, 2015). PISA attempts to not only assess what students know, but also their reflective capabilities and their ability to apply their understanding to real-life situations (Eivers and Kennedy, 2006). PISA tests are not based on common curriculum themes across countries as demonstrated by other global testing methods such as TIMMS (Trends in International Mathematics and Science Study).

2.8.3 Scientific Literacy in PISA tests

2.8.3.1 2006 and 2009 tests

Due to the international delivery of PISA tests and the requirement for consistency (Bybee et al., 2009), the basic definition of scientific literacy was kept constant to facilitate the development of trend indicators for countries (Olsen et al., 2011). However, as Science was the major domain in 2006, four different components were included in OECD's definition of scientific literacy (Table 5)

Table 5: The components of scientific literacy used by OECD in the delivery of PISA tests (OECD, 2006, p.26).

Component	Examples
Scientific contexts	Life situations that involve science and technology
Scientific competencies	Identifying scientific issues, using evidence and explaining scientifically
Scientific knowledge	Knowledge of the natural world and about Science itself
Attitudes towards science	Interest and support of scientific enquiry

Scientific Contexts

The context is a specific setting within a situation that is used in a question and includes health, natural resources, environment, hazard and frontiers of science and technology. These are then considered at three different levels: personal, social (i.e. the community) and global (OECD, 2006).

Scientific Competencies

This aspect is linked directly to scientifically important skills such as reasoning, critical thinking, data transformation, data evaluation, modelling and application of mathematics (Bybee et al., 2009).

Scientific Knowledge

This section involves students demonstrating their knowledge of science. This includes being able to understand fundamental scientific concepts, in addition to understanding inquiry and the nature of scientific explanations (Bybee et al., 2009).

Attitudes towards Science

The OECD further focuses on this concept by considering three main aspects: interest in science, support for scientific enquiry, and responsibility towards resources and environments (Olsen et al., 2011).

Unusually, PISA embeds interest items within the cognitive test unit, rather than as a separate section (Drechsel et al., 2011).

2.8.3.2 2015 tests

Part way through my research, the OECD published a document that reflected the issues surrounding the absence of a definitive definition for scientific literacy. This was published in response to scientific literacy being the major domain for PISA 2015. The OECD recognised that previous PISA documentation has produced "a broad consensus among science educators of the concept of scientific literacy" and so the 2015 framework was written in an attempt to refine and expand upon previous explanations of the concept.

OECD's new 2015 definition of scientific literacy is: "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen". This definition is then expanded to explain that scientifically literate people are willing to engage in reasoned discourse about science and technology and is a movement away from an internal understanding of science (Lederman and Abell, 2015). Pupils will be tested on scientific contexts, but through three main competencies outlined in Figure 3. Their ability to do this will be affected by two factors: their knowledge and their attitudes towards Science (OECD, 2013).

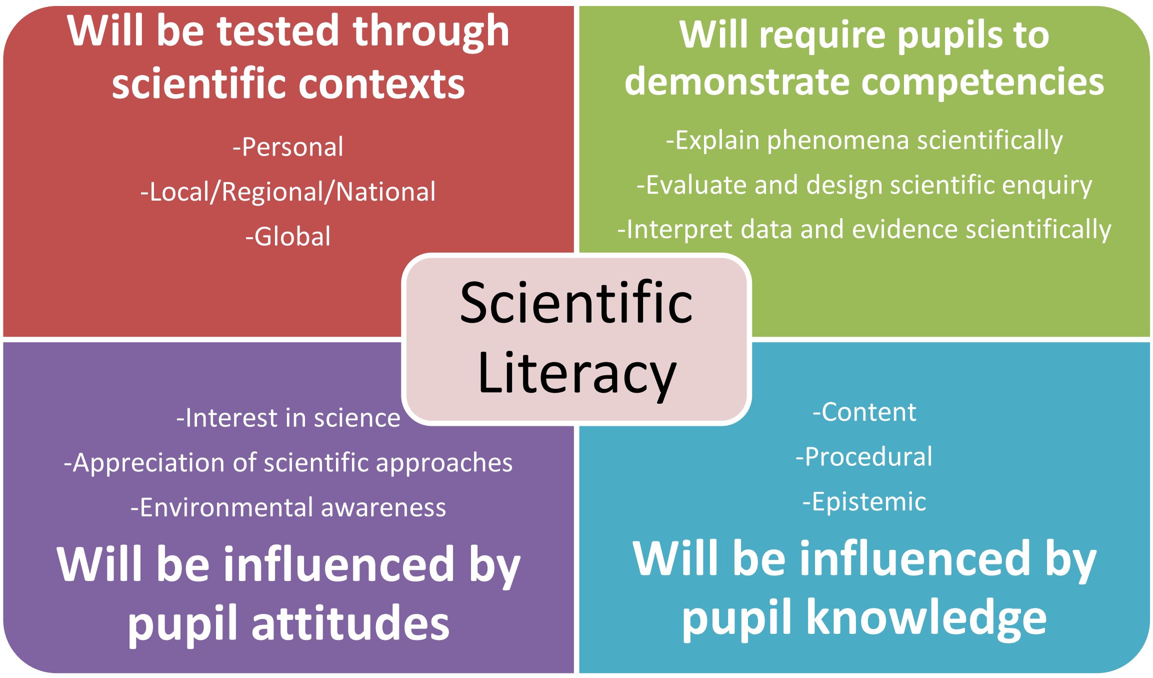

Figure 3: Components of the PISA 2015 Scientific Literacy Domain (OECD, 2013)

Scientific Contexts 2015

This section is likely to be very similar to the 2006 and 2009 tests, requiring pupils to consider Science at three different levels.

Scientific Competencies 2015

The details of this section have been reworded from the previous PISA tests, as outlined in Table 6.

Table 6: The three main competencies of scientific literacy required for the 2015 PISA tests (OECD, 2013).

Competency	Explanation
Explain phenomena scientifically	The ability to recognise, offer and evaluate explanations for a range of natural and technological phenomena.
Evaluate and design scientific enquiry	The ability to describe and appraise scientific investigations and propose ways of addressing questions scientifically.
Interpret data and evidence scientifically	The ability to analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions

2.8.3.2.1 Scientific Knowledge

This is the area that has changed the most. The 'content' will be likely to be very similar to the previous tests and follow the general worldwide commonality of teaching Biology, Chemistry and Physics. It will encompass the knowledge of the content of science (including physical systems, living systems, earth, and space science). However, the 2015 PISA test will place an increased emphasis on knowledge **about** science, and this area will be separated into both procedural and epistemic aspects (OECD, 2013).

2.8.3.2.2 Procedural Knowledge

This is the knowledge of the diversity of methods and practices that are used to establish scientific knowledge as well as its standard procedures. It could be briefly summarised as the skills required to design a successful scientific investigation. The main aspects of procedural knowledge are outlined in Table 7.

Table 7: The main aspects of PISA 2015 procedural knowledge, as outlined by the OECD (2013)

• The concept of variables including dependent, independent and control variables;
• Concepts of measurement e.g., quantitative [measurements], qualitative [observations], the use of a scale, categorical and continuous variables;
• Ways of assessing and minimising uncertainty such as repeating and averaging measurements;
• Mechanisms to ensure the replicability (closeness of agreement between repeated measures of the same quantity) and accuracy of data (the closeness of agreement between a measured quantity and a true value of the measure);
• Common ways of abstracting and representing data using tables, graphs and charts and their appropriate use;
• The control of variables strategy and its role in experimental design or the use of randomised controlled trials to avoid confounded findings and identify possible causal mechanisms;
• The nature of an appropriate design for a given scientific question e.g., experimental, field based or pattern seeking.

2.8.3.2.3 Epistemic Knowledge

This is the knowledge of how people's beliefs in science are justified as a result of understanding the functions of scientific practices, their justifications, and the meaning of terms such as 'theory', 'hypothesis', and 'observation'. This will require pupils to consider the purpose and values of Science. The main aspects of epistemic knowledge are outlined in Table 8.

Table 8: The main aspects of PISA 2015 epistemic knowledge, as outlined by the OECD (2013)

1. The constructs and defining features of science. That is:
• The nature of scientific observations, facts, hypotheses, models and theories;
• The purpose and goals of science (to produce explanations of the natural world) as distinguished from technology (to produce an optimal solution to human need), what constitutes a scientific or technological question and appropriate data;
• The values of science e.g., a commitment to publication, objectivity and the elimination of bias;
• The nature of reasoning used in science e.g., deductive, inductive, inference to the best explanation (abductive), analogical, and model-based.
2. The role of these constructs and features in justifying the knowledge produced by science. That is:
• How scientific claims are supported by data and reasoning in science;
• The function of different forms of empirical enquiry in establishing knowledge, their goal (to test explanatory hypotheses or identify patterns) and their design (observation, controlled experiments, correlational studies);
• How measurement error affects the degree of confidence in scientific knowledge;
• The use and role of physical, system and abstract models and their limits;
• The role of collaboration and critique and how peer review helps to establish confidence in scientific claims;
• The role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues.

The knowledge section is almost philosophical in its approach (Eijkelhof, 2013), and so it remains to be seen how the PISA 2015 questions will be written to ensure that every 15 year old can access them.

2.8.3.3 Attitudes towards Science

Similarly to the concepts section, the attitudinal aspect of the PISA testing will be very similar to the previous tests, and this aspect will again be likely to be embedded within the cognitive test unit.

2.8.4 Measuring Scientific Literacy within PISA tests

This PISA assessment method attributes numerical values to each scientific literacy task, dependent upon the complexity of the question. These certified values enable the production of a complex proficiency scale for measuring scientific literacy (Telford, 2010). Pupil scores are assembled into one of six levels of scientific literacy outlined in Table 9 (Thomson et al., 2013). To reach each proficiency level, a pupil must correctly answer a majority of items at that level. They are classified according to their score, with students being placed below level one if they achieve less or equal to approximately 335 (Baldi et al., 2007). Level 2 has been defined as the baseline proficiency level as it is representative of a benchmark level of scientific literacy proficiency where those who take the test start to demonstrate the necessary skills that fulfil the PISA scientific literacy definition (Fleischman et al., 2010).

Table 9: Summary descriptions of the six proficiency levels of scientific literacy in PISA testing (taken from Thomson et al., 2013 and Baldi et al., 2007)

Level	Score	Skills demonstrated by students
6	>707.93	identify, explain and apply scientific knowledge in a variety of complex life situations; link information sources and explanations and use evidence from those sources to justify decisions; clearly and consistently demonstrate advanced scientific thinking and reasoning; use their scientific understanding in support of solutions to unfamiliar scientific and technological situations.
5	>633.33	identify the scientific components of many complex life situations; apply both scientific concepts and knowledge about science to these situations; use well-developed inquiry abilities; link knowledge appropriately and bring critical insights to situations; construct explanations based on evidence and arguments.
4	>558.73	work effectively with situations and issues that may involve explicit phenomena; integrate explanations from different disciplines of science or technology and link those explanations directly to aspects of life situations; reflect on actions and communicate decisions using scientific knowledge and evidence.
3	>484.14	identify clearly described scientific issues in a range of contexts; select facts and knowledge to explain phenomena and apply simple models or inquiry strategies; interpret and use scientific concepts from different disciplines and apply them directly.
2	>409.54	use adequate scientific knowledge to provide possible explanations in familiar contexts or draw conclusions based on simple investigations.
1	>334.94	present scientific explanations that are obvious and follow explicitly from given evidence; scientific knowledge is limited to a few, familiar situations.
Less than 1	≤334.94	not demonstrate even the most basic types of scientific literacy that PISA measures. These students are likely to be seriously disadvantaged in their lives beyond school.

2.9 Potential issues surrounding PISA testing methodology

2.9.1 General Issues

"PISA seems to be well on its way to being institutionalised as the main engine in the global accountability juggernaut, which measures, classifies and ranks students, educators and school systems from diverse cultures and countries using the same standardised benchmarks." (Meyer and Benavot, 2013). In May 2014, eighty three academics from across the world wrote an open letter to Dr Andreas Schleicher, director of the OECD's Programme for International Student Assessment, denouncing PISA for sampling problems, for being the driver behind countries' short-term "fixes" and their desire to quickly improve PISA rankings and for questionable alliances with for-profit organisations that often financially benefit from issues that PISA unearth (Meyer, 2014).

Some authors have commented on the fact that PISA was not originally designed as an international education comparison tool, and there is growing concern that the tests and subsequent results are having a greater influence over national education policies that they were initially intended to have (Breakspear, 2012).

Replacement sampling takes place within PISA testing and the schools originally selected can choose not to participate. This is possibly more likely with lower attaining schools. Replacement schools are then approached, but again, there is no obligation to participate. It is therefore clear that there must be a recognition of the upward bias of the responding schools (Prais, 2004). Similarly, the situation in China can lead to bias. China participates in PISA testing, but only in four regions: Shanghai, Hong Kong, Taiwan (Chinese Taipei) and Macao. The local economic success, and development status of these areas means their results are likely to be positively biased compared to the rest of China (Coyle and Rindermann, 2013). Interestingly, students in twelve Chinese provinces have already taken PISA tests, but there is an arrangement with the OECD that these results were not published (Baird et al., 2011).

According to the PISA 2009 technical report, participating countries were able to exclude up to 5% of the student cohort. This consisted of up to 0.5% for "organisational reasons" and up to 4.5% for intellectual or functional disabilities or limited language proficiency. However, the exclusions for intellectual ability were solely the decision of school staff (OECD, 2012), leading to a questioning of the validity of the results. The interpretation of "intellectual disability" is also open to debate and possible abuse. For example, in the 2006 PISA tests, students were excluded on the basis of dyslexia in Greece, Ireland and Poland, dyscalculia in Denmark and Maori students in immersion or bilingual programs in New Zealand (OECD, 2009). In the 2003 tests, Luxembourg omitted recently immigrated students (OECD, 2005).

Anecdotal evidence from schools that have undertaken the PISA tests has shown that once students have been randomly selected by the OECD, they can opt out of the tests and be substituted with other students. It was noted by Mike Hedges, the Swansea East AM, in his article "Are these tests fair?" that pupils were "walking out after they are told [the tests] are optional (Hedges, 2014).

"There are very few things you can summarise with a number and yet PISA claims to be able to capture a country's entire education system in just three of them. It can't be possible. It is madness." (Morrison, 2014). There are problems with merely assigning a numerical scoring system to something as provocative as educational ranking, including the presentation of the results in a 'league table' format. This leads to competitiveness where it is not necessarily required. For example, in the 2006 PISA tests, Taipei was ranked in fourth place with a score of 532, and Korea was eleventh with a score of 522. These results were not significantly different from each other, or any of the countries placed between them (Eijkelhof, 2013). This is especially true when considering the implementation of the tests. Each PISA test has a standard set of questions, but there is no requirement for the students taking the test to complete them all (Ammermüller, 2005). Pupils are not given identical questions but this is accounted for as the results are be standardised using the 'Rasch model' (Adams et al., 2007, Le, 2009). This model has repeatedly been challenged by academics and statisticians (Heene, 2011) and places individuals on a common scale, despite them completing different booklets of items (Stacey, 2012). This individual-level data is then combined to form a whole-country score. Some researchers have questioned whether this particular scaling model is reliable or even consistent among the different countries. Can countries be ranked on the basis of student performance when the students are performing different tasks?

There are problems when considering the age that students take the PISA test. PISA defines the sample group as those who are born in a particular year, irrespective of the class that they are in. This is a relatively simplistic idea in the United Kingdom where school children rigidly follow ascension through school based on their age. However, other countries allow children to be accelerated or 'held behind' a grade. The UK's PISA scores would not be affected by this issue, but countries that follow the latter schooling format might demonstrate a decrease in their PISA scores due to the inclusion of 15 year olds in lower grades (Prais, 2004). In addition, at fifteen years old, the ability of a child to abstractly reason is still in full development. PISA therefore systematically underestimates the abilities students have "near the end of compulsory schooling" (OECD, 2004, p.294). Interestingly, in some countries, 15 is also not an age near to the "end of compulsory schooling". For example, children are compulsory schooled until they are 18 in Germany (McIntosh, 2001).

The tests also do not take into account 'non-standard' schooling such as countries where there is a sizeable proportion of home-schooled children, or countries where large numbers of children do not attend school (Wuttke, 2007). For example, in less economically-developed countries, poorer children may not have the opportunity to attend school, producing a PISA sample that is largely composed of richer children and their associated demographic background. Authors in Africa found that these children are from households that have the finances to allow formal education, and are often able to afford private tutoring (Nishimura and Yamano, 2013). This may produce a very different set of PISA results when compared to a country where every child attends school, regardless of their household income. Children may also not be in formal education due to other reasons other than financial. In very remote areas of Australia, children are enrolled in distance learning programmes (Lyall and Mcnamara, 2000) and again, this affects the sample of children who *could* be participating in the PISA tests.

In addition, PISA tests must be translated into multiple languages and there have been some reservations about the rigor of the translation. "The nuances and subtleties of a subject area will be lost on a translator unfamiliar with the subject matter. Too often, translators without technical knowledge will resort to literal translations that threaten test validity" (Hambleton et al., 2004, p.11). Likewise, India withdrew from the 2012 PISA tests, citing their pupils being at a disadvantage due to 'cultural bias'. An official from its education ministry claimed that some of the topics covered in PISA questions may be difficult for pupil that live in rural areas: "If the child has not heard of airbags, hot-air balloons and ATMs, he won't even attempt those questions" (John, 2012).

2.9.2 Science-specific Issues

PISA does not specifically assess the aims of the science curriculum within each country as it is not based on the science curriculum being taught there (Mortimore, 2009). Alternative methods of gauging pupils' science ability are not considered. For example, their practical or fieldwork skills are not tested. One study made note of the fact that some countries may have performed less well as their 15 year olds had dropped Science as a subject. However, interestingly, it was found that those pupils who were no longer studying Science were equal in their performance to those who were still taking the subject. Therefore, the authors concluded that "it could be argued that some of the PISA science items assess generic reading comprehension and/or problem solving skills rather than purely scientific concepts" (Shiel et al., 2001).

Equally, in countries such as the UK where there are multiple options for science education from the age of 15, there are obvious disadvantages to those pupils who opt to study a more 'vocational' form of science. For example, those pupils who are studying the separate science option may be at more of an advantage to those who opt for the BTEC route. This is not necessarily due to their scientific knowledge as PISA tests are not based on a science curriculum, but certainly due to their experience of answering examination questions.

2.10 The Current Status of Science Education within Welsh Schools

2.10.1 PISA results for Wales

2.10.1.1 2009 results

According to PISA, pupil performance in Science is lower in Wales than the rest of the U.K (OECD, 2010). The most recent PISA report, published in 2009, found that pupil performance in Science is not significantly different between England, Scotland and Northern Ireland, but is significantly lower in Wales. Wales was ranked at number 30 out of the 68 countries that participated in the testing (Research Service, 2011). This performance was lower than the other individual UK countries (Table 10).

Table 10: Mean score in student performance on the 2009 PISA science scale (Bradshaw et al., 2010, p.80)

	All students		Percentiles		
Country	**Mean PISA score**	**Standard Deviation**	**5th Percentile**	**95th percentile**	**Difference between 5th and 95th percentile**
England	515	99	349	673	324
United Kingdom	514	99	348	672	324
Scotland	514	96	358	669	311
Northern Ireland	511	103	341	676	335
Wales	496	95	336	655	319

Despite this, the overall performance in Wales was not significantly different from the overall OECD average (consisting of 68 countries), putting Wales in the middle ranks of achievement (OECD, 2010). However, although Science was the focus of the PISA 2006 survey (OECD, 2007), it was only considered a minor subject in the 2009 study. This meant that a smaller cohort of children was assessed and there were fewer science-based questions than for the reading tasks. Therefore, the results reported are merely an estimate for the entire population and consequently may not be entirely accurate. Science will be the main focus again in the 2015 tests.

2.10.1.2 2012 results

In 2012, the main focus of the PISA tests was Mathematics, with Science and Reading being minor strands. Wales' performance in science was placed at joint 36th, a drop of six places from the 2009 tests. Wales' score was significantly below the OECD average, with the mean pupil score decreasing since PISA 2009 (Wheater et al., 2013). In addition, there was no significant difference between the mean scores of

England, Scotland and Northern Ireland, but Wales again scored significantly lower (Table 11). According to the scored levels outlined in Table 9, all members of the UK are currently performing at a Level 3.

Table 11: Mean score in student performance on the 2012 PISA science scale (Wheater et al., 2013)

	All students		Percentiles		
Country	**Mean PISA score**	**Standard Deviation**	**5^{th} Percentile**	**95^{th} percentile**	**Difference between 5^{th} and 95^{th} percentile**
England	516	101	343	674	331
United Kingdom	514	100	344	672	327
Scotland	513	89	365	658	293
Northern Ireland	507	101	338	669	331
Wales	491	94	334	639	305
OECD Average	501	93	344	648	304

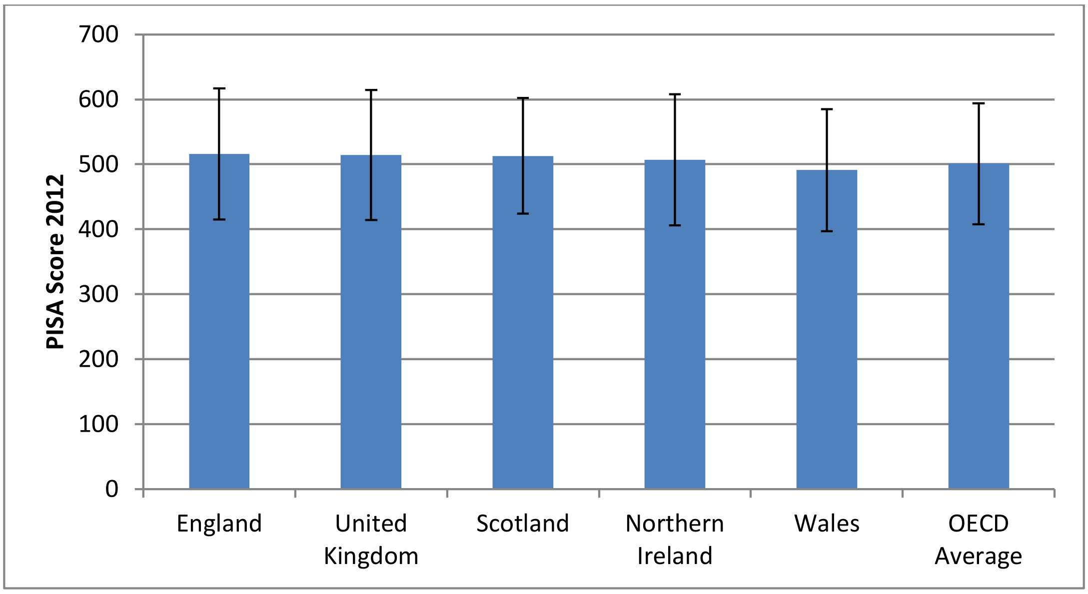

Figure 4: Mean scores and standard deviation in student performance on the 2012 PISA science scale (Wheater et al., 2013)

2.11 Possible reasons for Wales' PISA results

Education in Wales is overseen by the Department for Education and Skills (DfES), a Welsh Government department that is responsible for education, training and children's services in Wales. This responsibility comes from powers devolved from the Department for Children, Schools and Families of the UK government in 1998. Historically, Wales was always closely linked to the education system of England, and quickly sought to produce their own education system. League tables and SATs tests were abolished and the curriculum was revamped with a heavier focus on skills. This devolution came with disadvantages too. In 1999-2000, the funding gap per school child between England and Wales was £58. This had increased to £604 by 2009-10 (Welsh Government, 2011). This may have an impact upon the education provided to Welsh school children.

However, interestingly, despite Wales' relatively low PISA results, it actually shares many features with Finland, a country that consistently performs well in the PISA tests. Like Finland, Wales has a fully comprehensive schooling system (Moran and Clarke, 2012), where there are no externally funded academies or free schools, as is found in England. Wales also abolished standardised testing, again consistent with Finnish practice. Nevertheless, Finland does have some clear differences. There are fewer external requirements such as school inspections (Richardson, 2013), and Finland advocates a research-based methodology of teacher education. Finland's teacher training faculties have control of their own schools where trainee teachers complete their training (Niemi, 2012). This has led to an environment where teachers learn to teach based on their own action research (Morris and Patterson, 2013). Teacher training courses are oversubscribed, competitive, and in particular, attract high-performing graduates (Asbury and Plomin, 2014) as teaching is a well-respected and highly valued profession (Goodwin, 2014).

Therefore, some other factors may be affecting the performance of Welsh school children. Wales' poverty levels are the joint highest in the United Kingdom (as outlined in Table 12.). Household income is the usual measure of poverty. A household is considered to be in poverty if its income (after tax and adjusted for household size) is below 60% of the UK median for the year (HM Government, 2014). This results in a high proportion of Welsh pupils being eligible for free school meals (FSM). In the UK, free school meals are available to disadvantaged children whose parents are in receipt of particular additional supportive payments.

Wales has a relatively low number of free school eligible children at primary school level but conversely, it has the second highest proportion at the secondary level (Northern Ireland Assembly, 2014) as outlined in Table 12.

Table 12: Proportion of children in relative and absolute poverty by country, United Kingdom (taken from HM Government (2014)) and the free school meal percentage for each country (taken from Northern Ireland Assembly (2014)).

		Free school meal entitlement in 2012/13 (%)	
Country	**Relative poverty (%)**	**Primary**	**Post primary**
England	18	18.1	15.1
Northern Ireland	23	29.9	19.0
Scotland	17	22.1	15.4
Wales	23	18.9	16.2

A pupil being entitled to free school meals has a profound impact upon their level of achievement. A report published in 2014 found that in Wales, the performance of pupils eligible for free school meals was lower than their non-eligible counterparts at every key stage and in all performance measures. This becomes more pronounced as pupils get older (Hughes, 2014a). *"There is a strong statistical link between poverty and low educational attainment. In general, learners from poorer families do not achieve as well as their peers. There is no simple explanation for this link between deprivation and underachievement or an easy solution to breaking it"* (Estyn, 2014)

Wales also has the highest pupil:teacher ratio in schools in comparison with the rest of the United Kingdom (Table 13). This has been the case for the past four years, with potential implications with regard to pupil attainment. There is much controversy regarding the level of impact that having smaller pupil:teacher ratios has on attainment, but there is no doubt that "smaller classes have positive effects on pupil academic performance" (Blatchford et al., 2011)

Table 13: The pupil:teacher ratio in all schools for the past four years (taken from (Jackson, 2014))

	Pupil:Teacher ratio in all schools			
Country	**2010/11**	**2011/12**	**2012/13**	**2013/14**
England	16.4	16.3	16.2	16.3
Northern Ireland	17.3	17.5	17.5	17.5
Scotland	13.5	13.7	13.8	13.9
Wales	17.8	17.9	17.8	17.7

2.11.1 KS2 and KS3 Results

Interestingly, the KS3 results for 2012/13 contradict the PISA results. During this year, Welsh pupils performed better than their English counterparts in Science for the first time since 2005 (Welsh Government, 2014b).

2.12 Literacy Policies within Welsh Schools

Worldwide, there are very few research studies on effective literacy practices and policies in secondary schools (May, 2007). Despite increasing diversity within classrooms, "the secondary curriculum is based on the assumption that knowledge can be objectified, verified, and disseminated via compartmentalised disciplines" (O'Brien et al., 1995, p.448) and this often results in a disassociation between whole-school literacy policies and subject-specific policies (Corson, 1999). The implementation of the LNF within Wales has attempted to reduce this dissociation (Welsh Government, 2013).

2.12.1 The Impact of PISA results on Welsh Government policy

In 2010, the low PISA results for Wales led to significant development of the education system. The Education Minister at the time, Leighton Andrews described Wales' PISA 2009 results as a "wake up call to a complacent system" and announced a detailed plan that was designed to "raise standards and tackle under-performance' in Welsh schools.

In June 2013, Huw Lewis was appointed the Minister for Education and Skills in Wales and he sought to build upon Leighton Andrews' legacy. In response to the 2012 PISA results, Lewis set a target of Wales becoming a "top 20" PISA nation in 2015, having the expectation that Wales would improve their results by at least twenty places: "The 2015 target [is] always going to be a challenging one for us but you've got to be ambitious when delivering the best for our young people".

However, in the autumn of 2014, Lewis abandoned the "top 20" target and set a new target of achieving a score of 500 in the 2021 PISA tests. As a comparison, Scotland achieved a mean score of over 500 points in the 2012 tests, effectively illustrating how Wales could be considered to be at least eight years behind the rest of the United Kingdom. Critics of this new target considered this to be stagnation, rather than aspiration, with the opposition shadow education secretary quipping that the Lewis' plan is to "raise Welsh performance from the worst performing UK nation to the second worst by 2021". Nevertheless, the changed target has been welcomed by some supporters who feel that it places more realistic expectations on the teaching profession in Wales (BBC News, 2014).

Over recent years, Wales has been openly tailoring their education system to specifically improve their PISA ranking. The OECD has classed Wales as "very" much using PISA scores to inform the policy-making process (Breakspear, 2012). Included in these education reforms were the introduction of a national school banding system to compare schools' performance and a move away from subject advisors and towards consortia arrangements that provide support and challenge to schools (Halliwell et al., 2015).

There are currently four education consortia in Wales covering:

- North Wales (Flintshire, Conwy, Wrexham, Gwynedd, Isle of Anglesey, Denbighshire)
- South West and Mid Wales (Swansea, Neath Port Talbot, Carmarthenshire, Pembrokeshire, Powys, Ceredigion)
- Central South Wales (Bridgend, Cardiff, Merthyr Tydfil, Rhondda Cynon Taff, Vale of Glamorgan)
- South East Wales (Caerphilly, Monmouthshire, Newport, Blaenau Gwent, Torfaen)

Each consortium is responsible for school improvement services in their targeted areas. They are specifically tasked with addressing the Governmental demand of improving standards of literacy and numeracy and minimising the poverty divide within schools. Nevertheless, the creation of these consortia has not been without problems. In particular, the initiative has been criticised for having a lack of consultation (Hepburn, 2012).

The implementation of the National Literacy and Numeracy Framework and the associated annual tests, in addition to a large-scale review of the National Curriculum that is currently ongoing, has all contributed to a period of significant educational reform in Wales. At the time of writing, further reforms were being announced, again to try to improve the effectiveness of the Welsh Education system and therefore, improve PISA results. Schools will now be assessed using a three-step system:

- Step One: judgement in relation to performance and standards in the school, using a range of performance measures provided by the Welsh Government;
- Step Two: a judgement in relation to the school's ability to self-improve, based on robust self-evaluation in relation to leadership, learning and teaching; and

- Step Three: combination of the two judgements leading to a colour categorisation, corroborated by education consortia Challenge Advisers and agreed by the local authority (Welsh Government, 2015a).

2.13 The Role of Teaching Staff

2.13.1 Science teachers in Wales

A 2008 report by Estyn found that the quality of teaching in Science is generally lower than other secondary subjects. The proportion of lessons classed as outstanding in science is significantly below the average for all other subjects (Estyn, 2008).

The report also found that there is a shortage of Physics and Chemistry teachers that have appropriately specialist qualifications. This is a common pattern throughout the UK, with only 22% of science teachers holding a Chemistry degree and 14% a Physics degree (Howson and McNamara, 2012). Approximately half of Headteachers have to re-advertise vacancies due to a lack of applicants, or hire non-specialists as an alternative (Estyn, 2008). Due to these shortages, specialist Physics and Chemistry teachers tend to be assigned to Key Stage 4 and A-Level classes. Although understandable, this means that Key Stage 3 classes are principally taught by Biologists (Jones et al., 2008), leading to pupils potentially not having the necessary foundation or motivation to progress on to studying these subjects at a higher level. In response to this issue, the Science Policy for Wales has a clear commitment to increase the number of initial teacher training (ITT) places in these shortage subjects (Welsh Government, 2015b).

2.13.2 Teacher Concerns about Literacy vs Scientific Literacy in Science

Science teachers have an important role in allowing individuals to understand and be critical about scientific evidence (Glasson, 2014). However, there is a greater focus on general literacy within lessons in Wales (Welsh Government, 2013) and few studies have examined the challenges that teachers face when incorporating general literacy into science lessons (Pegg, 2010). It is apparent that the majority of teachers are concerned about the low standards of literacy and understand that they have a pivotal role in improving this situation (Lewis and Wray, 1999) but with the focus on literacy, there could be a risk that less time is spent on science content. This may be particularly true if classes were particularly weak in literacy. Much literacy teaching is based on teacher intuition (Glynn and Muth, 1994), and many teachers believe that they do not have the expertise or time to effectively deal with literacy problems (Harreveld et al., 2008).

2.13.3 The Role of Professional Development in Improving Scientific Literacy

Teachers understand their role in improving literacy standards, but recognise that their own skills in teaching literacy need to be developed (Lewis and Wray, 1999) and there are concerns about the ability of teachers to teach literacy effectively (Harper and Rennie, 2009). “High quality literacy teaching demands high quality literacy teachers “(Wray and Medwell, 2000, p.1) and teacher expertise is central to the processes which shape pupils’ scientific literacy (Smith et al., 2012). Therefore, any attempt to raise literacy standards must allow the opportunity to maximise the proficiency of teachers in teaching literacy (Wray and Medwell, 2000). However, this can be problematic when considering school resources and finances. Nevertheless, an improvement in the skills of staff results in an improvement of literacy strategies utilised during lessons (Cantrell and Hughes, 2008).

In addition, Estyn (2008) found that very few non-specialists receive the necessary professional development opportunities to improve "subject knowledge and pedagogic skill". The opportunity to have further specialist training, if required, could impact upon lessons, especially if linked with scientific literacy training. This complements the acquisition of scientific knowledge, finally leading to an improvement in pupil performance (Faulkner et al., 2012).

2.14 Improving Scientific Literacy

2.14.1 Current Strategies used to Support the Improvement of Scientific Literacy

Engagement in science is not possible without a reasonable level of pupil literacy (Hodson, 2008). Improving this allows pupils to be able to move beyond the process of replication, where they merely reproduce knowledge, towards a system where they are capable of producing knowledge (Hand and Prain, 2006), thus allowing them to act like 'real scientists' within any science lesson. This process is not a quick one and different teachers utilise different methodologies. However, many strategies that are designed to improve literacy often have no evidence for their effectiveness and instead rely on personal experiences or ideas (Yore and Treagust, 2006).

Introducing key vocabulary, such as on word walls (Bromley, 2007), is a well-established strategy for supporting literacy, possibly because it provides a quick method of promoting literacy, especially for teachers that may have had no specific literacy training (Lewis and Wray, 1999), although there is a lack of evidence for their effectiveness. Other common strategies include shared reading, where teachers and pupils read aloud (Fisher et al., 2002); writing frames (Hand et al., 1999) and interactive whiteboard games (Smith et al., 2006). However, it is evident that there are actually very few strategies that specifically focus on the improvement of *scientific literacy.* Most strategies are often generalised and there are very few science-specific ideas that can be utilised by teachers (Yore et al., 2003).

2.14.2 How can Scientific Literacy be further improved?

For many years, there has been great debate about the best ways to improve pupil literacy (Fisher and Lewis, 1999), especially as most of the research into effective teaching is generic rather than specific to literacy teaching (Wray, 2002). However, many authors have found that the greatest success is achieved when a school has a clearly defined strategic vision that is fully understood by staff (Whitehead, 2009). Initiatives that are understood and supported by the teachers who will be implementing them have a higher likelihood being successful (Lewis and Wray, 1999). Therefore, any current literacy projects that are being undertaken through schools need to be reviewed, allowing strategies to be built into “coherent, working policies” (Lewis and Wray, 1999, p.280). Importantly to science, this must take place with representatives from each subject area, as even “literacy education experts do not fully understand science as a discipline, including the nature of science, scientific inquiry, argumentation, and the particular forms of representation used in science” (Hand and Prain, 2006, p. 102). This interdisciplinary approach throughout the school has the greatest positive impact due to the consistency it achieves (Wright et al., 2008). Nevertheless, any implementation of measures to improve literacy will not have an immediate effect. May (2007) found that it can take a minimum of three to five years to create a literacy learning community that begins to have a positive impact upon pupil performance. This is important when considering the length of time the Welsh Government takes to consult, implement and review any new initiative. At the time of writing, the LNF had been in use for three years, with some improvement being seen within the average range scores (Table 3).

There appears to be very little advice regarding the improvement of scientific literacy. However, some recent strategies are beginning to include computer-based interactive simulations in order to improve scientific literacy levels (Fan and Geelan, 2013, Lawless et al., 2013). In America, the University of Illinois at Chicago is currently developing resources that are designed to improve pupil scientific literacy. Their instructional approach integrates reading and writing with science inquiry, and hopes to provides pupils with opportunities to engage in the literacy practices of science. This work is being developed through Project READi (Reading, Evidence, and Argumentation in Disciplinary Instruction) (Greenleaf et al., 2013) and in close partnership with working teachers. At the time of writing, this project was mid-research, so the findings are unknown.

2.15 Summary

This review of the literature has demonstrated that despite scientific literacy being an internationally recognised outcome of science education, the meanings and motivation behind it are still unclear. Pupil performance is lower in Wales than the rest of the UK, including in the area of scientific literacy. Although there are recognised issues regarding PISA testing, it is largely becoming a worldwide utilised tool for measuring educational performance. It is therefore important that Wales minimises its differences with the rest of the UK. The 2009 and 2012 PISA results instigated great educational change within Wales. This includes the National Literacy and Numeracy Framework, a Wales-specific exam system and the increased provision of Consortia throughout the country. These ongoing changes potentially provide an opportunity to greatly improve standards within this area if that change is research-driven.

3 Research Methodology

3.1 Introduction

This chapter explains the rational which led to the formulation of the research questions and the methods used in the collection of data to answer the research questions. The ontological and epistemological rationales behind my choice of research methods are firstly provided, followed by a full explanation of data collection techniques, including the development and piloting of research instruments. The methods behind the data analysis are also explained. Aspects of reliability, validity, and ethical issues are also covered in this chapter.

3.2 Research Questions

As a science teacher, improving the understanding, attainment and enthusiasm within my lessons is of paramount importance. When first considering the focus of my research, scientific literacy was one of my main interests, due to the 2009 PISA results and Wales' relatively poor performance. I was interested in *why* Wales performed so badly in comparison with the rest of the UK. Once I started to speak to colleagues about this possible focus, an interesting question arose: "what **is** scientific literacy?" We were all aware of the OECD definition, but there was a lack of understanding about how this related to science within secondary schools. As professionals, we are tasked with improving the scientific literacy of our pupils, but I felt that there was confusion over how that could be done.

It was also clear that there had recently been a focus on literacy and numeracy within Wales, but the Welsh Government had yet to place their attention on science. The implementation of the LNF was a huge task that was still ongoing (Welsh Government, 2013), so the focus on science could only begin after this had been fully embedded. I felt that it was important to explore how scientific literacy could potentially be improved if there was a future initiative involving science.

Therefore, this study aims to provide a more comprehensive description of the ways in which teachers and educational professionals in Wales understand the term *scientific literacy*. The link between PISA testing, Governmental guidance and classroom teaching will be addressed through the following questions:

- What are teachers' interpretations and perceptions of scientific literacy in Wales?
- What methods are used for measuring and improving scientific literacy in Wales?
- What factors support or hinder the development of scientific literacy in Wales?

These questions provide opportunity to explore how teachers and educational professionals consider scientific literacy. This includes how they define it, how they measure it and how they improve it. These individuals are at the forefront of science education within the country, and therefore, can provide incredibly valuable information. I'm also interested in what these individuals believe support the improvement of scientific literacy, in preparation for any potential initiatives that may be developed by the Welsh Government.

The release of the 2012 PISA results relatively early into my research process reiterated the importance of developing scientific literacy within Wales, especially as the 2015 PISA tests would have their main focus on this area (OECD, 2013).

3.3 Ontological Position

Although the research questions had been decided, the ontological position of my study had to be decided before my research approach was designed. I will aim to explain and justify the ontological approach that is behind this thesis, in addition to giving consideration to the approaches which were deemed unsuitable.

Auguste Comte was the first philosopher to propose positivism (Cohen et al., 2000). The rationale behind this approach is that philosophy must be based on entities which could be perceived or measured directly. This philosophical approach prevents the researcher from involving their own ideologies and values.

Initially, this positivist approach was deemed to be suitable for my study, but this approach is not without its problems. Positivism requires an epistemological approach where the research methodology must be objective and scientific. Therefore, it is not a suitable paradigm for any issues where conclusions are not distinct and easily obtained, for example, where there may be divisions between subjectivity and objectivity. As my study is considering the views of educators about **education**, it is unlikely that any participants could be entirely objective, indeed, their responses would be subjective. Positivism has been attacked by many philosophers of science for this very reason (Zammito, 2004). Cohen noted that a positivist approach "fails to take into account of our unique ability to interpret our experiences and represent them to ourselves" and that it does not enable an "important debate about values, informed opinion, moral judgements and beliefs" (Cohen et al., 2000, p.19). Essentially, positivism prevents the relationship between a person and their knowledge, despite that person being the one who assimilated the knowledge.

I therefore decided not to use a positivist paradigm with my research, and instead moved to a post-positivist ontology. This philosophical movement was created to allow the clear link between knowledge and personal experiences to be able to be maintained. Post-positivism allows the truth to be gained progressively through the process of research (Kennedy and Lingard, 2006), where answers can be gained through the utilisation of varied research methods. These methods may include both quantitative and qualitative approaches and are based on the premise of "critical multiplism" (Guba and Lincoln, 1994, p.205) where any questions can be considered from different perspectives, often combining different methods (Johnson et al., 2007). Ryan (2006) describes post-positivism research as “not being either subjective or objective” and that post-positivist researchers “do not prefer subjectivity over objectivity” (p. 16).

I have opted for a post-positivist approach in my research as it allowed me to use both quantitative data to provide simple patterns and conclusions, as well as qualitative methods that provided in-depth detail. It was especially important for me to gain insight from “multiple perspectives, rather than a single reality” (Creswell, 2012, p.24), something which post-positivism allows.

3.4 Epistemological Position

The aim of my research was to discover the current status of scientific literacy in Wales, based on the responses of educators. It is the perceptions and attitudes of these educators that formed the main basis of my findings. This is a very subjective approach, and therefore, a mixed methods approach was deemed to be necessary to improve the confidence of the conclusions. This study employed the technique of data triangulation or the use of multiple data collection processes, which involves using different *sources* of information in order to increase the validity of a study (Creswell and Clark, 2010) through comparing and integrating quantitative and qualitative methods (Patton, 2002). The three research techniques selected were questionnaires, semi-structured interviews and a case study. This was later changed to reinterviews, with the reasoning behind this explained in section 4.8.2.

As post-positivist researcher, I recognised that information is gained from educators and related professionals through their personal experiences and their “individual subjectivity” (Ryan, 2006, p.24). The data I collected included distinctly factual information, such as how many years an individual had been teaching or the subjects that they taught, but the main body of the research required an insight into the participant’s individual views and perceptions. For the former, a quantitative approach was required, so a questionnaire was utilised to produce the necessary descriptive statistics. It also increased the probability of a large number of respondents to be reached, whilst minimising costs.

The latter required a qualitative approach to allow more detailed information to be obtained. The research instruments available were interviews, case studies, observations and focus groups. The latter two choices were deemed unfeasible in terms of time constraints and their inability to collect the required data. Observations were too limiting in terms of the number of teachers that could be watched, and I felt that focus groups would merely become a repetition of the data collected in the interviews.

Interviews were used to produce a deeper insight into the attitudes and perceptions of educators, especially areas which were not elicited in the questionnaires. The specific type of interview chosen, and the initial rationale behind the case study is further discussed in section 4.8.2.

Mixed methods research allows both qualitative and quantitative data to be utilised together, "improving validity" (Denscombe, 2010, p.140) and allowing a more detailed analysis to be achieved. It allows the convergence and corroboration between different methods (Greene et al., 1989). The following chapter will outline how this mixed-methods approach was used.

3.5 Research Design

Careful consideration of the appropriate philosophical approach and methodology was undertaken to guide the research design. As previously stated, a mixed method approach was utilised. This involved the use of questionnaires, followed by interviews and originally a case study that was later changed to reinterviews.

The questionnaires were used for two reasons. Firstly to gain descriptive information about the participant's background, and secondly to elicit basic responses about scientific literacy in Wales. There are two options available when using questionnaires: paper-based (i.e. postal) or digital (i.e. hosted online). Postal questionnaires generally produce notoriously low response rates, with a general decline in responses being found in a range of sectors, including education and medicinal (Glidewell et al., 2012). Internet questionnaires are becoming a more popular method of collecting data (Burgess et al., 2012), especially due to their reduced cost and ability to instantly analyse results. Digital questionnaires eliminate the need for paper, printing, postage and data entry costs and can reduce the time required for implementing the survey (Dillman, 2002). However, it was very difficult to obtain the relevant email addresses for each educational establishment in comparison to obtaining their postal addresses. In addition, the potential for the email to be rejected by school email servers, or for it to be lost within the general everyday school emails was quite high. I therefore chose to offer both alternatives. Each paper-based questionnaire had the appropriate web address on it that would allow any recipient to complete the questionnaire on the internet.

The next stage of the research was to complete interviews. For the purpose of my research, I opted to use semi-structured interviews. I rejected structured interviews as their format is too constricted and would provide information that is far too similar to that obtained by the questionnaires. Semi-structured interviews provide the researcher with the opportunity to approach each respondent slightly differently, subject to their role, while still allowing the same range of data to be collected, allowing information that might not have become available or lacking in detail through the use of questionnaires. They are designed to have a number of questions prepared in advance, but these questions are sufficiently open to allow flexibility in the conversation (Wengraf, 2001). This also suits the post-positivist ontology of this study, as it allows a social narrative with the participants, allowing access to a "stock of knowledge" (Ritchie and Rigano, 2001, p. 744).

Finally, a case study was planned to be completed at one school. The case study approach allows a broad range of data to be collected to form a deep and descriptive understanding (Bassey, 1999), thus leading to a greater understanding of one educational environment. Case studies can be considered as an enquiry in a real-life context (Yin, 2014) which again, suits the post-positivist ontological approach to the research and are often used to evaluate, to gain clarity or to further explore previous findings (Cohen and Manion, 1981). Case studies can be variable in their implementation, which Robson (2002) considers to be useful due to their flexibility. Logistical issues meant that this case study was later changed to reinterviews (section 4.8.2).

Alternative research design options

Other data collection methods could have also been selected, but these were disregarded for a number of reasons. Although very valuable research tools (Cohen et al., 2000), I opted not to interview pupils or complete observations due to the time and organisational restraints of being in a full time teaching position whilst completing this research. The decision to not interview pupils also minimised any ethical issues.

3.5.1 Triangulation

The research methods chosen allow triangulation to occur. This is the use of multiple methods, theories and data within a study (Duffy, 1987) in order to establish validity (Coleman and Briggs, 2002). Devin (1970) was the first to consider four different types of triangulation: data, investigator, theoretical and methodological. Data triangulation involves collecting data from numerous different sources; investigator triangulation refers to more than one researcher collecting the data; theoretical triangulation allows more than one theoretical stance within the research, and finally, methodological triangulation involves utilising more than one method of data collection.

I used both data triangulation as I sought information from both teachers and educational professionals, in addition to methodological triangulation as I utilised three different methods to obtain my data. Data triangulation is the most popular type of triangulation (Guion et al., 2011) as it is possibly the easiest to implement. Methodological triangulation is also very popular (Cowman, 1993), but requires more resources (Guion et al., 2011). Using triangulation in this way prevents unreliable or invalid results (Hall and Rist, 1999).

One main issue with triangulation is how it can produce results which are inconsistent or contradictory (Mathison, 1988). However, post-positivist researchers consider this to be an advantage as it allows them to consider the "unpredictable and contradictory nature of human experience" (Giddings and Grant, 2007). Therefore, the use of multiple methods will produce more valid conclusions (Mathison, 1988).

3.5.2 Trustworthiness of the Study

The term reliability is not appropriate in my study as my research is qualitative. Reliability is the level of precision, accuracy and consistency of results in a research study (Cohen et al., 2000). Joppe (2000) defines reliability as "The extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable". These are terms that are only appropriate when completing a quantitative study.

Therefore, I must use different terminology. Guba (1981) spoke of considering the trustworthiness of qualitative studies rather than their reliability. Agar (1986) also suggested that an entirely different language was necessary within qualitative studies. Instead, he offered terms such as "credibility, accuracy of representation, and authority of the writer".

Trustworthiness was separated into four distinct strands by Lincoln and Guba (1985): credibility, transferability, dependability and confirmability.

<u>Credibility</u>

This has also been referred to as the 'truth value', but is essentially the confidence in the truth behind any findings. "It establishes how confident the researcher is with the truth of their findings based on the research design" (Krefting, 1991). This was ensured through selecting research methods that were already well established (Shenton, 2004). Both the methods of data collection and the subsequent analysis were based on previous completed comparable studies. I have also attempted to provide a 'thick description' (Ponterotto, 2006), otherwise known as a detailed description to convey the situation that was being investigated.

In addition, I had 'prolonged engagement' (Lincoln and Guba, 1985) in the area of my study so I fully understand the research context. This allowed me to be able to approach respondents with a detailed former understanding of the topics they were discussing. This allowed the discussions to become more in-depth. Linking with this, I attempted to ensure the honesty of my participants by allowing them the right to refuse participation and by reiterating that there are no "correct" answers to the questions they were being asked.

Credibility in the questionnaires largely relied on participants sharing the same basic understanding of the questions, and answering all questions honestly. As this could not be fully guaranteed, this problem was addressed by then interviewing some of those participants to allow confirmation of their credibility. Another attempt at improving the credibility of the questionnaires was trying to ensure a representative sample was used, as this has been considered a principle of validity (Cohen et al., 2000). Participants were not selected by myself as the questionnaires were sent to the Headteacher, for the attention of the Head of Science. It is therefore prudent to assume that the participants were "self-selecting", and this lead to a varied sample of respondents. In addition, before starting my study, I knew there was no guarantee of a particularly large response rate to my questionnaires. Therefore, the design of my study was such that the impact of a low response rate would be negated through the use of further qualitative research in the form of interviews and a case study, thus ensuring more credibility. Section 4.5.1 considers the role of this triangulation in maximising the credibility of my research.

Transferability

This involves being able to prove that any findings are applicable in other contexts. However, since the findings of my project are specific to a particular cohort of people, it is extremely difficult to demonstrate that any conclusions I draw are applicable to other situations and populations (Krefting, 1991). Therefore, I followed an alternative idea advocated by Bassey (1981) and Lincoln and Guba (1985) that if a reader of a study believes that their own situation is similar to the one being described in my study, then they may be able to link any findings to their own environment. It is therefore important to provide as much contextual information as possible (Krefting, 1991).

Dependability

This shows that any findings are generally consistent and could be repeated elsewhere. However, qualitative work is often transient and "the changing nature of the phenomena scrutinised by qualitative researchers renders such provisions problematic in their work" (Krefting, 1991). Nevertheless, I have ensured that the research design and implementation and data collection and analysis have been described in detail to allow any future researcher to repeat any stage of the work.

Confirmability

This describes how the extent of which the findings of a study are shaped by the respondents and not the bias, motivation, or prior interest of the researcher. It is important that any outcomes are as a result of respondent input, rather than from myself as a researcher (Krefting, 1991). Again, triangulation is important in this subsection as it reduces the potential for any researcher bias. Section 4.5.1 considers the role of this triangulation in maximising the confirmability of my research. Equally, the descriptions of the research process should be rigorous enough to ensure that the reader is confident in the outcomes.

Together, a consideration of these four strands should assure the reader of the trustworthiness of my study and enhance the rigor of my research.

3.6 Ethics

Ethical considerations are very important in education research. Social science involves the study of people and therefore, ethical issues are of paramount importance throughout the whole project (Cohen et al., 2000). Participants must be confident of their privacy and the anonymity of their data. Each participant was protected through their 'informed consent' and the ability to withdraw from the research at any point. The basic premise of informed consent is that participants should have volunteered their involvement after being provided with sufficient information. This information should allow participants to make a reasoned judgement as they are able to fully consider any potential benefits or risks. No risks were foreseen, although participants were informed of supportive agencies if they felt affected by the research.

Formal ethical approval was granted by the College of Business, Law, Education and Social Science ethics committee in April 2013, in adherence to the British Educational Research Association's (BERA) guidelines. The anonymity of the participants was guaranteed by separating the descriptive questions (name, place of work, etc) from the rest of the questionnaire and then coding each individual. These papers were then held separately in a locked cabinet. Once transferred onto a spreadsheet, similar coding and password protection was utilised to prevent any security lapses. Likewise, the transcriptions from the semi-structured interviews and case study were assigned identification codes and stored in a secure area.

Participants were also sent the Participant Information Sheet, as contained in Appendix 9.1, which gave more information to participants and thus allowed them to be fully informed of the research process.

3.7 Research Instruments

The three research approaches that were chosen for this study are online and paper-based questionnaires, semi-structured interviews and reinterviews.

The questions and layout of the questionnaire required careful consideration to enable the necessary information to be collected, without being too lengthy or poorly structured that it was deemed to be a 'difficult' task to complete. I intended for the questionnaire to be as easy to follow as possible to encourage the greatest return rate. Essentially, only those questions which were considered to be "vital for the research" were included (Denscombe, 2010). The questionnaires can be seen in Appendices 9.3, 9.4, 9.5 and the questions asked in the questionnaire are listed in Table 14, alongside an explanation about their inclusion.

Table 14: The questions asked in the questionnaire and why they were chosen for inclusion.

Question	Explanation
• Where is your workplace located? • How would you describe your workplace? • What is your job role? • What Key Stages do you teach?	Demographic information that were designed to gather information about differences in location, job role and workplace type and how these are related to scientific literacy.
• What is your subject specialism? • Are you required to teach GCSE lessons outside of your subject specialism? • How many years have you been involved in the delivery or organisation of scientific education?	This was more demographic information that were more specifically related to science education.
• Do you understand the term "scientific literacy"? • In the box below, outline your interpretation of the term "scientific literacy".	This was asked to discover the extent of Welsh teachers' understanding of scientific literacy.
• Have you ever received any CPD (professional development) training regarding scientific literacy? • If relevant, please give details regarding the scientific literacy CPD training (name of the training provider, length of session, main learning outcomes, etc).	This question was included to determine how much scientific literacy training is provided to education professionals within Wales, and if more would be useful.

Question	Explanation
• Do you feel that you would benefit from scientific literacy training?	
• Every three years, the Organisation for Economic Co-operation and Development (OECD) undertakes the Programme for International Student Assessment (PISA). This is an international study which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students in the key subjects: reading, mathematics and science. Prior to this questionnaire, were you aware of PISA testing? • Place the following countries in order of who you think achieved the best PISA score for scientific literacy. No more than one tick should be placed in each column. • In 2009, 68 countries participated in PISA testing. In your opinion, what place do you think Wales came? Please only use numerical values (1-68).	The educational reforms in Wales are in response to the 2009 and 2012 PISA results. These questions were asked to establish the level of understanding that education professionals have of PISA and Wales' results.
• In September 2013, the National Literacy and Numeracy Framework (LNF) will become statutory for all learners in Wales aged 5 to 14. Do you believe that the LNF will have a positive impact upon the scientific literacy levels of pupils?	One of the initiatives in response to Wales' PISA results was the LNF. This question was included to determine how useful teachers believe the LNF will be to improving scientific literacy.
• In your opinion, what is the purpose of science education?	There are many ideas about the purpose of science education, as outlined in section 3.4. This question was included to compare these ideas to what Welsh professionals believe.
• Do you feel confident in improving the scientific literacy levels of pupils?	These questions focussed further on scientific literacy in particular, in order to establish the current methods of measuring and improving

Question	Explanation
• Does your school have a specific policy regarding scientific literacy? • In your school, what methods are used to improve the scientific literacy levels of pupils? • In your school, do you specifically assess the scientific literacy levels of pupils? • In your school, which methods are used to assess the scientific literacy of pupils?	scientific literacy in schools. This enabled me to compare methods in Wales with those described in sections 3.7 and 3.14.
• In your opinion, what factors support the development of scientific literacy in Wales? • In your opinion, what factors hinder the development of scientific literacy in Wales? • If you have any further information that you feel may be relevant to this study, please outline below	These were open ended questions that allowed participants to provide more information about their own views without being constrained.

The semi-structured interviews that took place after the questionnaires had been returned provided a greater understanding of the participant's thoughts, allowing the flexibility of expanding upon certain areas of interest. They essentially followed the same structure as the questions in Table 14, but as they were asked in an interview, interviewees were able to elaborate further.

3.7.1 Pilot Study

The research instruments chosen were first piloted to ensure they were suitable and would elicit appropriate responses. It is important that adequate pilot work is carried out during the development of a new questionnaire to ensure that it is successful. Failure to develop a questionnaire sufficiently may lead to a potential difficulty in interpreting the results. Both the design and the actual questions were tested before being posted out to participants. "Everything about the questionnaire should be piloted; nothing should be excluded, including the font or the paper quality" (Oppenheim, 2000, p.48).

In accordance with the suggested methodology (Robson, 2002), a pilot study was undertaken prior to the final questionnaire being sent out. Ten individuals were selected to participate in the pilot study. These individuals were friends or acquaintances of mine and they were all involved in the delivery or organisation of Science education in North Wales. Initial contact was made via email or telephone to determine if they would participate in the pilot study. All individuals contacted agreed to participate, and were sent a preliminary draft of the questionnaire. An accompanying letter (Appendix 9.1) outlined the rationale behind the pilot study and requested feedback on both the layout and content of the enclosed questionnaire. One hundred percent of pilot study participants returned the pilot questionnaire with accompanying feedback. Following piloting, minor changes were made to the layout of the questionnaire, involving making the answer boxes bigger. In addition, a further question was added considering the support of other departments in improving literacy (Appendix 9.3 and 9.4, question 20).

Likewise, the semi-structured interview questions were piloted with colleagues. Both the timing and phrasing of each question was considered in turn with colleagues who had volunteered their time. No major changes were undertaken in response to this pilot, as the interviewees were very positive about the original format of the interview.

3.8 Data Collection

This sub-section considers the data collection methods and includes sections that describe the processes of collecting the data, in addition to its analysis. The effectiveness and the limitations of the data collection instruments are considered, before outlining the analysis process and the effectiveness and limitations of that. The selection of the data collection instruments and their associated methods have been discussed earlier in this chapter, so this section will only consider their implementation.

3.8.1 Data collection instruments

Earlier in this chapter, I explained my decision to use a mixed methods approach involving questionnaires, semi-structured interviews and a case study. These were selected to ensure the maximum amount of relevant data would be collected

3.8.1.1 Questionnaires

For the questionnaires, a mixed-mode approach was utilised. This provided an electronic and digital form of the same questionnaire to allow the widest range of participants to be reached (Dillman, 2011). The software package Adobe FormsCentral was used to both create the questionnaire, and then host it online. Details of this questionnaire are included in Appendices 9.3, 9.4, 9.5 and 9.6 of this thesis. The design features of the FormsCentral package allowed questions to be designed that would elicit responses to particular questions. Great care was taken to ensure that the questionnaire was respondent-friendly and easy to manipulate. This was largely achieved through the use of the pilot study. Questions contained a mixture of open and closed ended questions, the latter including Likert scale, multiple choice, ordinal and numerical questions (De Vaus, 2002). An 'unsure' option was offered in any relevant question, to avoid manufactured responses (Yu and Cooper, 1983).

Ideally, the quickest and cheapest way of completing this questionnaire would have been by contacting every educational establishment directly via email. This would have allowed the online questionnaire to be directly linked for completion. However, obtaining a factually correct and up-to-date email list for this purpose proved problematic. Instead, a current list of educational establishment mail addresses was downloaded from the Welsh Government website and mail-merged to produce self-adhesive address labels. Likewise, I produced return address labels for the completed questionnaires to be returned to Bangor University.

Three hundred and fifty five questionnaires were distributed to every secondary school in Wales, in addition to services and facilities known to provide for pupils with special or alternative educational needs. Bilingual paper copies of the questionnaires were sent to the Headteacher, for the attention of the Head of Science. A further fifteen bilingual questionnaires were distributed to professionals involved in the implementation or organisation of Science Education within Wales. These included Estyn, the Welsh Government and PGCE training providers. Each questionnaire had a shortened url included on it that was a link to the online version of that particular questionnaire (either Welsh or English, Teacher or Professional). A return paid envelope was also enclosed in all posted questionnaires. As part of the questionnaire, respondents were also invited to volunteer for further involvement in semi-structured interviews or focus groups.

No 'follow-up' emails or postcards were sent out, firstly due to the aforementioned email address problem and secondly, due to the cost implications. Follow up contact is a contentious issue, with Solomon (2001) noting that both internet and mailed follow-ups irritate respondents, without "noticeably increasing response rates".

3.8.1.2 Semi-structured interviews

Semi-structured interviews were used to enable me to gain an in-depth understanding of key areas of my research. The questions were created so they were sufficiently open, thus preventing the interviewees from being led by myself, or being constrained in their answers. A crib sheet was utilised to ensure that each area was covered (Appendix 9.7).

The questionnaire included a question that asked if the respondent would be interested in participating in further research by completing an interview. Twenty respondents (5.6%) indicated that they would be interested. Contact was made with these interested individuals via email, but the majority did not reply to that contact. Six interviews were eventually completed, lasting between 23 and 58 minutes, and these were conducted either face-to-face or by telephone. The former was appropriate where a respondent was local, but the geographical locality of the other five meant that a telephone interview was the only feasible option. In both of these, informed consent was obtained by reading the consent form out and asking them to confirm that they were happy to participate and if they understood the purpose of the study. Each participant was happy with this arrangement and all refused the offer of having the consent form emailed or posted to them. With permission, each interview was recorded with a digital recorder to enable later transcription.

3.8.1.3 Case study

A case study can be useful in educational research as it provides an opportunity to capture the developing and intrinsic aspects of life within the complexity of a school.

A school local to the researcher was approached to participate in the case study. After a brief explanatory meeting, where an information pack was provided (Appendix 9.9), the Headteacher agreed to the research taking place. Unfortunately, this school later withdrew from the research, so other schools were approached and asked to participate. Two schools responded positively, although only one was able to fit in with my scheduling so late in the academic year. The second school expressed regret at not being able to participate, but asked to get into contact again at the start of the 2014-15 academic year.

The school that positively responded and was able to accommodate the case study within the 2013-14 school year was visited late in the summer term. Contact was initially made with the Deputy Headteacher who then arranged meetings with the Head of Science, the Teacher of Science and the Literacy Coordinator for the school. The interviews took place over a morning, starting with the Science department members, before speaking to the Deputy Headteacher. The Literacy Coordinator had agreed to be interviewed, but just prior to the arranged interview time, withdrew from the process. This issue is further outlined in section 4.8.4.

This resulted in a lack of information and data, including the policies and the insights that the literacy coordinator would have been able to provide. This meant that the case study was not a valid option and the methodology had to be reviewed. This is explained further is section 4.8.2.

3.8.2 Change to the Methodology

As outlined in the Research Design section, triangulation was a fundamental part of the methodology. After the issues surrounding the case study section were realised, it became apparent that alternative provision would have to be made to ensure the trustworthiness of the research. The interviews undertaken at the case study high school were still valid and useful, as they followed the same basic format as those completed under the semi-structured interview section. The data from the case study was therefore transferred into the semi-structured interview section.

A number of alternatives were available and these are briefly explained in Table 15, along with the potential advantages and disadvantages of each option.

Table 15: The potential alternatives to the case study originally planned for this research, including associated advantages and disadvantages.

Alternative	Advantages	Disadvantages
Return to the original case study high school, complete the interview with the literacy coordinator and gain access to the relevant literacy policies.	This would allow the original research design to be implemented, allowing a deeper insight into one school.	The literacy coordinator had been contacted twice, but there was no reply from the individual. It is unknown whether the messages were successfully received.
Complete a case study in my own school, interviewing Science staff, members of senior management, English staff and the literacy coordinator, in addition to analysing relevant policies. There would be the added possibility of interviewing pupils too.	Easy access to interviewees and the necessary policies. Could complete a lot of work in a relatively short period of time	My school would be easily identified, leading to problems in guaranteeing the anonymity of the interviewees. Any work with pupils would have to have new ethics clearance, in addition to parental consent.
Re-interview the original participants of the semi-structured interviews, establishing if they believed that my interpretation of their original views was correct and what their current views are, now a prolonged period of time has passed.	Improves the trustworthiness of the interview data. Gives an indication of how the views on scientific literacy may have changed over time.	There is no guarantee that the original interviewees would agree to being reinterviewed.

After careful consideration, it became clear that the third option was the most viable one. The methodology and rationale for the reinterviews is explained in section 4.8.2.1.

3.8.2.1 Reinterviews

Interview-reinterview studies help to establish the trustworthiness of the original responses by testing the temporal stability of the data (Crano et al., 2014). This is concerned with the level at which data obtained in an original testing situation resemble those gained from a second testing. It is often known as test-retest (Haynes et al., 2011) and can be used to ensure that previously received information gathered from a respondent was accurate. Once information has been collected from a respondent, asking the individual about it at later dates can reconfirm the accuracy of the data (Lewis, 2009). This method may have its disadvantages though; the initial responses may influence subsequent responses, and thus weaken conclusions (McConnell et al., 1998).

The reinterview would provide the opportunity for participants to consider their original responses, and my interpretations of them. There would then be opportunity for them to share their current views on the topics that were originally discussed. This provides two advantages: firstly, it increases the trustworthiness of the research. When undertaking analysis of qualitative data, the researcher must be aware of interpretative validity. One of the main threats to valid interpretation of data is the researcher imposing their own beliefs behind what is being said, rather than understanding the perspective of the interviewees and the meanings they attach to their words and actions (Maxwell, 2012). Secondly, reinterviews provide a valuable opportunity to explore whether attitudes and beliefs have changed over the period of time between the first and second interview. For this research, this is potentially a very useful tool.

The original semi-structured interview participants were all contacted via email to establish whether they would be interested in participating in a follow-up interview with a brief explanation of both the purpose and the structure of these secondary interviews.

In order to give opportunity for the respondents to consider their original responses, interviewees were sent a copy of their original transcript. In addition to this, they were also provided with a summary document of my interpretations of their data. This was to increase the interpretative validity of the study. Participants were given adequate time to read over their transcription and summary document, before they were interviewed. They were asked their opinions on the original data, whether they felt that the transcription was a correct and whether they agreed with my interpretation. They were then asked their current views and if anything had substantially changed in the time period between the first interview and the second interview. They were also asked if there was anything else they wanted to speak about.

3.8.3 Data analysis

This subsection will consider how the data from each research instrument was analysed.

3.8.3.1 Questionnaires

Data from the questionnaire responses were collated on a spreadsheet using Microsoft Excel and subsequently analysed using a mixture of Excel and R (R Development Core Team, 2014). Questionnaires that were completed online were exported directly into Excel. Data from paper-based questionnaires were inputted into this spreadsheet.

3.8.3.1.1 Statistical Analysis

Although my research project used a mixed-methodology approach, it did rely upon the analysis of some quantitative data, primarily for a comparison of the demographic characteristics of the teachers as the questionnaires included questions that would obtain nominal, in addition to ordinal data. R was chosen as the most appropriate statistical package for this purpose (R Development Core Team, 2014).

The chi-square test was used to assess differences in the frequency of individual views between the participants. Due to the small sample size, a Monte Carlo simulation was used to estimate the distribution and compute a p-value. This produces a reference distribution, based on randomly generated samples which will have the same size as the tested sample, in order to calculate p-values when test conditions are not satisfied (i.e. such as a small sample size).

3.8.3.2 Semi-structured interviews and Reinterviews

The interviews and case study interviews were professionally transcribed by Dictate2Us Ltd. Transcription is the process by which spoken words are reproduced into written text (Halcomb and Davidson, 2006). It would have been more logical for me to transcribe the interviews due to my knowledge of the terminology being used. However, one hour of interview time can take anything up to eight hours to transcribe (Hove and Anda, 2005, Dearnley, 2005, Park and Zeanah, 2005), so although there was expense involved, I felt it would be more efficient to hire a professional. Nevertheless, each transcription was read whilst simultaneously listening to the original recording to ensure that the transcription work was reliable. This process revealed a number of discrepancies within the transcriptions, in particular with any education-based acronyms. Mistakes such as PPA (planning, preparation and assessment time) was transcribed as PTA; levels science instead of A-Level science; AX instead of AS (advanced subsidiary) and six four instead of sixth form. In addition, terms not specific to education were incorrectly transcribed. The phrase “head above the parapet” was transcribed as “head above the power”. By going through the transcriptions whilst listening to the recordings, I was able to successfully correct the mistakes.

The interviews were initially analysed by coding specific sections that were deemed to be particularly interesting or significant to the research questions. This was done using the software package, NVivo and allowed me to separate the different parts of each interview into specific themes. The themes generally reflected the topics on which the interview questions were developed which were initially influenced by the literature. Nevertheless, using NVivo allowed me to collate the emergence of any new themes in addition to the expected themes I had from my original research questions. Themes were categorised and relationships between these themes were identified through repeated comparison of codes and categories.

To ensure that I had accurately determined the themes running through the interviews, my supervisors independently read the transcribed documents and noted their own interpretations of any themes. These were then cross-referenced with my own perceptions.

3.8.4 Limitations of Data Collection

Schools are busy environments where teachers are constantly under pressure to complete a large amount of work. Although the questionnaire return rate was reasonable, it is impossible to know how many questionnaires actually made it to their intended recipients. I addressed the questionnaires to the Headteacher, for the attention of the Head of Science to ensure that the Headteacher was aware of the research. There is a strong possibility that some questionnaires may have been lost in the post or either the Headteacher or Head of Science being absent from school on the day of delivery. It would be sensible to assume that some questionnaires simply 'got lost' in the school system.

Those questionnaires that made it to the Head of Science could then be completed by that person, or alternatively passed on to another member of the Science department. As previously mentioned, schools are very busy and incredibly transient, so again, there is a strong possibility that the questionnaire was not completed immediately. Interestingly, one questionnaire was returned with simply "No time – I teach Science" scrawled across it.

One question on the questionnaire asked if the respondent was interested in participating in an interview. Many respondents indicated that they would be happy to complete an interview, but it was incredibly difficult to actually complete these. This is a common issue within real-world research and completing an EdD there are numerous external factors that are outside of the researcher's control (Burgess et al., 2006). Within this research, the majority of respondents contacted as a follow-up to organise a suitable interview time simply didn't reply. Those that did reply were then either constrained by either their own teaching timetable or mine. As an educator myself, I was limited by the times I could call during the school day, and inevitably, these times did not match the interviewee. Therefore, the interviews largely took place via telephone during the evening. However, there were again problems, as both myself and the interviewees all had meetings, parents' evenings and revision classes to run after school.

The organisation of the case study was initially very easy. I contacted one school and had no response, but a second school immediately replied asking me to meet with the Headteacher. The meeting was successful and the Headteacher enthusiastically agreed to participate in the study, and instructed me to wait for an email from the Head of Science. After two weeks, I still had not received an email, so I made contact to query if the email had been sent, and potentially been blocked by the university server. Unfortunately, despite this and then further contact being made with the school, the school did not respond. I therefore assumed that the school had withdrawn from the study and did not press it further.

I then needed to make contact with alternative schools, but again, many schools responded negatively to my request. Each negative response was unexplained, although there could be a number of different reasons. At this stage, the academic year was nearing to a close and it became imperative that the case study has to take place quickly due to the difficulties in being able to do the same in the new autumn term. To aid this process, my supervisors got in touch with some of their professional contacts at their partner schools. A few schools responded positively to this contact and the case study was arranged. Nevertheless, once the school had agreed to the case study, then the same workplace constraints outlined when discussing the interviews arose. As I needed to speak to four members of staff, it quickly became apparent that this would be difficult to arrange around my normal workday. Fortunately, some funding allowed me to take a day off work to visit the school, and they were flexible in their organisation to ensure that I could speak to each member of staff.

Finally, another problem presented itself during the day. The Literacy Coordinator for the school has agreed to participate, but after waiting for a number of hours, I was informed that the meeting would no longer be possible. As a follow-up, I emailed the point of contact in the school to thank them for their time, before querying whether the Literacy Coordinator would be available at a later date. The point of contact was amenable to this suggestion and said they would pass on my email. After not receiving any response after a month, I contacted the school for the final time to definitively confirm whether the Literacy Coordinator could participate. Again, I received no reply, thus meaning I lacked a potentially valuable component of data.

3.9 Summary

The research methods selected for this research were strongly affected by a post-positivist ontological approach. This meant that a mixed method approach was deemed to be the most suitable, allowing the complexity of educational professionals and their environments to be fully explored and appreciated. Despite this, the difficulty of completing research in a real-world setting was not fully comprehended until the advent of the research. An EdD seeks to address a real-world problem, rather than a theoretical topic (Wisker, 2007) but this produces a situation which is easily influenced by a number of external factors. This is especially true within the transient environment of a school. The aim of this chapter was to present a balanced and critical view of different research philosophies and provide evidence that supports my choice of a post-positivist approach.

4 Findings and Analysis

4.1 Introduction

This chapter considers data presentation, analytical findings, a discussion about the emergent themes created by the data. The data collected is evaluated for its quality, trustworthiness and effectiveness, before considering any limitations. Finally, the findings are briefly summarised and linked to the original research questions.

4.2 Questionnaires: Teachers

A total of 61 of the 355 questionnaires sent to educational establishments were returned, which represented a response rate of 17%. Six (10%) of the returned were completed online. The questionnaire produced valuable results on its own, but was also designed to initiate discussion points for the semi-structured interviews.

4.2.1 Demographic Characteristics

Questions one to seven asked participants their demographic information, including their job role, the location of their workplace and the number of years the participant has been working in education. The demographic characteristics of the respondents is outlined in Table 16.

Table 16: Participants' Demographic Characteristics (n=61).

	Independent Variables	Frequency	%
Location of Workplace	North Wales	25	40.98
	Mid Wales	7	11.48
	South East Wales	21	34.43
	South West Wales	8	13.11
Type of Workplace	School with attached sixth form	41	67.21
	School with no attached sixth form	13	21.31
	Pupil Referral Unit (PRU)	5	8.20
	Other	2	3.28
Job Role	Headteacher	3	4.92
	Head of Science	41	67.21
	Teacher of Science	8	13.11
	Curriculum leader (e.g. Head of Biology)	4	6.56
	Other (e.g. Pastoral Leader)	5	8.20
Key Stages Taught	KS3 (11-14 years)	1	1.64
	KS4 (14-16 years)	1	1.64
	KS3 (11-14 years) and KS4 (14-16 years)	21	34.43
	KS3 (11-14 years), KS4 (14-16 years), KS5 (16+ years)	38	62.30
Number of Years Teaching	1-3	1	1.64
	4-7	6	9.84
	8-10	8	13.11
	11-15	11	18.03
	16+	35	57.38
Subject Specialism	Biology	26	42.62
	Chemistry	21	34.43
	Physics	7	11.48
	Other (e.g. Geology)	7	11.48

Participants were asked the location of their workplace, and the subjects they taught. They were also asked if they were teaching subjects outside of their specialism. The location of a school is significantly related to whether a teacher is required to teach outside their specialism (Chi squared homogeneity test, $\chi 2 = 8.9451$, df = 3, p=<0.05). Teachers that are required to teach outside of their specialism are particularly prominent in Mid Wales (73%), but also high in South East and South West Wales (67% and 63% respectively). This is very different in North Wales, where only 28% of teachers are required to teach a subject outside of their trained specialism. The number of years that a teacher had taught was not significantly related to teaching outside their specialism (Chi squared homogeneity test, $\chi 2 = 2.499$, df = 4, p=>0.05). Likewise, the teacher's role and subject they were trained to teach had no impact either (Chi squared homogeneity test, $\chi 2 = 9.929$, df = 7, p=>0.05 and $\chi 2 = 9.086$, df = 7, p=>0.05).

4.2.2 PISA performance in Wales

The majority of participants (93%) had some knowledge of PISA. Participants were asked to rate each country of the United Kingdom in rank order of how they performed in the most recent PISA tests. No demographic characteristic had a statistically significant impact on the position that Wales was placed. Seventy nine percent of participants placed Wales in fourth position. A further 18% placed the country in third position. No participant thought that Wales came in first place. Participants were also asked to indicate what position Wales came worldwide, out of the 60 participating countries. The mean score was 45.3 (SD=14.3, range=53), compared with the actual ranking of 30 (OECD, 2010).

4.2.3 The Importance of Science within Secondary Schools

Participants were asked what they felt was the most important skill acquired through the provision of Science education (Figure 5). There was no clear distinction between what participants felt was the most important. Opportunity was given for participants to suggest an alternative purpose of the subject, but there was no response to this.

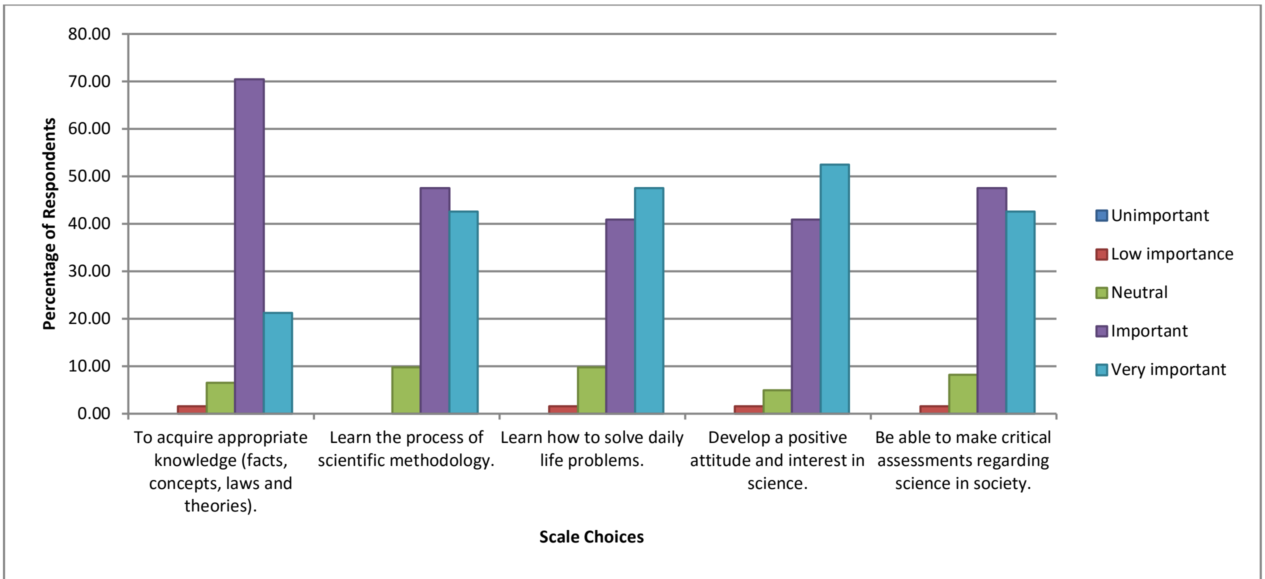

Figure 5 Results for the question "In your opinion, what is the purpose of science education?" (n=61)

4.2.4 Understanding of Scientific Literacy

The majority of respondents (79%) indicated that they understood the term *scientific literacy*. The remainder of participants selected "unsure" as their response. No respondent said that they did not understand the definition of the term. 68.85% of teachers felt confident in improving the scientific literacy levels of their pupils. Participants were asked if their school had a scientific literacy policy, if they had ever had any professional development on scientific literacy and whether their school assessed scientific literacy. The confidence regarding the definition of scientific literacy is interesting to note, considering that 84% of schools did not have a policy, 77% of teachers had not had any scientific literacy training and 67% of respondents do not specifically assess scientific literacy levels within their school. There was no correlation between respondents' scientific literacy CPD training and an understanding of the term scientific literacy. Likewise, there was also no correlation between a school's type or location and both the presence of a scientific literacy policy and the specific assessment of scientific literacy.

Participants were asked the role that that they had in their workplace. A teacher's role was marginally significant in being related to their understanding of scientific literacy (Chi squared homogeneity test, $\chi 2 = 12.956$, df = 3, p=0.06). Respondents who are a Head of Department believed they understood the term the most, closely followed by Headteachers, Science Curriculum Leaders and then teachers that had non-science roles within a school. General teachers of Science were the group that were mostly "unsure" about the term. No other demographic characteristic had a significant impact on a teacher's understanding of scientific literacy.

A teacher's role was not significantly related to their confidence in being able to improve their pupils' scientific literacy (p=>0.05), and although the number of years a teacher had been teaching had a bigger impact, it was still insignificant (p=0.09).

There was no statistical significance between a teacher's location and their own personal, self-reported understanding of scientific literacy (Chi squared homogeneity test, $\chi 2 = 2.8977$, df = 3, p=>0.05). Teachers in North Wales had the lowest understanding of the term *scientific literacy* (68%). This is in comparison to the other regions of Wales where 86-88% of teachers thought they understood the term. North Wales also had the lowest rate of scientific literacy school policies (8%), compared with a high of 24% in the South East of the country.

4.2.5 Defining Scientific Literacy

Participants were asked to outline their own interpretation of the term 'scientific literacy'. Fifty seven respondents attempted to define this term (95%).

Sixteen (28%) definitions were essentially the same, albeit the ordering of the words may have been slightly different: *"The knowledge and understanding of scientific concepts and processes"*.

Fifteen respondents wrote about being able to use "scientific terms correctly", fourteen respondents referred to "scientific terminology", and another four made reference to "key (scientific) words".

Two respondents also considered scientific literacy in a practical light: *"The ability to use, participate in, convey and understand areas of science, including experimental, analytical and general scientific terminology"* (Participant 9) and *"Use and understanding of key words in science - using terms in the correct context and not just in subject areas* (sic) *but investigative work"* (Participant 7).

4.2.6 Improving Scientific Literacy

Participants were asked "In your school, what methods are used to improve the scientific literacy levels of pupils?" with some commonly used methods provided. Participants also had the opportunity to provide other methods not listed. Within schools, writing frames and extended writing activities were the two most common activities utilised by teachers to improve scientific literacy (Figure 6), although these are often used as generic literacy development tools. Commercially available activities such as worksheets and interactive whiteboard activities were the least used interventions. No participant suggested an alternative method.

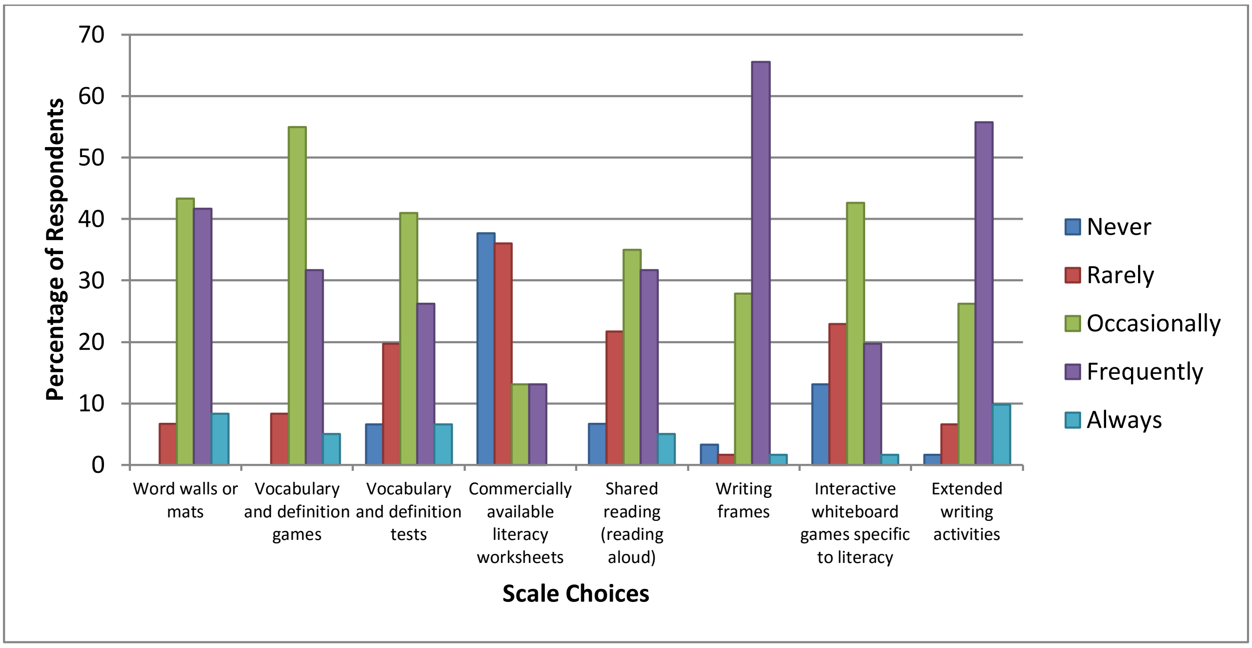

Figure 6 Results for the question "In your school, what methods are used to improve the scientific literacy levels of pupils?" (n=61)

4.2.7 Assessing Scientific Literacy

Participants were asked "In your school, what methods are used to assess the scientific literacy levels of pupils?" with some commonly used methods provided. Participants also had the opportunity to provide other methods not listed. The most common method of assessing pupils' scientific literacy levels is through teacher judgement, teacher-developed tests and to a lesser extent, pupil portfolios (Figure 7). Again, the use of commercially available assessment materials was very low.

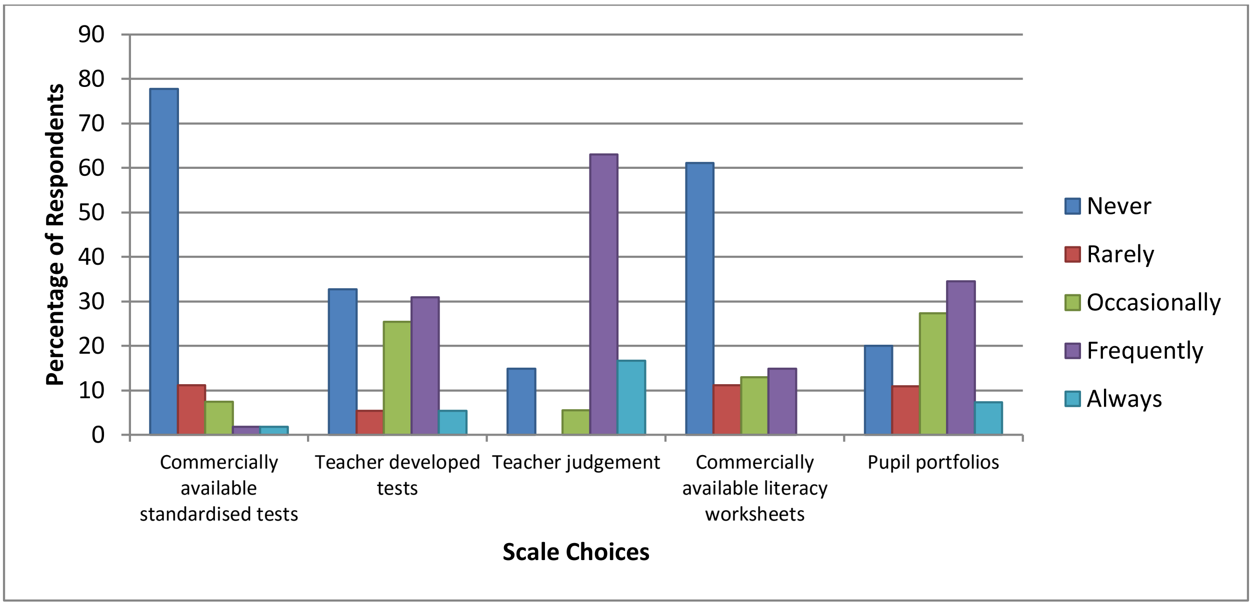

Figure 7 Results for the question "In your school, which methods are used to assess the scientific literacy of pupils?" (n=61)

4.2.8 The National Literacy and Numeracy Framework

Participants were asked "In September 2013, the National Literacy and Numeracy Framework (LNF) will become statutory for all learners in Wales aged 5 to 14. Do you believe that the LNF will have a positive impact upon the scientific literacy levels of pupils?"

Fifty percent of participants either agreed or strongly agreed that the National Numeracy and Literacy Strategy would have a positive impact upon the literacy levels of pupils. However, in the final questions where participants had freedom to write additional comments regarding the study, some answers referred to the LNF. Some were particularly speculative; suggesting that the framework *should* improve literacy levels, rather than it *will* improve literacy levels. Teachers were largely concerned with "the lack of time and support to develop the LNF, including a lack of teacher training" (Participant 41).

4.2.9 Factors that support and hinder Scientific Literacy in Wales

Participants were asked "In your opinion, what factors support the development of scientific literacy in Wales?" and "In your opinion, what factors hinder the development of scientific literacy in Wales?"

The qualitative data from the open-ended questions provided valuable details of the perceptions of teachers regarding scientific literacy in Wales.

4.2.9.1 Factors that support Scientific Literacy

Nearly 28% of answers suggested that the provision and availability of specific training sessions would have the biggest impact on improving scientific literacy within schools. This ranged from simply "*more CPD*" (Participant 45) to "*proper training across schools to share ideas*" (Participant 37).

Teachers also felt that the National Literacy and Numeracy framework has the potential to be beneficial, with 15% of the answers given specifically mentioning it.

> *"I think the [LNF] will help show improvements in the future but it will take some time. The new National Curriculum has also helped by reducing content"* (Participant 58).

4.2.9.2 Factors that hinder Scientific Literacy

One clear issue was the confusion with *what* scientific literacy actually means, and the difficulties that creates when trying to improve those levels.

> *"The concept of 'scientific literacy' is unclear. What is meant? Does it differ from literacy? Is it a part of literacy? Will general literacy strategies improve scientific literacy? Most importantly, what standard is expected and how will it be measured?"* (Participant 46).

The same factors that teachers felt supported scientific literacy were also the ones that were felt to be a potential hindrance. Six respondents felt that due to a lack of training, they were incapable of supporting their pupils with scientific literacy.

> *"Lack of CPD training specifically on improving scientific literacy. [I] would welcome far more commercially available materials to develop reading and writing, in both Welsh and English."* (Participant 11).

A large proportion of respondents felt that they were unable to "keep up" with the continual changes and amendments directed by the Welsh Government. Comments such as "*Constant changing of the rule/expectations by those in Government*" (Participant 12), "*Constant change*" (Participant 42), "*Lack of support/guidance from the Welsh Assembly*" (Participant 52) and "*Not enough guidance in the early stages of the implementation of the new framework*" (Participant 27) indicated a perceived lack of guidance and too many changes in quick succession. There was also some confusion as to what teachers should be targeting first.

> "*So many other things to deliver in and also a drive towards numeracy - what do we do first for the benefit of the pupils/students?*" (Participant 7)

There was a large consensus that there simply isn't enough time to support scientific literacy like they should. *"Time. Teachers [are] not given time to develop strategies. [There's] no time given to support pupils"* (Participant 34). More specifically, many teachers felt that they did not have the time to deliver the Key Stage 4 content <u>and</u> spend adequate time on improving scientific literacy.

"*KS4 content pressure"* (Participant 33).

> *"The overloaded content in the GCSE specifications - as dictated by QCA and the organisations who advise them. This is especially the case for GCSE Biology modules."* (Participant 13).

A very common theme was simply that children lacked the basic literacy skills to be able to cope with higher-level scientific literacy. Typical responses included "*Poor literacy levels generally"* (Participant 31), "*Poor general literacy and numeracy*" (Participant 32) and "*Poor general literacy skills – schools are too busy 'pushing' general literacy and numeracy strategies to allow specialists to develop*." (Participant 25).

> "*Literacy across the curriculum, their literacy skills are so poor on entering KS3, that this hinders their development in Science*" (Participant 43).

Conversely, some respondents felt that it was poor teacher literacy that was having a detrimental impact on pupils' scientific literacy levels. "*Literacy standards of some teachers. Staff feeling unprepared for correcting/assessing literacy*" (Participant 21) and "*Teachers not knowing the vocabulary themselves!*" (Participant 22) summarised how some teachers felt about their colleagues' literacy abilities.

Teachers also felt that there was simply a lack of resources available to support the improvement of scientific literacy. "*[I] would like to see examples of good practice, e.g. DVDs, worksheets of classroom activities regarding literacy*" (Participant 11). Where resources are available, some respondents felt that they were inadequate. "*Many publishers at KS4/KS3 are aiming for middle ground or accelerated books regarding literacy and science*" (Participant 25).

4.3 Questionnaires: Professionals

Only one questionnaire was returned from the 15 sent to the professional bodies involved in the implementation of scientific literacy in Wales. The respondent was an employee at the Welsh Government and had been in post for 1-3 years.

4.3.1 PISA performance in Wales

The interviewee was aware of PISA testing, and correctly placed Wales in fourth position for the 2009 tests. He also correctly placed England in the top position, but had Ireland and Scotland the wrong way around. He put Wales at position 38 out of the 68 countries that participated in the 2009 tests, eight places lower than Wales' actual placing of 30.

4.3.2 The Importance of Science within Secondary Schools

The participant felt that Science was important in secondary schools. In terms of the skills that the subject offered students, Table 17 outlines how the professional ranked the different purposes of science. He felt that being able to acquire knowledge and be critical were the most important, but being able to solve problems was the least important.

Table 17: The ranking given to the potential purposes of science education by the professional respondent.

In your opinion, what is the purpose of science education?	Ranking
To acquire appropriate knowledge (facts, concepts, laws and theories).	Very important
Be able to make critical assessments regarding science in society (positive and negative aspects of scientific and technological development).	Very important
Learn the process of scientific methodology.	Important
Develop a positive attitude and interest in science.	Important
Learn how to solve daily life problems.	Neutral

4.3.3 Understanding and defining Scientific Literacy

The respondent felt that they understood the term 'scientific literacy and defined it as "Literacy and its relation to understanding science".

4.3.4 Improving Scientific Literacy

The respondent felt that pupils' scientific literacy levels should be frequently improved through using extended writing activities, interactive whiteboard games and word walls. He felt that vocabulary or definition tests and games should only be used occasionally, in addition to shared reading and writing frames. He stated that commercially available literacy worksheets should only be used rarely.

4.3.5 Assessing Scientific Literacy

The participant felt that the only methods of assessing pupil scientific literacy should be teacher judgement and pupil portfolios. The alternatives of teacher-developed tests and commercially available literacy worksheets were considered to only be used in rare situations. The respondent was also very clear that commercially available standardised tests should never be used.

4.3.6 Factors that support and hinder Scientific Literacy in Wales

The respondent noted that the recent emphasis on scientific literacy in the new GCSE specifications was having an extremely positive impact upon pupil performance, but was neutral in his opinion that the exam boards were appropriately supporting teachers in their attempt to improve the scientific literacy levels of their pupils. He felt that the National Literacy and Numeracy framework and the associated standardised testing, in conjunction with school improvement data, would improve scientific literacy in Wales. Furthermore, *"STEM outreach initiatives and increasing emphasis and public debate around the demand for STEM"* were also considered to be advantageous.

Factors that hinder the development of scientific literacy were varied and included the availability of science trained teachers in some areas and the sometimes poor 'active marking' of learner written work. Interestingly, the skills-only focussed curriculum was deemed to be problematic in improving scientific literacy as well as the lack of understanding of *"how science relates to the real world employment opportunities"*.

4.4 Semi Structured Interviews

Both teachers and other professional individuals associated with the organisation of education within Wales were invited to participate in a semi-structured interview. Six teachers agreed to be interviewed, but no educational professional chose to participate. After the issues surrounding the case study, the individuals interviewed as part of that process are also included in this section. The rationale behind this is explained in section 4.8.2. Each of the nine teachers interviewed are briefly described in Table 18.

Table 18: Characteristics of the nine teachers interviewed.

Individual	Role	Time in Post (years)	Location
A	Head of Science Department	10	North West Wales
B	Head of Science Department	16	North West Wales
C	Head of Science Department	15	South East Wales
D	Teacher of Science	1	South East Wales
E	Head of Biology	3	North East Wales
F	Teacher of Physics	7	Mid Wales
G	Deputy Head (case study school)		North East Wales
H	Head of Science (case study school)		North East Wales
I	Teacher of Chemistry (case study school)		North East Wales

4.4.1 Main Themes

The main themes that were discussed within each interview are outlined within this subchapter.

4.4.1.1 Importance of Science

Interviewees were asked "What do you think are the most important skills science develops in pupils?" and "What advantages does science offer to pupils?" Each interviewee mentioned the skills that science offers pupils, although the 'type' of skills differed between each respondent. It is also interesting to note that no respondent answered this question immediately. In each case, the individual had to think very carefully for a marked period of time. On average, this was five seconds, although one participant was silent for twelve seconds whilst considering the question.

One interviewee simply answered with: "*It gives them life skills."* (A) and this was expanded upon by another respondent: "*The ability to be able to read and understand the facts and find through around them and interpret them and put them into everyday life [situations]."* (C);

The skills developed in Science was considered to be transferable, including thinking skills and the ability to independently learn: *"It gives them such a wide range of skills that they can transfer to lots of other subjects around school. Just like their main investigative skills looking into different areas of science. It gives them life skills."* (F). Likewise, *"It is probably things like thinking skills. So, being able to adapt the information they're given and apply [it] to their own situations...I think that builds up and you can apply it in a lot of other ways."* (D). There was a general belief that it gives pupils a feeling of independence and provides them with the necessary skills to ensure that they question what they are told. Science has the capability of promoting curiosity and encouraging pupils to challenge, oppose and dispute the world around them: "*Thinking skills, their ability to problem solve, to investigate a hypothesis, to look for patterns. They're able to become independent and you know that's what we try and do, make them independent really. It is make them able to come up with the suggestions, to think about the questions, the why's...rather than be content driven."* (H).

The only non-scientist to be interviewed also felt that thinking skills were important, but it was apparent that his phrasing was typical of official documentation, rather than the language that a science teacher would use. He had less focus of specifically mentioning the *pupils*, and his phrasing was not specific to activities that would happen in a science lesson*: "I think the skills that they develop really are the thinking skills to make sure that you ask the right questions but wherever possible you've got an evidence base to support your thinking and you can provide a reason and rationale for your answers. You can evaluate information, synthesise it, and come to conclusions that would be repeatable."* (G)

Two respondents partly considered the practical element of Science: "*I think practical skills is definitely one that science would address, problem-solving skills, develops numeracy, and, how to explain scientific concepts."* (E); *"I will say being able to work independently. Being able to research, be able to find things out, being able to manipulate equipment, use equipment effectively."* (B); *"I think the way they work together to get to test different things out they might not have ever came across before to get like a hypothesis that they've been given or that they've developed and then they go and think of maybe their own ways to test it or just like the way they're thinking about things to get to that final goal and find out what they want and to think about things differently really, to look for evidence as well rather than just accepting what they're told."* (I)

4.4.1.2 Definition of Scientific Literacy

Interviewees were asked "How would you define scientific literacy?" The ability to define scientific literacy was varied and dependent on the working role the respondent had. It was interesting to see how each participant struggled with this question. This question was considered difficult, and again they were unable to quickly think of a definition. There was a lot of hesitation, and the interviewees were almost apologetic about their inability to define the term. This was particularly true of the science teachers.

"Scientific literacy is being able to use key scientific terms in a correct manner." (A); *"The ability to converse in a [the subject of science]. To be able to access and understand and converse in [the subject of science]"* (B); *"[The ability of the child] to read and understand science to be able to use it."* (C); *"I think that it is the skills that you probably use later on in life as a scientist. So things like short reports and research skills. In my mind, that's what scientific literacy is."* (D); *"Being able to write in good concise English or Welsh, to express scientific facts accurately."* (E).

One interviewee had a much more practical-based view of the term: *"I suppose scientific literacy is slightly different because It is the ability of pupils to use different apparatus and things like that, so their ability to measure and to write up results."* (I)

One interviewee felt they could not answer the question: *"That's one of those things that I used to know exactly what it was. Now, we're dealing with literacy in Science."* (F). Another interviewee recognised the issues with the term and even queried if there was a definition. She felt that it was the ability to use scientific terminology: *"It is difficult. Is there a definition? I think that it is...I suppose it is understanding the key terminology which is often very different to other subjects, these varied technical terms."* (H)

The non-scientist took a far broader view of the term, seemingly explaining it in terms of general literacy, but within Science: *"This is more difficult. Scientific literacy would be the application of speech and writing skills in the scientific domain."* (G)

4.4.1.3 Scientific Literacy within schools

Participants were asked a number of questions to determine the teaching, improvement and assessment of scientific literacy. Each interviewee was asked the standard questions of "What strategies are used by you and your department to develop Scientific Literacy?" and "How is scientific literacy measured in your school?", but other questions developed as the interview continued.

The majority of interviewees recognised that the development of scientific literacy was an issue within their schools. Some teachers specifically mentioned the complexity of scientific language as being a barrier to their pupils, pointing out that in some lessons, the pupils have the potential to be exposed to a barrage of completely new words: *"It is almost like a foreign language sometimes."* (D)

Five participants mentioned the prior education that pupils had received in their primary schools as a major cause of this lack of performance. This included their lack of basic literacy and numeracy skills, in addition to the shortage of science specialist primary teachers: *"I would say probably quarter to a half of the kids were at some point or other had a reading age three or four years less than what they should have been. And that's got to come from the primary school."* (B).

There was some questioning of the science knowledge that primary school teachers possess, and the consequences this then had on both pupil understanding and their end of Key Stage 2 assessment levels: *"Teacher assessment has allowed many mistakes to come through from primary school. Primary school teachers may only have a C grade at GCSE science. Now, they're teaching children, giving them levels at the end of Key Stage 2 based on their sole judgement....so [high schools] are being judged on what a primary school teacher who is only just got a C grade in science is judging a child to be able to do a Key Stage 2. They're predicting our Key Stage 4 results and their knowledge is lacking. We find we're repeating work."* (C). In addition, there were clear cases where huge misconceptions or complete fallacies were being taught to pupils: "*For instance, one of our primary schools, every year, tell the children that blood is blue."* (C).

Two respondents felt that the curriculum style of Key Stage 2 and 3 did not support the development of scientific literacy within Wales. Although some respondents blamed the primary school and their "foundation phase" teaching, it was also recognised that the skills-based curriculum at Key Stage 3 possibly had a detrimental impact upon science: "*I suppose It is easy for me to put the blame on primary schools, teaching in the secondary school. But, I think there's a lot of emphasis these days in primary schools where they make the pupils learn to play. There tends to be a lot of skills-based assignments, which is the case as well at Key Stage 3. I think It is a bit wishy-washy, the whole skills-based thing. I think that maybe has an effect on their literacy and numeracy when they come into the secondary school.*" (E)

Over half of the teachers interviewed spoke about how they felt that the skills curriculum was being taught to the detriment of scientific knowledge. One teacher said that her senior management team had disregarded this problem of pupils not getting detailed subject knowledge when she brought it up by saying "They can go and get a book and they can always find it out if they need to". The teacher felt that children no longer have these skills, because they lack the formative science knowledge to be able to correctly research a certain phenomenon; "*No they can't. They need some basic principles taught to you before you can do something*" (A). One individual was keen to point out how she felt that science had become less of a priority within her school and the pressures she felt of teaching a large content-based course at Key Stage 4 with fewer lesson periods: "*And now, all the focus is literacy and numeracy. [Science has] dropped right down. We certainly dropped down in priority [in this school] you know in terms of timetabling as the timetable is done around Math and English...they get more periods. So all of that focus hopefully will be readdressed when we come back into the capped points score. At the moment, we're thought to be a core subject, but we're not. I hope we're not taken over by the whole fight for literacy. I mean It is like that at the moment. Even numeracy is under the radar and we should be pushing them both as much. But time is given to literacy."* (H)

This thought was mirrored by others who had great concerns that Wales would no longer be a worldwide competitor in the scientific professions if children were not given the opportunity to learn Science as previous generations had: "*Obviously, literacy and numeracy are really important, but at the same time, you still need your doctors and you still need your research scientists, things like that. So I think that It is important that [Science] is not completely brushed under the mat. I think [the Government] need to keep their eye on the ball with Science as well rather than focusing too much on other the things. I think they all need to help each other out."* (I)

SATs were abolished in Wales following devolution, thus leading to a greater emphasis on teacher assessments. Some schools wholly rely on these assessments, but many schools are starting to incorporate testing into their lessons to prepare pupils for GCSE exams. *"But even the tests are not actual tests of the knowledge. They're more test of the application of the knowledge to a skill so they might be given a table or they might be given an experiment, what would you expect to see happening or what decision would you make, which is still not really testing their knowledge. It is testing what they understand from what's written in front of them"* (C).

Some schools knew that they were expected to be teaching a skills-based curriculum, but felt that this was very difficult without a deep level of associated knowledge: "*As a department, we decided that we need to go back to some knowledge teaching because they're finding that they can't use the skills to do the practical work without that knowledge. So perhaps you know if we get pursued by Estyn, they would* *actually say you don't need to be teaching that content. Well, in our professional opinion, we need to, to be able to give the kids something to work with"* (D).

Other issues were the lack of specialist or well-trained teachers at secondary level. One Head of Science commented on how difficult it was to find suitably (and well) qualified applicants for any posts that were advertised at their school. The lack of rigor in some of the teacher training courses was also raised. A comment was made about a university course where a BSc (Hons) in Secondary Science with a secondary subject could be studied in just two years, leading to qualified teacher status (QTS). Some respondents felt that this did not provide the individuals who graduate from that course with a suitable scientific background: "*If you want good science you have to go to start putting in good foundations with people who have got a good science foundation. How can you honestly expect for children to have a good grasp of knowledge if you haven't got somebody who haven't got stories to tell and information to tell and be able to relate it to the big, wide world?"* (C).

One school is in a position where they do not have a Chemistry specialist on their staff, so all Chemistry lessons are taught by non-specialists. The Head of Science is very keen on hiring a Chemist, but never receives any applications when posts are advertised. Once the school started teaching the Level 3 BTEC in Applied Science, specific Chemistry assignments had to be written. One option is to purchase the assignments from the exam board directly, but the school was financially constrained. Due to the nature of the assignments, a Doctor of Chemistry from a neighbouring private school wrote the assignments. This was done as a favour for the Head of Science, and also involved a new Chemistry scheme of work being written. When asked why these tasks could not be done within school, the Head of Science spoke about the entirely different standard being produced: *"The level was so different, the way it was written, the thought that it had gone into it, the ideas that had gone into it, is totally different. Because that person had more Chemistry knowledge to be able to do that."* (B)

Some interviewees cited problems with bilingualism in trying to teach pupils to be more literate in Science: "*I think the Welsh issue, although the protagonists for Welsh will say, that kids can develop equally as well as learning two languages or more, well there may be evidence of that. But in my experience, I think they'll be far better off just learning one language. And learning the correct terms, vocabulary for that."* (B). The difficulties of teaching science through Welsh was also mentioned: *"If (the pupils are) doing the Welsh paper, they can ask for an English paper so that they can read some of the words alongside. There's some of the Welsh words and things that are sort of designed by the exam board. And that, some of the words the pupils might not be that familiar with in their everyday lives. So, they'll have the English paper at* hand so that, you know, that'll aid them." (E).

There was a large amount of frustration regarding the lack of time teachers were able to spend on specifically teaching science, when there's an expectation that they must also largely improve literacy and numeracy skills: *"We're not teaching science. I'm not teaching science knowledge. I'm not teaching them about how things work. And the kids want to know. I haven't got time to do that now."* (C). One individual felt that there was a lack of support given to her department in order to implement these new general literacy initiatives: *"The focus is almost you've got to help us rather than it being we're going to help everybody."* (H) Essentially, she explained that the department is contributing to the literacy audit through listing the activities they do (regardless of their rigor), rather than being trained in the delivery of highly effective, appropriate activities.

This was then furthered by pupils specifically missing Science lessons through being removed for other initiatives: *"At the moment, we have so many kids out of our classroom on literacy initiatives, on numeracy initiatives, on different trips. They're spending less and less time in Science."* (D)

There were also constraints with the working environment: *"I've got eight labs, three labs have been rented out to the local authority for numeracy, literacy and Welsh. So I'm actually squeezing up into five classrooms and sharing them."* (A). The Head of Department felt that this reduction in subject-specific teaching space had impacted on both pupil and staff performance. Likewise, individuals in positions of science leadership feel under pressure to do their roles effectively with the lack of time to ensure that their work is completed, especially with the advent of the new literacy initiatives. One individual mentioned that the Head of English was teaching ten hours less than her per fortnight, and this would increase to twelve hours in the 2014-15 academic year (H).

4.4.1.4 National Literacy and Numeracy Framework

Each participant was asked "Do you know about the National Literacy and Numeracy Framework?" and "In what ways do you think NLF will affect you and your pupils?" as not being literate is a barrier to scientific literacy (see section 3.14). At the time of this research, the LNF had been implemented within schools for a year. Two respondents felt they didn't know anything at all: *"If I'm being honest, nothing... if it has come to the school, it has not filtered down to me."* (B); *"I would not say I could go in to specifics"* (D). One interviewee mentioned that It is "*something that (they'd) been talking a lot about"* (E), but was unable to go into any further detail.

Two interviewees had slightly more confidence regarding their understanding of the initiative, but were still unsure: *"I'd like to think [I understand the LNF]. I understand what my sort of…how I can help and stuff like that. And it needs to be addressed by everyone rather than just English and maths teachers."* (I); "*There's more information coming about the literacy and numeracy framework. I feel It is quite a kneejerk* *reaction with both of them. And, we're being pushed into doing things that we don't really know what the outcome's supposed to be."* (A).

One respondent felt that there was a difference between the literacy and numeracy aspects of the framework: *"I think we're still in the fairly early stages of implementing, or further down the line with literacy than we are with numeracy. I would hope that, over time, it would, that it…that it sometimes really, it would allow students to appreciate what literacy feels and numeracy feels like when they are used more broadly in life."* (F).

In terms of the impact that the LNF would have on pupils, again, reactions were mixed and mentioned the shortage of time and training available to implement it: *"In theory it will have a positive effect, because improving literacy and numeracy in pupils is really important. But, I think that everything has got to be put in place before it is actually put out there for people to do with pupils."* (A);

One respondent felt that they could not begin to have an impact on their pupils, because they lacked the necessary guidance to do so: "*I haven't received any documentation on it."* (B). Science teachers generally felt that they lacked the necessary teaching skills themselves to be able to effectively improve the literacy levels of their pupils.

There were also questions about the role of the primary school in providing the basic literacy and numeracy skills, especially since the advent of the Foundation Phase in 2008: *"[About] five years ago, we noticed that literacy was going down for the primary schools where children could not even write sentences in science to say what's going on. And I brought it up in one of our meetings and nothing was done in school. We picked it up a long time ago. And it is the primary school. You know they're often doing all these fantastic, wonderful stuff and making a variety and I agree with that to a degree but they're losing what basic numeracy and literacy is about and learning to read and write"* (C).

Often, respondents were only able to explain the initiative in terms of their own subject. It was clear that one individual was only able to speak about the different things she's had to do in order to fulfil requirements, rather than talking confidently about the framework as an independent initiative: *"A fair bit, trying to implement it, trying to map it to national curriculum orders. You know we're including literacy and numeracy in every lesson as a focus for every lesson. We've tried to map it with the national curriculum orders for science and the skills that we develop and where it is relevant. We look at the different text types so when they're writing an explanation or whether they're planning. We look at instructional writing. We look at those features and we've started to now use the descriptions from the LNF to assess pupils' work."*

Another respondent felt strongly that they are expected to implement the LNF to the detriment of their own subject: *"Well, for instance I mean in our school, I refuse to do English stuff (in lesson), and I refuse to do this because I'm a core subject and therefore I believe (we) have (our) own status. And sometimes a practical would take a whole lesson and I haven't got the time to fit numeracy and literacy things. My passionate belief is that numeracy and literacy should be placed in the work where it belongs, where the child can see its purpose, not just a stick-on."* (C). This was also a concern of other individuals: "*Because we've got numeracy and literacy that's got to come in as well and data logging and you find that there isn't time to do everything. So children only get a snapshot which means they really aren't learning to a degree that say ten years ago, the children might've been learning science or 20 years ago*" (E). This lack of embedded scientific knowledge was impacting upon practical skills too: *"[When] I was in school, we did knowledge learning and then you did experiments and stuff with that knowledge. You actually could do the experiment better because you could see why something was going in somewhere or going out somewhere. Children can't see that and could not understand the process of what they're looking at"* (C).

Conversely, some interviewees felt that the LNF would be easily embedded within Science lessons and it would eventually become inherent: *"Well, quite a lot of tasks that we do in Science can support literacy and numeracy anyway. So in Physics, you have your calculations or planning experiments and writing them up. You're going to have longer writing task as well. So, in the long term, I don't think it will affect the actual way science is taught because it is pretty much built in."* (D); *"I suppose (it will) allow the students to realise that a lot of the skills they pick up in lessons are not just for those lessons. That they're transferable across all sorts of different applications as they go through life."* (F)

Nevertheless, there was some concern of the workload impact that the LNF would have: *"There's probably going to be more workload to try and master literacy and numeracy across the different key stages and put them into the schemes of work."* (E), in addition to the flurry of changes that seem prevalent in Welsh education: *"One minute, It is this and then It is that. It is changed so often."* (C)

The respondent working at a senior leadership level had the deepest understanding due to his role in needing to oversee the implementation of the LNF throughout the school. However, he was only able to talk about the direct impact on his role within his school, rather than the initiative itself: "*It is going to impact on me massively because I line manage a number of subject areas. I have to check that they've done the audit for their subject areas, then see where the strategy goes into their schemes of work, if their extension materials are going to be relating to literacy and numeracy, how they will come to make judgements about pupil's literacy and numeracy within their subject area, how their subject area contributes to the big picture, whether there are evidence basis – say for extended writing, I'll have to check that that is appropriately marked and does respond to the different aspects appropriately so that* *they can say, 'Yeah, we're hitting the Literacy and Numeracy Framework at this point, this point, and this point. Here's the evidence base for it and this is how we've contributed."*

4.4.1.5 Attitudes towards teaching literacy

Each participant was asked how much they agreed with the statement 'every teacher is a teacher of literacy and has a responsibility in improving pupil literacy levels' on the basis that science teachers are expected to implement the LNF within their lessons. There was some positivity regarding this idea: *"I think it is true. I mean, if a kid can't read or can't write then obviously that's going to be detrimental to your results. I mean, if they can't read a test paper or they can't write out their answer then they're not going to be able to do that. But I suppose, in a way, the amount of reading, the amount of writing, the amount of different writing styles are used in science or other subjects is going to help them in English and in Maths as well. So I suppose it is true. I mean, we all need to be doing our bit rather than just leaving it to those lessons."* (I).

However, conversely, other individuals were far less supportive: *"It gets me quite cross really because yes, obviously we've got to be good models of literacy. We've got to, you know, help them in that way. But to teach it, it is very difficult. We're not trained. We're not ready. And surely, it is the responsibility of the English teachers. When they're telling us that, "Oh we don't do it this way. We don't teach them complex sentences." And then we're having training sessions and we're supposed to make a literacy target saying, "Try to vary your sentence structures." Well, that's, you know, that's not what I signed up for. That's not what my job is. And at the end of the day, I'm paid to deliver science results. I'm paid to deliver key stage three results and key stage four results. And at the moment, we're being pushed to say that by our literacy coordinator that the literacy should be the main focus of the lesson and that the subjects come secondary. And I'm fighting that all the time because for me It is the science has to come first, you know, accessing it is important and you know questions can be difficult but there are some really good scientists in this world who are not that great at literacy and, you know, should we stop them trying to change the world? No. I don't think we should."* (G).

One respondent made an interesting observation regarding to the recent emphasis of literacy and numeracy within lessons: *"From what I've seen, I think a lot of kids are starting to sort of resent the extra literacy and the extra numeracy tasks. I suppose when you're getting it non-stop in every lesson, then I suppose that's starting to try to drive them away from it, rather than sort of drip-feeding it, little by little."* (I).

4.4.1.6 PISA tests

Interviewees were asked "What do you know about PISA testing?" and "Wales came 30^{th} (out of 68) in the 2009 PISA tests. This was much lower than the other UK countries. Why do you think this is?" The interviewees were not overly confident with their understanding of PISA testing: *"I just know the basics of it, what it is. So, it is talking about the tests that's done in lots of different nations. And, based on that, you then get a rank order as to how the pupils are doing within it."* (A); *"I must admit, I'm not so hot on PISA. I know it is an international standardised test so it compares different countries. From what I was told, it is more application of knowledge rather than the actual knowledge that you know."* (D); *"I don't know too much to be honest. I know it is sort of the worldwide sort of ranking system. I'm not sure. It was one of those that was mentioned when I was doing my training but they never sort of went into it. It was weird in the way that we had some lecturers who are coming in and going on and on about it, and then some lecturers were sort of not so...not that they didn't seem to like it but they didn't place as much importance on it. So I suppose I've sort of got that. I'm not sure whether it is important or whether it is really important. So I suppose one of those things I find out myself really."* (I).

Some felt that they knew about the testing system, but made mistakes in their explanations, assuming it was merely a European test: *"[I know] a little. I know It is an assessment test that's been used in Europe where they test 15-year-olds, get their scores and knowledge."* (E)

Those that did have a greater understanding were often in positions of leadership within the Science department and had been directed to incorporate PISA-based activities within lessons. One respondent had been involved in implementing PISA style questions into the schemes of work and also had the experience of the school being directly involved in PISA testing a few years ago. Nevertheless, despite this experience, their answer was not particularly detailed and rather focussed on the specific science section of the tests: *"There is a scientific element. We've used quite a lot of the PISA questions or rather the data. We steered away from looking at the questions and we focus on what is that, what can you gain from that information? So using, developing those skills. I suppose in Science we try to develop those skills anyway."* (H)

The non-scientist had a wider perspective of the PISA tests, and was possibly considering it from their improvement leader status. However, they did not mention the scientific aspect of the test, merely focussing on the numeracy and literacy sections: *"I know there's a strong emphasis in Wales to improve the quality of the results for the PISA testing and there's an emphasis coming through from the Welsh Government to make sure that we are teaching in a way that will enhance students' ability to perform better in the PISA tests, particularly in Maths and English are looking at the way that students are tested within those areas and see if their method of testing will prepare and equip students to do well in those examinations. So that's the comparative studies Wales seem to be going up the league table basically amongst the other countries that were in that table."* (G)

The interviewees were then asked their thoughts about why Wales was 30th in the 2009 PISA tests, then dropping to 36th in the 2012 test. Participants were informed that these results were significantly lower than the rest of UK. This provoked very mixed reactions. Some participants cited the funding issues facing Wales, suggesting that the difference in funding between England and Wales placed Welsh students at a disadvantage: *"Obviously, there's a problem with funding. We get less money for education in Wales."* (A); *"I've come from England into Wales, and I would say that the financial difference is significant and that will have an impact."*(G)

Many interviewees mentioned the fact that they felt the Welsh education system did not provide pupils with the necessary background or skills to enable them to answer the PISA questions successfully: *"I think the PISA testing; the way the questions are worded is in quite a strange away. And, I think that maybe our education system doesn't train them in the way that they need to answer—specifically answer the PISA questions. I don't think it is necessarily the knowledge. I think [pupils] lack the skills needed to answer those specific questions."* (A); *"I don't believe that our education is conducive to 'knowledge learning' and to be able to use that knowledge within an exam or testing context. Whether you are testing skills or whether you are testing knowledge or whether you're testing to use that knowledge, you cannot do that if children don't have it."* (C); *"We're definitely seeing that there's a difference in the knowledge of the pupils when they finish Key Stage 3 and they move on to GCSE. Before the skills levels came in, it was very content-based, what we were teaching them. So their knowledge was a lot better by the time they finish Key Stage 3."* (E)

In addition, the difference between the assessment methods of Wales and the other UK countries was considered to be an issue. Wales currently assess pupils via teacher assessment until Key Stage 4, and the abolishment of SATs means that children do not have formal examinations until they are at least fifteen years old: *"I think the PISA test, from what I've seen, the questions testing quite a different way to the way we've been assessing and examining children over many, many years... I think there probably is an element of the way that the teacher assesses activities at key stage three."* (F); *"With the SATS going, they're not being prepared for tests."* (H)

One participant looked at this question from a very personal view, *"I suppose it could be that not so much emphasis is placed on Science in Wales. I mean, I've heard people in here…since I've been here saying things like teachers openly admitting they hate Science and saying it is not important. So, I suppose if they're being told that, then if kids are hearing that, they're going to get that attitude themselves. I mean, I've heard kids say, 'I'm not good at Science,' when they're easily a C grade pupil, which is…. But they don't see as…because they're getting A's and B's in other subjects. I don't think they realise that sometimes Science is much more difficult than other things. So they sort of get disheartened when they're* *not getting an A* or A. So puts them off maybe. I suppose mainly, It is like, in my opinion, the emphasis on it isn't as great as maybe it is in England or Scotland or anywhere else in the UK perhaps."* (I)

There was a great deal of frustration from one individual regarding what she felt to be the constant changes to the Welsh education system. She felt that there was no consistency, and no opportunity to embed new initiatives properly to see if they would be advantageous: *"We're constantly changing things. We're always changing things and bringing new things in"* (H). This was echoed by another participant who felt that the education system is more rigorous in England: "*There's a tendency in my view for the rigour that is, well, more prevalent in England, has had a quicker impact.",* although he was confident that Wales is beginning to make the necessary changes to ensure that they are competitive: *"Wales is just catching up really, would be my observation."* (Deputy Headteacher)

There was also some confusion about how much scientific knowledge is required to answer PISA questions well: *"How can the children do the science questions in the PISA test because they don't have some real good sound knowledge to be able to apply it to the questions that are being asked"* (C).

4.4.1.7 Exam Board Support

Interviewees were asked "How much support has your exam board offered in terms of the new literacy focus (extended answer questions)?" Generally, interviewees felt that there was a lack of support and resources from their exam board and there appeared to be a wide range of opinions about the different exam boards: *"I don't think we have had any support other than 'Here's the question. Here's the mark scheme'."* (F). Two respondents' schools switched their exam board because their science departments felt so strongly about the lack of support offered to them by the former exam board. Due to a lack of consistency, exam boards are being swapped and changed regularly to allow pupils to achieve the best results possible. One interviewee specifically said that their department had not chosen to use AQA as they considered the exam board as being *"very, very wordy. Too wordy for our children [as] we do have low literacy levels in our school."* (C)

The majority of respondents spoke about how the exam boards seemed more inclined to offer support based on content, rather than the quality of written communication (QWC) or literacy questions. These questions are marked on the basis of whether the answer is structured clearly, with appropriate specialist terms. Two teachers recollected how, when they asked their exam board for support on improving their pupil's QWC answers, the exam board representative merely recited the markscheme answer back to them and was unable to offer any tangible advice for those style of question.

Teachers also cited difficulty in accessing support materials: *"The issue that I have with the exam board is that information is just uploaded to a website. You're not actually told when it is on there. So, unless you're checking the website all the time, you have no idea that it is actually there."* (A)

4.4.1.8 Measuring Scientific Literacy

No respondent was able to answer the question "how does your school measure scientific literacy". Nevertheless, some respondents were looking at developing a method of measuring it: *"Not really but It is part of our development plan for this year because we've got to assess and report on it by the end of the year which is going to be quite difficult."* (H)

A pupil's *science* ability is measured by teacher assessment in Key Stage 3 and external assessments in the form of GCSE or BTEC qualifications in Key Stage 4. The *rigor* of the Key Stage 3 teacher assessment was queried. Teachers felt that there is no standardisation between different schools and a difference between the assessment beliefs of primary and secondary school teachers. Some respondents felt that they had never truly been taught how to level correctly, and this problem has continued for many years: *"The way teacher assessment was brought in was so flimsy in the first few years and teachers are still stuck about the flimsy way of doing teacher assessment. The primary schools are so sure they've got it right. All the people who are involved with it they say they're right because they're getting the [good] marks. But just because you're getting the marks, it doesn't mean that you're right. And I think the system is flawed further down and I don't think people want to see it better because that means the marks will go down."* (C);

Other individuals had very basic methods of assessment that did not fully measure the scientific literacy levels of their pupils, but instead focussed on literacy and numeracy: *"We do lesson objective sheets. So at the beginning of a topic, they're given these sheets with all their objectives for each lesson that's coming up and at the end they'll have a literacy target, a numeracy target."* (I)

4.4.1.9 Improving Scientific Literacy

Interviewees were asked the methods they used to improve scientific literacy. Ironically, some respondents felt that they were in a poor position to improve scientific literacy, because they don't truly understand what it means: *"Because we don't really know what scientific literacy is, I think it is quite difficult to actually say what we're doing."* (A)

Seven out of nine interviewees merely cited extended writing as their way of improving scientific literacy. Other teachers had developed their own methods of trying to improve the scientific literacy skills of their pupils. For example, one teacher provided their classes with 250 biological words at the start of the year, with the expectation that they would all be learnt. Another mentioned that they felt that they spent a large amount of time searching for resources on the internet, but they had no idea if they were of a suitable standard. Other science departments have spent time developing resources that are specific for their calibre of pupils: *"We ourselves have to be very aware of the language and the words that we need to use to move the child on. So we often talk about in department meetings. We sit around. We write worksheets together. We'll write workbooks together. We do write tests together.*" (C)

Key word walls or noticeboards were also a popular choice, with one teacher mentioning that they had to make a portable one due to the fact they taught in a number of different labs. Likewise, writing frames were mentioned regularly, although these were also made by the teacher themselves, rather than anything provided by an external body. *"We've got in every lab, there's sort of* (the) *different writing styles we use in Science...all displayed on the wall."* (I); *"We use a lot of keywords. We use a lot of what we call command words and getting pupils to understand what they're being, what's being asked of them, so how it relates to science is quite different to how it relates to other subjects when they're asked to describe and explain and when they're asked to look at data and draw conclusions. It can be quite different. So we focus on those, the key terminology that they need. We focus on different writing styles and what we'd expect to see. We use success criteria to model specific writing that we'd use in Science and to, and reading as well. We're looking at reading different information, you know, different scientific reports. So we're having a good go."* (H)

Some teachers specifically spoke about correcting spelling in pupil work, although there were some discrepancies in what different schools expected. Some schools were happy with science teachers just correcting *scientific* spelling, whereas other schools were expecting basic literacy to be corrected in preference to scientific spellings: *"I have a kind of like nagging doubt that It is going to go too much towards the literacy, which means that you then can't [mark] for your actual subject."* (I). Most teachers were trying to do both, thus increasing the marking time for each book.

Most interviewees could not think of any initiatives or training that currently supports the development of scientific literacy in Wales: *"I don't really feel that there are any factors that are supporting (scientific literacy in Wales)".* (A); *"I'm not sure."* (D); *"I don't. I don't really know how much there is, to be honest."* (F); *"Not a great deal. Not a great deal at all."* (H)

However, some interviewees felt that if things changed and there was a provision of teacher training, this would have a positive impact: *Obviously, (if we had) in-depth training. First of all, we definitely need to have a definition for it. And then, obviously resources to be able to support it, frameworks, you know, just anything to push them in the right direction to know what scientific literacy is."* (B)

One participant felt that pupil enjoyment in Science would lead to an improvement of their scientific literacy levels. He believes that school-based initiatives such as a STEM club improve pupil enthusiasm, in addition to their relationship with teachers, but would also lead to an increase in attainment: *"Well, we've got STEM Club here which is good. The kids who go to that really enjoy it and they are the sort the ones you can see going on to do like Separate Science and really achieve."* (I). The participant did not mention an equivalent initiative for those pupils who would not be of the appropriate calibre for Separate Sciences.

The member of senior management noted that his lack of experience within a Science department resulted in his response being very limited, but he felt that there should be a greater dissemination of good practice in order to develop better teaching of scientific literacy: *"I think that the schools that are doing it effectively, it would be very useful if they [could be told]. We want to know what aspect they're doing really well, what is it they're doing really well, and how do we know that they're doing really well, what's the impact of that work? That can then be showcased and sign posted so that staff can really go, "ah I see what you're doing...we could do that or we're not at that point, but we can start at this point."* (G)

One respondent felt that the lack of understanding about the term 'scientific literacy' was an issue; *"I don't think that the Welsh Assembly Government really know what scientific literacy is. So, therefore, they aren't able to give any guidance and support with that."* (A). There was a perceived lack of support from the Government: *"The government, you know, they produce guidelines for the literacy and numeracy framework and you might be a paragraph about how it applies to science and, you know, so It is basically go alone."* (H). In addition, there were issues with the large number of changeable initiatives that are constantly implemented by the Welsh Government: *"If we try to do really well at a number of things, we'll end up doing none of them particularly well. So it needs to be, what are the absolute priorities? So what do you really, really want to do well at and maybe reduce the focus on some things."* (G). Nevertheless, his personal view was that literacy will be one of the top focuses: *"[However], literacy isn't going to go anywhere. It is a number one priority."* (G)

Again, the formative education undertaken in primary schools and the lack of science specialists at the level was cited to be problematic: *"It is based on the teacher's knowledge and what they've got. And if they're weak, that class goes pass them every year is going to be as weak"* (C)

The time constraints felt by teachers, especially at KS4 and 5 was also cited as being problematic: *"Frankly, I have to rush through so many topics to get to the end point. Sometimes, you don't have the time to develop it."* (D).

One participant pointed out issues with finding Wales-specific resources: "*You try and find information. I mean, we struggle in Wales because there's not a lot support material out there anyway. There's not a lot that, you know, there's no publishers producing books that are suitable. We constantly get phone calls from new people supplying new textbooks but they're never relevant."* (H)

Another individual was concerned with the disparity between the technologies utilised by scientists in the 'real world' and that which is used in the school laboratory: *"[We need to get] new technology in place in schools, rather than doing the same old experiments every year, maybe to update it a little bit. I mean, there's are a lot of different technologies and things that could be used now or even to go somewhere where you could see that in use rather than bringing it into to school, maybe take them to see it somewhere else. There are so many different places they could go on science trips."* (I). They recognised the benefit that this would have to the pupils, including the improvement to their scientific literacy levels. Unfortunately, they also recognised the financial difficulties in allowing this to happen.

One participant noted there are a range of overlapping topics within the curriculum which she felt were being poorly taught in other departments, and therefore having a negative impact upon pupil understanding and progress in Science: *"I think we're hindered by Geography teaching things like climate change and plate tectonics not as well as maybe they should be doing. So that can hinder [pupils] when they come in [to Science]."* (H)

Many respondents had a perception that science as a subject is being sidelined in favour of literacy and numeracy: *"I think the way It is been marginalised. Science has been marginalised. You know that's It is no longer a core indicator. The literacy and numeracy framework has pushed us out of Key Stage 3, even though we're still responsible for CSI and get included in meetings. It is all Maths and English and nothing else. Well, if you're going to do that we might as well not be a core subject anymore and you don't need to be compulsory. But they're still making it compulsory."* (C); *"Senior management just don't seem to appreciate the importance of Science as a subject. For example, kids could just be taken out to Science lessons. No questions asked. Just to go and do, for example, English or Maths, because now Science is lower down the pecking order."* (F). However, the non-scientist member of senior management recognised the pressure that Science teachers are under in being required to teach the scientific content of their lessons, in addition to the expected focus on literacy and numeracy: *"[Science teachers] are going to have to give an account for Key Stage 3 results, level 4s, level 5s, level 6s, level 7s, and A*-Cs and capped point scores. All those things are not necessarily going to be enhanced by teaching literacy within Science."* (G)

These thoughts are comparable to a poignant statement made by one respondent: *"We have to help English. We have to help Maths. We're the key subject that links the two together. I understand that. But there's no one out there that helps us."* (H)

4.5 Reinterviews

As no case study took place (see section 4.8.2), there was a need to re-interview the participants from the semi-structured interviews. This was to ensure the trustworthiness of the research. A year after the first interviews, all of the original participants were contacted to ascertain if they would be willing to take part in the second interview. Of these, six agreed to be interviewed. Three did not reply to the invitation to be re-interviewed.

Table 19: Characteristics of the six teachers interviewed.

Individual	Role	Time in Post (years)	Location
A	Head of Science Department	10	North East Wales
B	Head of Science Department	16	North West Wales
C	Head of Science Department	15	South East Wales
E	Head of Biology	3	North East Wales
F	Teacher of Physics	7	Mid Wales
H	Head of Science (case study school)		North East Wales

4.5.1 Responses to the transcriptions and my interpretations

Every participant agreed that the transcription and my interpretation of their interview was correct and represented their thoughts at the time. As these documents were emailed to the participants, before a telephone re-interview took place.

Every participant responded to the email, usually as a courtesy reply, but each of these replies had written confirmation that the documents were correct: *"Both look accurate - though [I'm not] particularly articulate!"* (F); *"I have read through the transcript and it all seems fine to me"* (A); *"Reading the transcript made me laugh as I can hear me saying it and having a rant"* (H).

The participants then reaffirmed this agreement in the spoken interviews: *"Yep, It is all fine"* (A).

4.5.2 Current views on scientific literacy in Wales

Many of the participants felt that little progress had been made regarding the status of scientific literacy in Wales: *"I don't think there has been massive changes…It is much the same. I think there may have been* *a little bit of progress, but not as much as you might have thought"* (F); *"there haven't really been any changes"* (H).

Any progress that was considered to have been made was deemed to be *"very slow"* (F). One participant mentioned that although some courses had been arranged by bodies such as the Science Learning Centre were either *"extremely difficult to enrol on, so people aren't sent"* (E).

GwE was mentioned by teachers located in North Wales. This body is a recently formed School Effectiveness and Improvement Service for North Wales and is tasked with improving education in the region. However, teachers felt that there was a *"lack of guidance from the likes of GwE"* (B). One participant mentioned that *"courses organised by GWE were advertised, then either disappeared or were cancelled with no notice"* (A). When questioned further about this, participant A had enrolled on two separate courses that had been organised and advertised by GwE. Their school had arranged supply cover, only for the participant to arrive at the arranged venue to be told that the course was not running because nobody had enrolled on it. Participant A had evidence of the confirmation of the course enrolment.

Participants also mentioned that there were *"too many changes in education. There are too many things happening. Slow progress is inevitable…there's too much to take on"* (B). One participant mentioned that "*the focus had broadened out a little bit…out into numeracy as well. As far as scientific literacy is concerned, this is probably a good thing"* (C). The lack of focus on scientific literacy at the expense of literacy and numeracy was again mentioned*: "there's plenty about literacy and numeracy, but nothing about scientific literacy"* (F); *"I don't know where we're heading. It is just gets more demanding all of the time. We're now expected to be using a learning objective that is a literacy objective for <u>every</u> lesson. And we're not doing it. We get monitored by the literacy coordinator and I've told her not to come here. But she's adamant that the literacy comes first and the subject comes second. I don't think It is needed. What I want them to achieve is the science. The literacy coordinator doesn't get that there are two different types of literacy, and thinks we should all be English teachers. Time's limited. Where does the science fit?"* (H).

There was also a concern of the detrimental impact that the LNF is having on examination results: *"I think the science results have gone down by the literacy drive"* (F). This was in contrast to what Estyn looks for when assessing a school. For one participant whose school in currently in the Estyn Monitoring category, there was concern that the emphasis on literacy was going to cause problems for a re-inspection: *"If our results are fine, then Estyn won't come back. But I feel that our results have gone down. They're not going to be looking at the literacy. They're going to be looking at the results. My Year 10s asked me about a 'quality of written communication' question. I told them that "you can write in bullet points, as long as* *you use the correct technical scientific terms", but this is against what we've been told to do in our literacy focus. They expect it in full sentences. But this wastes time in the exam. Why would I make them do that when it has no benefit?"* (E).

4.6 Attitudes of Teachers

One emergent theme from the interviews was the relatively negative views of the teachers in both the interviews. I felt that in some situations, the interviewees appeared frustrated and sometimes angry. These feelings were directed at a range of different things, such as a perceived lack of guidance from the Welsh Government: "*we're being pushed into doing things that we don't really know {about}*" (A); to the pressure of teaching: "*That's not going to make any difference if the inspector's mark that they give me, because I haven't filled in notes or tick boxes that the criteria I'm supposed to fulfil for them*" (C)' "*So {this literacy and numeracy focus} combined for me…it's making science a bit diluted quite frankly. I don't feel like science teacher anymore*" (B); "*Literacy is hammered from everywhere*" (D).

When reading the interviews, I felt that there was very little positivity in the participants' responses. This was confirmed by my supervisors when they read through the transcripts. However, I undertook the reinterviews to establish if the participant responses were coincidental. This proved to not be the case, as explained in section 5.5.1.

4.7 Summary

The results from the study were gained through a mixed methods approach: questionnaires distributed to every educational establishment, followed by interviews of willing participants, and then further reinterviews after a period of approximately a year. The questionnaires and original interviews provided a valuable insight into how scientific literacy is considered, measured and improved within Wales. Teachers in Wales have a varied understanding of the term, and although they have some understanding of PISA testing, it is not in great detail and Wales' performance is often considered to be lower than it actually is. The questionnaire respondents and the interviewees noted the importance of science to young people, but were concerned about different pressures within school, taking their focus away. For example, there is a belief that there is a greater focus on teaching 'general literacy', rather than scientific literacy within science lessons.

There appeared to be great negativity surrounding science education within the country, so the reinterviews were utilised to ascertain whether these attitudes were coincidental or had improved in the interim. The reinterviews showed that respondents still felt the same as when the original interviews took place.

5 Discussions of Findings

5.1 Introduction

This study was designed to answer three research questions in response to the 2009 and 2012 PISA results:

- What are teachers' interpretations and perceptions of scientific literacy in Wales?
- What methods are used for measuring and improving scientific literacy in Wales?
- What factors support or hinder the development of scientific literacy in Wales?

The findings are based on data collected from questionnaires and during semi-structured interviews, and a case study taking place at a North Wales school. In this chapter, the findings are discussed.

The chapter is in four separate parts. Firstly, to answer the first research question, the importance of science and a definition of scientific literacy within Wales is considered. In light of the problems regarding a definition outlined in section 3.3, the extent to which Welsh professionals understand the term is examined. Then, the main discussion focuses on scientific literacy itself; exploring the reasons why Wales does not perform as well as other countries, reviewing the findings concerning scientific literacy being taught and measured in schools, the extent and nature of improving scientific literacy. This section answers the second research question. The third research question is addressed by a consideration of factors that either support or hinder the development of this area. Finally, the trustworthiness of the study is discussed.

5.2 Importance of Science

It was very clear that the teacher respondents were passionate about their subject. They had an enthusiasm for Science that they want to instil in their pupils. However, teachers had a fear that Science as a subject is slowly being marginalised in Wales due to the greater emphasis on English and Mathematics lessons. There was full understanding of the necessity of improving the literacy and numeracy skills of Welsh children, but the teachers involved in this study felt that the importance of Science was only being recognised by themselves. This 'competitive' nature between school subjects is something that was commented upon by Donaldson in his independent review of the Welsh education system (Donaldson, 2015). He feels that there must be more collaboration both within and between schools, including at subject level, in order to lead to progression within the Welsh education system.

Interestingly, the views of the teachers and the professional respondent regarding the importance of skills that Science offers to students were essentially the same, except in one area: Science offers children the skills that will enable them to solve daily life problems. Teachers felt that this was a key skill, with 89% of respondents deeming this to be important or very important. Conversely, the professional respondent was neutral about this skill. This is possibly because the professional was understandably not knowledgeable about what happens within a science lessons.

5.3 Definition of Scientific Literacy

One of the biggest findings from the study is that the respondents were unable to confidently explain the meaning of the term 'scientific literacy'. I am even unable to compare their definitions with a globally accepted definition, as one simply does not exist (see section 3.3). Within the interviews, the respondents were almost apologetic about not being able to quickly and concisely define the term. However, responses covered at least part of the definition that the Welsh Government is currently utilising from the PISA documentation: scientific literacy "requires core knowledge of the concepts and theories of science. It also requires knowledge of the common procedures and practices associated with scientific enquiry, and how these enable science to advance" (Welsh Government, 2014c). Although phrased in different ways forty nine respondents (80%) made some indication of the importance of 'understanding science', linking to the former part of the Welsh Government's definition. Less emphasis was made on scientific enquiry, with only two respondents mentioning this.

Throughout the country, being able to define the term 'scientific literacy' was not linked to person's job role. Some respondents were not science specialists and yet felt that scientific literacy was the "ability to use, participate in, convey and understand areas of science, including experimental, analytical and general scientific terminology".

The Welsh Government employee was understandably the most vague about the term due to their position being outside of a school-setting. Their understanding was more heavily based on standard literacy, but in a science lesson: *"Literacy and its relation to understanding science"*.

5.4 PISA results in Wales

Every respondent recognised that Wales underperforms in the PISA tests, but there was a definite over-exaggeration of just how badly Wales performed. Wales' PISA results were well broadcasted ("Pisa ranks Wales' education the worst in the UK" (BBC News, 2013)), and regularly utilised for political agendas ("Labour has failed a generation of Welsh pupils" (Roberts, 2013)) so it would be expected that participants would have a good knowledge of this. However, the extent of negativity was surprising. It could be suggested that this is possibly due to the negative portrayal of the Welsh education system by the media. For example, the media's reporting of 'The Annual Report of Her Majesty's Chief Inspector of Education and Training in Wales 2009-2010' largely ran with the headline "1 in 3 schools 'below standard'"

(BBC News Wales, 2011) or “Third of schools in Wales not good enough” (BBC News, 2011), rather than focussing on the fact that the report found that the majority of establishments are achieving their targets and that "inspectors did find some significant improvements in some individual settings" (Estyn, 2011). This reporting is important as no school should be below standard, but it could potentially have ramifications with people who work in education thinking their sector is performing worse than it actually is. No respondent felt that the bilingual aspect of Welsh education was advantageous, despite some research providing evidence that bilingual children have greater mental flexibility (Latham, 1998) and increased communication skills (Baker and Sienkewicz, 2000).

5.5 LNF

Although not an initial main focus of my research, the new National Literacy and Numeracy Framework became a larger part of the research. Teachers recognise that pupils often lack basic literacy skills and understand the importance of such skills in improving pupil attainment. Norris and Phillips (2003) noted that the ability to read and write is closely linked to the ‘very nature and fabric of science and by extension, to learning science” (p.226) and therefore, any initiative to improve scientific literacy must include strategies needed to cope with science text, meaning Science teachers need to “unify their efforts in fostering literacy in its fundamental sense” (p.232). However, there were strong views from the respondents regarding the current focus on literacy and numeracy, at the expense of teaching actual Science. These attitudes have been noted in other studies where teachers felt that external accountability measures that focus on literacy and numeracy concerns can force out the teaching of Science (Brand and Moore, 2011, Lumpe et al., 2012).

Consultation on the LNF took place between 11 June and 12 October 2012, a time period of approximately 17 weeks. This was also a time period where schools were in the midst of examinations and then on holiday for at least six weeks. It was then quickly implemented with what many teachers consider to be minimal guidance. At the time of this research, the LNF had only been in place for a year. As a result, there may have been some confusion regarding aspects of the framework. Although there is no debate that improving the literacy and numeracy skills of Welsh children is important, there is an indubitable debate regarding how it should be implemented within schools. The Science teachers within this research are increasingly becoming frustrated at the lack of guidance offered to staff outside of English and Mathematics lessons. The general consensus amongst the respondents is that they are currently teaching literacy through the medium of science, rather than scientific literacy. Anecdotal evidence shows that Science teachers are progressively factoring in tasks such as “writing a letter” or “writing a newspaper article” into their lessons in order to provide evidence to their senior leadership teams that they are incorporating a literacy element to their lessons. These tasks have always been an important part of science schemes of work, but in many schools, they are required by literacy coordinators when completing any audit. Science teachers are disheartened that their lesson time is being taken up by what they consider to be rudimentary literacy tasks, but this offers potential to explore the potential of cross-curricula lessons. Both science and English content could be taught simultaneously, leading to an end product of not only a scientifically correct piece of work, but also one that is grammatically correct and presented in the appropriate format.

An apparent perceptive division between Science teachers and their Senior Leadership Team with regards to the current emphasis on literacy and numeracy skills could potentially become a major obstacle to productive improvement of scientific literacy. My research findings illustrate that the managerial conception of scientific literacy not only differs from that of teachers, but can sometimes exclude their opinion and undermine Science as a subject. Appropriate and relevant training could alleviate this issue.

There is currently a strong managerial drive to improve the general literacy and numeracy levels of pupils within schools, but in some areas, this is being done at the expense of Science. The removal of pupils from Science lessons in order to undertake English or Mathematics interventions may negatively impact upon a pupil's science performance. Equally, the reduction of Science lessons in the timetable to allow an increase in English or Mathematics could produce the same result if not managed correctly.

Within lessons, the pressure of having to provide evidence regarding the improvement of pupil literacy and numeracy skills has produced a situation where literacy tasks in particular are 'shoehorned' in to lessons, with little advantage to a child's actual scientific literacy. Poems, letters and newspaper reports certainly have their place; but senior leadership expecting to see regular examples of such work is counterproductive to the achievement of science.

Science teachers spoke about trying to facilitate trips to places of scientific interest, ranging from places such as Techniquest to field trips to sixth form genetics conferences. These trips are designed to further pupils' understanding and enthusiasm for science. However, throughout the country, science teachers are finding difficulty in providing these trips. This is for a number of reasons, including the 'rarely cover' policy meaning It is become increasingly expensive to provide supply cover to teachers that are on the trip; difficulties in finding transport companies that can provide transportation at a reasonable cost and issues with risk assessments for field trips.

5.6 How Scientific Literacy is measured in Wales

Scientific literacy is currently not being measured through any standardised means at any of the schools involved in this study. It is being measured through teacher assessment, but there is no consistency in this approach, both within and between schools. Interestingly, the professional respondent felt that the advent of standardised testing would improve scientific literacy levels within Wales, but contradicted themselves when saying that commercially available tests should never be used with pupils.

Within Welsh schools and the revised 2008 National Curriculum, statutory testing was abolished. Since then, a pupil's ability in Science as a subject is recorded through teacher assessment at Key Stage 1, 2 and 3: a highly subjective method that lacks the objectivity that SATS may provide. At the end of the Foundation Phase and Key Stages 2 and 3, schools then report the results of these teacher assessments to the Welsh Government.

At Key Stage 4, pupils are either completing GCSEs in all three sciences, a GCSE double science award or a BTEC qualification. This produces an interesting quandary. BTEC qualifications are considered to be equivalent to GCSE, but they are currently assessed in very different ways. Therefore, there is also no standardisation in measuring scientific literacy at Key Stage 4 level either. Pupils can then opt to not continue studying Science once they have left secondary education, again producing difficulties in accurately establishing the scientific literacy levels of 16-18 year olds.

5.7 How Scientific Literacy is improved in Wales

At the time of writing, the methods for improving scientific literacy were on a similar level to the methods used to measure scientific literary: there is currently a lack of improvement methods, and those which are being used are often considered rudimentary by the teachers that designed them. This level of inconsistency is again present within and between schools across the country. Scientific literacy training is very infrequent and the very few resources that are available are better suited to the English curriculum. Many resources are being created by teachers themselves, and there is a distinct emphasis on word walls or definition lists. Interactive resources are very rarely used. I believe this is due to a range of reasons, including a simple lack of such resources, but also a cost implication for schools. Many schools are financially unable to provide interactive whiteboards in each lab, or provide their pupils with access to different digital platforms. Teachers may lack the relevant expertise to be able to make similar resources on an open-access platform, hence the reliance on more physical resources. Similarly, commercially available resources are never used, simply because after research, ones appropriate for the Welsh Education system do not exist.

5.8 Factors that support and hinder the development of Scientific Literacy in Wales

5.8.1 Governmental Support

The role of the government was a fundamental part of the respondent's answers. Most teachers felt that there was very little support, and where it was implemented, it was mainly focussed on improving literacy and numeracy standards. In October 2014, a document was published by the Welsh Government that gives key information and guidance in preparation for the scientific literacy aspect of the 2015 PISA tests (Welsh Government, 2014c). This document is very brief and essentially rewords the draft documentation produced by the OECD (OECD, 2013). However, interestingly, the guidance outlines how a regional Education Consortium advisor or leader of learning will be available to support the Key Stage 4 teaching and learning of scientific literacy. These advisors are privy to a "Matrix Comparison document" that tracks the three areas of scientific literacy that will be assessed in the 2015 tests against what is currently being taught at Key Stage 4. Teachers will be expected to use this tool to identify and address any potential weaknesses.

The advisor will also be in a position to be able to coordinate school to school professional learning communities (PLCs) in order to support the development of scientific literacy. The document mentions that during 2014/15, the following resources will be available for teachers to use:

- PISA-style Scientific Literacy sample questions in a class ready format
- Refreshed Guidance on STEM, including information on the Scientific Literacy approach
- An online INSET Module on Scientific Literacy for your further development
- An online directory of STEM enrichment programmes and materials
- A calendar of science events and activities for learners, teachers and parents
- Information for learners on science related careers and further learning

At the time of writing, there has been no further information regarding either the regional Education Consortium advisor or the apparent resources that will be provided in preparation for the 2015 PISA tests that will take place from November - December 2015. However, in June 2015, posters were produced by the Welsh Government for the "Focus on Science" campaign. One of these posters was entitled 'Scientific Literacy' and consisted of a background map of Wales with "Llythrennedd gwyddonol sy'n gyrru Cymru/Scientific literacy makes Wales go around" as the headline, then "Diolch i wyddoniaeth, gallwn…/Thanks to science, we can…" and small logos with words such as "Ei ddatblygu/Develop it" and "Ei ddarganfod/Discover it" scattered across the map. This document came with no guidance regarding the development, measurement or improvement of scientific literacy.

5.8.2 Lack of appropriate training

Seventy seven percent of questionnaire respondents reported never having received any training or professional development in improving the scientific literacy of their pupils. This was a common theme throughout the country.

At the time of writing, no training provider runs a specific ‘scientific literacy’ course. Large scale providers of specific science teacher training such as the Science Learning Centres do not have any facilities in Wales at all and Wales is categorised as being in the “North West”, leading to considerable travelling distances when attending any course and the associated financial implications related to that. These courses are also not Welsh-education specific, and by being held in England, are clearly tailored for English educators. In terms of generic science courses being offered at the Science Learning Centre, courses entitled “Enhancing literacy skills in science” and “Linking the Core Subjects: Literacy and Science” are being run in 2015. Again, these courses are designed to improve literacy in science, “increasing the repertoire of teaching and learning strategies to enhance students’ literacy skills” rather than actual scientific literacy. They are also not Wales-specific, so do not take into account the Welsh education system.

5.8.3 The Impact of Previous Education

The role of the primary school was repeatedly mentioned throughout my research and the issues surrounding the misconceptions developed in primary school are of great concern. Most primary school teachers often have minimal experience of Science beyond their own formative learning (Sharp et al., 2011) due to their ‘generalist’ role (Sorsby and Watson, 1993). Other authors have found that primary school teachers lack the confidence and necessary scientific knowledge to be able to teach science effectively (Loughran et al., 2008, Cooper et al., 2012). A 2003 study found that fifty percent of primary school teachers feel they have “a general lack of knowledge and expertise as well as training, and therefore lack the confidence to teach primary science effectively” (Murphy et al., 2005). Thirty three percent of respondents in the same study found that there was a poor availability of, or limited access to appropriate resources.

One option is to use specialist teachers to teach Science in primary schools, particularly in the latter stages of Key Stage 2. The story about the primary teacher who annually tells her pupils that the blood is blue is concerning as the teacher had clearly never been corrected by any of her secondary colleagues, leading to an ongoing issue. Specialist teachers can provide a higher level of subject knowledge, commitment and enthusiasm for Science and have the potential to have a positive impact on the work of other teachers (Colley, 1991). Specialist teaching guarantees that pupils have access to high quality Science teaching, and may aid the transition process by allowing pupils to become accustomed to having different teachers facilitating different lessons. In his independent review, Donaldson felt that specialist teachers would be advantageous to the education system (Donaldson, 2015).

In addition, there should be greater cooperation between secondary schools and their associated primary feeder schools to ensure that pupils are being levelled appropriately. The general belief that primary teachers overestimate the levels of their pupils was common and this has huge implications for secondary science teachers. For example, if a pupil leaves primary school with a level 6, this is generally considered an acceptable level for Year 9 pupils. Secondary schools are not allowed to decrease a pupil's level, so that pupil will be expected to produce work of at least a Level 6 standard. One pupil I taught who was in the same situation wryly commented "How can I already be a Level 6 when I've never heard the word 'variable' before".

Secondary school trainee teachers are required to spend a week in a primary school during their training. Perhaps it would be useful for the primary school trainees to also do the same to fully understand the challenges encountered at the higher level. Equally, opportunities for secondary-primary working parties would be a way of ensuring consistency and improving the rigor of the levelling process. Alternatively, allowing primary school science coordinators to spend some time in a secondary school science department may also be useful. Whilst not in Wales, such initiatives funded by the Primary Science Teaching Trust are taking place in England (Davies et al., 2014). These projects, with titles such as "Increasing the impact of science primary liaison from St Anne's Catholic School Southampton on science teaching and learning in their feeder schools" and "Using primary and secondary collaboration to deliver the curriculum for science" are being designed to improve the quality of science teaching at the primary level as teacher assessments do not take place in England. However, such projects could easily be implemented within Wales with an additional focus on improving the rigour of pupil levelling.

In terms of general literacy, there has been some concern that the advent of the Foundation Phase in 2008 has had a detrimental impact upon the literacy and numeracy skills of pupils (Rhys et al., 2015). The Foundation Phase places a greater emphasis on experiential learning, thus leading to a depletion of basic skills. Nevertheless, the Foundation Phase is based on Scandinavian practice, and Finland are consistently high performers in the PISA tests. However, in Scandinavia, it is implemented from birth and an independent review of the Foundation Phase in Wales found that there were "varying interpretations and attitudes" towards the initiative (Siraj and Kingston, 2014). One report warned that key factors of the Foundation Phase had been misinterpreted and the quality of the delivery varied hugely between local education authorities (Taylor et al., 2013).

5.8.4 Lack of Specialist Teachers

One of the major issues uncovered was the issues surrounding a lack of specialist teachers. To become a qualified teacher in a secondary school in Wales, an individual must have a bachelor's degree and obtain qualified teacher status (QTS). This can be done by either completing initial teacher training (ITT) or through an employment-based route. For the former, there are two routes: a concurrent route combining theory and practice that lasts between three and four years, or a consecutive where individuals pursue an extra year of professional training after gaining their undergraduate degree to achieve the Post

Graduate Certificate in Education with QTS (PGCE with QTS). The Graduate Teacher Programme (GTP) and Teach First scheme are an alternative way of becoming a teacher whereby an individual trains whilst working.

Recently, Wales has tried to strengthen the recruitment, development and retention of its teachers through various measures. These include the provision of various grants that offer incentives to graduates with “best degrees” to teach, or to attract students into key subjects where there are teacher shortages, such as Physics and Chemistry. However, mid Wales and south-east and south-west Wales all still have a high proportion of non-specialist teachers which could be having a far-reaching effect. In some areas, schools are struggling to attract any specialist applicants to advertised vacancies, or have to ‘call in favours’ to ensure resources are produced to a suitable standard. The shortage of quality teachers has been an ongoing problem in science education in many countries (Wang, 2004) and many studies have described the disappointing state of science teaching throughout many countries (Yung et al., 2011). Even where teachers are scientific-area graduates, Sperandeo-Mineo (2006) found that good knowledge of subject matter at degree level did not equip teachers with the necessary deep knowledge for teaching the subject. When teaching outside of their specialism, teachers have to improve their subject knowledge as this is imperative for effective teaching (Childs and McNicholl, 2007). The impact of non-specialist Science teachers has been well documented. For example, Sanders (1993) found that non-specialist’s lessons were less structured and the teachers became so concerned with how to respond to pupils with sufficient depth and accuracy, that they were regressing back to their trainee-teacher level. “Science teaching outside a teacher’s subject specialism is limited, unadventurous and lacking in cognitive challenge” (Childs and McNicholl, 2007, p.5).

It has been well documented that Biology teachers teach outside their specialism (Childs and McNicholl, 2007). However, there is also a problem with the deployment of Physicists and Chemists, where they are in a departmental minority. Often, these teachers teach Key Stage 4 and 5 only. Although this strategy is understandable, it may be counterproductive. Osborne et al. (1998) found that when such specialists are in a minority, “they should be used where they have the greatest effect; that is in Key Stage 3 which all research shows is the crucial, formative period for attitudes towards Science” (p. 31).

It is therefore important that more is done to attract good science graduates to the teaching profession, and furthermore, explore the idea of recruiting these graduates into teaching at schools which lack a specialist. This strategy is employed in London with the ‘London Challenge School Improvement Programme’, established in 2003 (Hargreaves, 2003). The programme uses independent, practised education experts to identify and support underperforming schools, and more recently, create valuable partnerships with ‘teaching schools’ that provide comprehensive training to groups of teachers that need support (Stoll, 2009). A similar approach could be utilised in groups of local schools which lack specialists, with the creation of Working Groups that would at least address the need for high-quality resources.

5.8.5 Curriculum Time

None of the questions that featured in the questionnaire or semi-structured interviews were specific to the time demands of being a teacher. However, a large proportion of Science teachers felt that the current emphasis that is being placed on improving general literacy and numeracy within Welsh schools was putting undue pressure on the teaching of Science. This was especially true of teachers that were teaching KS4 and KS5 exam classes. The questionnaire mentioned in section 4.8.4 which was returned with nothing but "No time – I'm a Science teacher" on it perhaps indicated the level of pressure that one Science teacher felt they were under. The implementation of the Welsh Baccalaureate in 2015 (Dauncey, 2015) has put additional pressure on to school timetables. To accommodate the new lessons, curriculum time in other subjects needs to be minimised. As science is essentially made up of three subjects, this may result in schools which have previously had equal curriculum time split between the three (i.e. six lessons a week, split into two lessons per science) now having to undertake a rota system as they have been reduced down to five lessons. This is erratic and often confusing for both pupils and teachers.

Likewise, during the research, there was a discovery that some schools are providing their Heads of English and Mathematics with extra PPA time in order to provide further opportunities for the improvement of literacy and numeracy. At the time of writing, I have been unable to find a Head of Science who has been provided with the same changes.

5.9 Attitudes of Teachers

Finally, although not planned to be a question at the beginning of the study, one emergent aspect of my results requires its own section due to its seriousness: namely the attitudes of the science teachers that were being interviewed. When reading through the transcriptions and interview responses, it quickly became apparent that there was an ethos of negativity, frustration and weariness surrounding teaching science in Wales. Teachers were able to explain and justify their negative responses in both the questionnaires and the interviews. This allowed me to understand the complexity of the issues contributing to the pervasiveness of these negative teacher attitudes. This therefore became an emergent theme, especially as it was present throughout each set of data.

Interestingly, after the 2012 PISA results were published, a National Foundation for Educational Research (NFER) study found that that the number of Headteachers in Wales who believed their staff morale was high was 8% lower than the mean score of the sixty four countries that participated in the 2012 PISA tests. The same report also outlined how Headteachers in Wales said that 96% of teachers work with enthusiasm, 96% of teachers take pride in their respective schools and 100% of teachers value academic achievement.

5.10 Trustworthiness of the Study

This was a small scale research project carried out by a single researcher. Both of these issues bring with them intrinsic problems and potential weaknesses. It must be remembered that any generalisations should be treated with caution and may not be reflective of the entire country.

The background of research has shown the influence of the researcher's background in shaping the original focus. This has the potential to affect the objectivity of the researcher. The importance of objectivity to improve credibility was explained by Boudah (2010). Denscombe felt that it is important to "stand back, lose predispositions and take the stance of a stranger" (2010). However, this can often be difficult to do, and the same author openly argues that "at a fundamental level, it needs to be recognized straight away that no research is ever free from the influence of those who conduct it" (p.300).

Instead of aiming for complete objectivity, this study aimed for the four strands of trustworthiness that are explained in section 4.5.2. In this study, the potential researcher bias has been recognised and acknowledged, demonstrating the integrity of the researcher. As described in section 2.3, as the researcher, I have had a number of years' experience teaching Science in Wales. The rationale for the study was largely driven by my own personal interest in the development of scientific literacy within the country, given my own personal experiences. These experiences have been both positive and negative, and therefore my own biases were acknowledged as a possible threat to the objectivity of the study. This led to the research design being carefully planned, in order to allow respondents to be unaffected by my personal history.

Participants in the study chose to participate and the research design prevented the respondents being affected by researcher bias. Closed or leading questions were avoided, and all respondents were strangers to me, thus improving the trustworthiness. I played the role of the researcher, rather than the 'researching teacher'. I encouraged all participants to consider the study as being exploratory, thus emphasising the necessity of having their own personal opinions. The reinterviews allowed participants to check the data that had been attributed to them. This was particularly important, as the extent of negative teacher attitudes throughout the study is worrying, and there is a danger that these participants only volunteered because they had biased views. This was why the reinterviews were so important. Revisiting participants after a prolonged period of time, allowing them to explore their original thoughts and then provide opportunity to develop these ideas further all add to the trustworthiness of the study. However, not all participants participated in the reinterviews, perhaps indicating that they had been given sufficient time to adjust to the changes and were now happy with their working situation. Equally, 370 questionnaires were mailed out to potential participants, but only sixty two individuals responded. The remainder may have views that were very different from the few that did participate. It is important to remember that the views of the participants within this study may not be indicative of the science teaching population as a whole.

The mixed method approach provided a range of different sources of data, which subsequently reduced researcher effects and the potential of respondent bias (Robson, 2002). My research gathered data from questionnaires, semi-structured interviews and reinterviews. The time that was spent on constructing the research instruments and then piloting and reviewing these also increased the trustworthiness of the research. The questionnaires and semi-structured interviews had participants from every region of Wales and in terms of the reinterviews, this gave extra opportunity for participants to further explain their views.

5.11 Summary

My research raises several issues regarding the teaching of scientific literacy within Welsh schools. One of the main issues stems from the contested meaning of the term. Tensions over the meaning of scientific literacy are by no means recent, but seem to be exemplified here due to the confusion surrounding science teachers teaching literacy in science, rather than scientific literacy. The questionnaires and interviews revealed that participants were largely negative about science education in Wales and this is a concerning finding. Science educators all agreed about the importance of the subject to young people, but had a number of concerns regarding its implementation and delivery. Recent and regular changes to the Welsh education have been implemented in response to Wales' PISA results, but at the time of writing, there has been more focus on the literacy and numeracy aspects of education, rather than scientific literacy.

6 Conclusion

In this final section, I revisit the research aims of my study, discussing the extent to which each of my aims were achieved. The outcomes are then discussed in terms of my original research questions, and the greater relevance of the research. There follows a review of the research methodology, concluding with a discussion of the implications for future research in this area of scientific literacy. The outcomes indicate highly significant issues which appear to be relevant across Wales. In addition, the conclusions reveal the requirement to re-evaluate the methods in which new initiatives are introduced to schools in Wales. Finally, some limitations of the study are identified and in the last section, recommendations for future research are made.

6.1 Did the Research Answer the Original Research Questions?

6.1.1 Research Question 1: What are teachers' interpretations and perceptions of scientific literacy in Wales?

As outlined in the literature review, with such variation in the meaning and use of the term 'scientific literacy', my research has recognised that Science teachers in Wales require clarification for what scientific literacy actually means and the associated impact for their classroom practice.

The word *literacy* derives from the Latin word, *'littera'* and means 'letter' (Bawden, 2001). According to the Oxford English Dictionary, the definitions of 'literacy' are 1. "the ability to read and write" and 2. "competence or knowledge in a specified area" (Stevenson and Waite, 2011). In terms of the first definition, although initially appearing simplistic, it becomes more complicated. What is required for someone to become *literate*? Can it be considered as just the ability to read? Or is it the ability to *understand* those words? Is there a pre-determined number of words that must be learned until you're considered to be 'literate'?

This same issue can be applied to the contentious issue of scientific literacy. When considering this term, the second definition listed by the Oxford English Dictionary is clearly the one that is appropriate, but as science is a multi-faceted subject, there are endless issues surrounding an authoritative definition. You could know *about* science, without actually knowing any science. When referring to scientific literacy, rather than scientific competencies or scientific skills, surely this means that there are a number of pre-requisite skills, where some have to be perfected before moving on to the others? Very often, the current definitions of the term focus largely on an individual's capability, with little regard for performance. The vast majority of the population has the *capability* to understand science, but in practice, this does not happen. An interesting analogy would be considering the term from a physical fitness point of view. Most people have the capability to walk, run, cycle and be active. However, the reality is that only a small proportion of the population get their recommended daily quota of exercise, and as a result, the population is now less fit and suffering from the associated health problems.

Through my research, I've determined that there is confusion between the teaching of scientific literacy and the teaching of literacy within Science. Although both important, they are both are distinct concepts and should be considered as such. However, greater emphasis is currently being placed on the latter within Wales due to the pressures of the Welsh Government and initiatives such as the LNF. It is probable that some of this emphasis has not been helped by the clear lack of understanding regarding the term, and an over-emphasis on the use of the word 'literacy'. As outlined by Norris and Phillips (2003), the fundamental sense of scientific literacy has a focus on the ability to read and write. However, these abilities are not exclusive to science education. Reading and writing are core aspects of Science education and if they are omitted, then the fundamental basis of science education may be lost. However, these tools are not just used in Science education, and there is a danger that teachers merely consider scientific literacy as just being able to read and write scientifically.

To further the confusion, terms such as "physical literacy" (Whitehead, 2010), "emotional literacy" (Orbach, 2000), "social literacy" (Arthur et al., 2014) and "health literacy" (Kindig et al., 2004) are just some of the appellations currently being used by researchers and theorists that are adding to this problem. But this is where the problem lies. In cases such as these, the word literacy could equally be replaced by the word 'competence' or 'skill'. However, where is the agreement on what that particular set of skills actually entails? A person can become an expert in Biochemistry without understanding Quantum Physics, they can equally complete a basic science practical without having the ability to write a scientific report on that said practical. Is a scientifically literate person required to know how to balance equations? Recall the Periodic Table? If a person had all of those abilities, then they'd certainly be more competent in science, but they could equally manage without that level of understanding.

The problem with 'scientific literacy' is there is no agreement regarding the basic skills and abilities required to consider a person literate in that area. Unlike standard literacy, there is no equivalent of 'reading' as a basic skill. When the term 'literacy' is used by a person or body, they are effectively imposing their own assumptions or thoughts on what they believe is the necessary level of competency.

Currently, the definition of the term scientific literacy in Wales has largely been influenced by international organisations and assessment activities, alongside the views of political leaders. "Literacy" in this political hierarchy is becoming an area reserved for politicians and is becoming disconnected from education, and furthermore, the general public. I therefore believe that the term 'scientific competencies' or 'scientifically informed' would be more appropriate. These alternative titles emphasise engagement, and will ensure that the importance of science is being considered independently, rather than being erroneously treated as 'literacy in science'. "Competency is the habitual and judicious use of communication, knowledge, technical skills, emotions, values, and reflection in daily practice for the benefit of the individual" (Epstein and Hundert, 2002). Competence is something that can develop over time, and is nurtured by experience and reflection.

Utilising the literature and my research, I propose that these *scientific competencies* are based on three key pillars, as outlined in Figure 8 and Table 20.

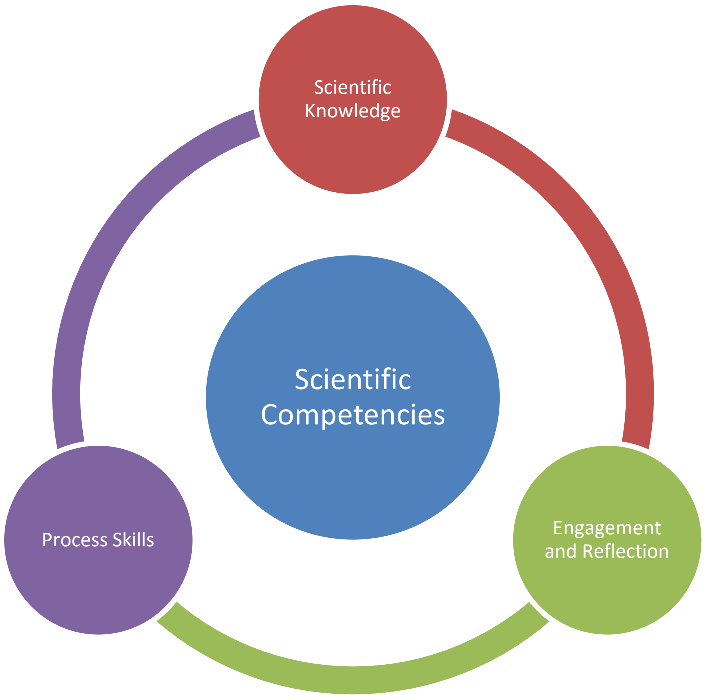

Figure 8: The three pillars of scientific competencies.

Table 20: Information about each of the three scientific competencies.

Scientific Competency	Information
Scientific Knowledge	The ability to acquire facts and an understanding of scientific processes, phenomena and technology, then use this knowledge to construct explanations, arguments and models.
Engagement and Reflection	Involves individuals being interested in scientific issues and the attitude that this is 'normal' practice. This process may involve discussion and debate. Individuals will be willing to ask questions and take an active role in local, national or global scientific issues. Individuals will also have an understanding of the role that science plays within the world, with an ability to understand and evaluate evidence. An individual with this competency will adopt a critical stance and understand that ideas can be continually revised on the basis of new evidence.
Process Skills	The ability of an individual to be able to research, hypothesise, experiment, observe, infer, analyse, conclude and evaluate.

These three components of scientific competency have arisen from different authors' interpretations of scientific literacy. By removing the term 'literacy' and replacing with 'competency', the issues of teaching literacy within science, rather than improving science is minimised. The three strands or pillars encapsulate what I consider to be the most important aspects of science education.

Competency One: Scientific Knowledge

Scientific knowledge is the traditional expectation of an individual to be able to understand and recall atypical scientific information. To comprehend the nature of science and how influences society, individuals should have knowledge about scientific content. There is a clear need for individuals to be appropriately knowledgeable about science, as outlined in section 3.4, although the level of this knowledge will understandably be linked to ability and career aspirations. This is what is currently measured through traditional examinations and there is still a place for this in any future model.

With 80% of participants mentioning pupils having an understanding of science, the questionnaires and interviews made it clear that Science teachers believe that scientific knowledge is a very important part of what they consider to be "scientific literacy" – one cannot be literate in a subject without understanding the concepts they are explaining.

Competency Two: Engagement and Reflection

Engagement has been included in response to a widely held belief that individuals should be able to understand and contribute to any societal scientific issues that may arise (Jenkins, 1999). The public should feel appropriately confident to be able to become actively involved in public decisions regarding science (Sadler and Zeidler, 2009), not be affected by propaganda (Boujaoude, 2002) and be critical thinkers (Norris and Phillips, 2003). By being informed and responsible citizens, individuals improve their societal usefulness (DeBoer, 2000) and are able to adapt to a world that is ever-changing (Dillon, 2009).

For scientific literacy to develop successfully, individuals should be reflective and understand the relevance of science to themselves, to their local community and to the global population (DeBoer, 2000). Interviewees and questionnaire participants felt that science provided pupils with the opportunity to "question" and research has shown that scientifically literate individuals are able to respond effectively to scientific arguments (Miller, 1998). The importance of teaching science in relation to social issues has been well documented (Kolstø, 2001), (Miller, 1998), so pupils should be introduced to provocative scientific issues, allowing them to explore the portrayal of science, providing them with the opportunity to make important decisions (Laugksch, 2000). This will require individuals being taught how to analyse critically scientific information, reflect upon their learning, and make informed decisions about the scientific information they are being presented with (Norris and Phillips, 2003).

To allow pupils to successfully be engaged with and reflect on science, pupils must be taught how to infer, hypothesise, conclude, justify and evidence claims (Norris and Phillips, 2003), but for this to occur successfully, teachers must teach these strategies to their pupils. This critical reflective practice should be a core part of any future curriculum with an establishment of a link between competency one and two. Scientific content should be socially relevant, with pupils being regularly exposed to socio-scientific issues.

Competency Three: Process Skills

Finally, the third pillar is the development of the traditional investigative, experimental and practical skills that science has typically nurtured. This is something that is currently very important during Key Stage 3 and the skills-based curriculum, but has been less focussed on during Key Stage 4 and 5. Although this is something that has been answered with the new Key Stage 5 curriculum, and is expected with the new Key Stage 4 specifications, it is important that this aspect of science is not forgotten. The data collection revealed that very few respondents considered this to be a necessary part of being scientifically literate (2%), but the practical importance of scientific enquiry has been well documented (Hand et al., 2003, Norris and Phillips, 2003) and should be a key aspect of science education.

From my research and after a consideration of the literature review, I propose that scientific competency (as a replacement of scientific literacy) should be defined as:

"The knowledge, understanding and application of scientific concepts and processes required for personal decision making and participation in society".

This definition incorporates the three pillars outlined in Figure 8 and Table 20.

It takes into account how a scientifically competent person will be knowledgeable about science, be able to undertake scientific enquiry and have an ability to apply this knowledge to different scenarios, leading to a scientifically engaged person.

6.1.2 Research Question 2: What methods are used for measuring and improving scientific literacy in Wales?

There is a clear lack of methods used to both measure and improve the scientific literacy of Welsh pupils. Scientific literacy is not measured as a separate entity; instead teachers assess science levels at Key Stage 2 and 3, before pupils are assessed externally at Key Stage 4. These give no indication of a pupil's scientific literacy level.

Welsh pupils need to be taught how to critically analyse any scientific information they are presented with, thus allowing them to be better prepared to be reflective learners and therefore able to make informed decisions about the information. Intentional scientific literacy teaching would include strategies for comprehension, evaluation and reflection. Currently in Wales, traditional reading comprehension strategies that are first developed during primary school do not normally develop an in-depth understanding of scientific texts. Therefore, efforts should be made to develop new comprehension strategies for pupils. One particular method for doing this is self-explanation, as outlined by Van Dijk (2011). This involves an individual generating their own understanding of each sentence when reading new information. This idea gives opportunity for a pupil to comprehend each part of the text, a sentence at a time and relates it to their current knowledge base. This is an example of how teaching for scientific literacy can be intentionally incorporated into a school situation. It is possible for science pupils to learn to question critically and reflect on the information that they are being provided with, thus not producing a 'dominant or differential stanced' individual, as outlined in section 3.5.1, but a critical one (Norris and Phillips, 2003).

What has become clear through the research and literature review is that developing an absolute measurement of scientific literacy would be complicated. Instead, it may be more useful to measure changes in the degree of scientific competencies outlined in section 7.1.1. Preparing standardised tests for some aspects of scientific literacy, such as knowledge, problem solving, attitudes or even critical thinking is relatively easy to achieve. Equally, assessing process skills through testing is also achievable and is currently being implemented in the new Key Stage 5 curriculum.

6.1.3 Research Question 3: What factors support or hinder the development of scientific literacy in Wales?

The general consensus was that the Government and their associated initiatives have the largest impact upon the development of scientific literacy. Until recently, it was evident that very little had been done to support scientific literacy, due to the emphasis placed on Literacy and Numeracy. However, the 2014 document produced by the Welsh Government seemingly gave evidence of a greater focus on this core strand of the OECD PISA tests (Welsh Government, 2014c). Nevertheless, the support outlined in the document has not been evident within schools at the time of writing.

Since 2010, the Welsh Government has a strategic agenda to improve science in Wales. In terms of education, they feel there is a "need to create an environment where learners want to study science, perform well internationally at school level, and progress in science-related careers, delivering excellence in industry and world-class standards in further and higher education" (Welsh Government, 2012b). The document outlines that this will be done by improving STEM outreach and engaging more young people in science through the National Science Academy. However, there is no specific mention of PISA or scientific literacy within the report. Likewise, the National Science Academy's 2015-18 plan to improve STEM engagement also makes no mention of scientific literacy (Welsh Government, 2015b).

It is clear that the lack of scientific literacy resources, especially those that are suitable for the Welsh curriculum, is having a negative impact upon the levels of scientific literacy in the country. This is worsened by the additional lack of training sessions for science teachers. Teachers feel that they are expected to improve the scientific literacy of their pupils, especially in response to the PISA results, but are struggling to do that because there is a lack of guidance.

The recent focus on literacy and numeracy due to the implementation of the LNF is laudable, but this study has illustrated the need for Governmental policy makers to reflect on the relative success or failure of any new initiatives, and to make better use of relevant research into any proposed new changes. While this may appear self-evident, new initiatives have repeatedly been introduced with substandard consultation and minimal consideration of their impact. This was recognised in a recent review of the LNF: "Practitioners considered a barrier to the implementation of the LNF and the National Tests had been what they saw as a lack of initial guidance on how the Welsh Government expected them to put it into practice and support to help them do so" (Roberts, 2014). Although the LNF may be improving the literacy and numeracy skills of Welsh pupils, the impact of this initiative upon other subjects, especially science, is unknown. The Welsh Government has a plan to improve science over the next three years (Welsh Government, 2012b, Welsh Government, 2015b), but school-level interventions are yet to happen.

6.2 Review of the research methodology

The research methodology, as outlined in chapter 4, suggested that my study would be best suited by a post-positivist approach. This was based on my belief that the perceptions of the science teachers I spoke to would largely be complex to categorise as it is difficult to separate values and facts. This ontological position meant that I utilised a mixed-methods approach in an attempt to improve the trustworthiness of my study, as outlined in section 4.5.2.

As mentioned previously in this thesis, the main method of collecting data for this research project was through questionnaires, with the results being triangulated by the semi-structured interviews and reinterviews. I believe that this approach met the requirements of the research questions, especially as it was driven by a pragmatic consideration of the methodologies that would be available to me as a full-time teacher in addition to being a part time researcher.

A difficulty within my study was being limited by working in a school and also seeking information from other educators. Although schools are highly organised establishments, they are also capricious and subject to stringent regulations. It therefore became difficult to coordinate meetings and interviews at times suitable for all parties. These problems considerably slowed the research process down, impacting upon the data that was being used. The questionnaires stage of the research was dealing with the 2009 PISA results, but the semi-structured interviews and the case study coincided with the release of the 2012 results. It became disadvantageous to have such a long research period as two thirds of the research methodology had access to additional information. Nevertheless, it also became beneficial. The 2012 science results had further decreased since 2009, leading to additional talking points during the interviews.

The sheer number of changes that took place in the Welsh education system throughout my research also became problematic, and it became difficult to keep up with new initiatives and reforms. As a result of this, the literature review was reviewed regularly with new information being continually added until mid-2015.

6.3 Recommendations for future practice

The findings of this research lead me to make a number of recommendations for future practice within Wales.

The central finding from this study is that, despite the disappointing scores from the 2009 and 2012 PISA tests, little has been implemented to support the development of Science teaching in Wales. Initiatives such as the National Literacy and Numeracy Framework have been largely insignificant due to the lack of detail regarding Science. The initiative is flawed when considering the impact it has on subjects other than English and Mathematics.

Key recommendations for future practice are to be:

1. **Scientific literacy should be rebranded as scientific competency or scientifically informed, or a standardised definition developed.**
   This will ensure the distinction between pupils becoming literate in science, and being taught literacy in Science.
2. **There should be a greater recognition of the status of Science in Welsh schools and the positive impact that the subject has on both the pupils during their schooling but also the wider world.**
   The potential economic advantage to Wales (Crowell and Schunn, 2015) must be recognised and therefore, it is imperative that the subject is ranked equally alongside English and Mathematics. Carefully considering the benefit of cross-curricula teaching, as outlined by the Donaldson report (Donaldson, 2015) would allow science to be taught within other areas of the school, thus leading to an improvement in attainment.
3. **Greater guidance for Welsh science teachers on strategies that improve the scientific literacy of their pupils, including relevant resources.**
   Science teachers in Wales should not have the perspective that science is simply a subject where independent facts and laws are learnt. In previous literature, Fang and Wei (2010) suggested including 'critical reading time' into science lessons. They hypothesised that a specific targeted initiative would firstly improve the reading proficiency of pupils, but also improve content knowledge. Alvermann, et al. (2011) also felt that this particular initiative could be beneficial and that comprehension development and scientific content learning could be simultaneous. One particular advantage to this method is that is does not alienate those more 'traditional' teachers who do not want to lose scientific content from their lessons. However, this is not without its problems. Fang and Wei (2010) note that there is minimal research into how these targeted reading comprehension tasks could be incorporated into actual lessons, and the impact that this would have.

4. **Investment should be made in producing a science curriculum that is rigorous, leading to science lessons that provide pupils with opportunities to learn both science knowledge and science skills.**

   Curriculum developers working for the Welsh Government should collaborate closely with science teachers to ensure that the new science curriculum best meets the different goals of science education, as outlined in the literature review. Although the current Key Stage 3 curriculum is pedagogically suited to improve scientific literacy, this is not the case at Key Stage 4 or 5. Encouragingly, the new Key Stage 5 curriculum that is being implemented in 2015 has a greater emphasis on practical skills and application of science to wider issues, so this could also be done at Key Stage 4. There could be greater emphasis placed on moral and ethical issues and an encouragement of pupils being able to argue and debate, utilise critical thinking, problem solve and be analytical. This is very similar to the current Key Stage 3 curriculum, and such an enquiry-based curriculum ensures that pupils engage significantly with both scientific content and the nature of science. This should also incorporate an increase of practical activities. These activities should ideally already be done at Key Stage 4, but there is often pressure to stick rigidly to the exam in order to maintain positive results. It is therefore important that in any new curriculum devised, that Welsh pupils are not overwhelmed by the amount of science content. This leads to a counterproductive situation where pupils believe they cannot engage with science, due to a presumed lack of science knowledge (Kolstø, 2001)

5. **Large scale implementation of rigorous professional development opportunities in the area of scientific literacy.**

   The findings in this study, in terms of the extent and nature of negative Science teacher attitudes point to an urgent requirement for more professional development in Scientific Literacy. Hackling, et al. (2001) noted that for scientific literacy initiatives to be successful, there must be effective professional development. Professional development is not only needed for Science teachers, but also Senior Leadership teams in schools so they can learn the distinct difference between scientific literacy and literacy in science. Professional development programs should acknowledge the fact that effective scientific literacy teaching can only occur if science educators understand the term itself. Welsh science educators need clear direction from both a research and a philosophical perspective, and this needs to be well supported by the Welsh science curriculum. Pupils will only be able to communicate scientifically and be successful citizens if teachers are supported in developing pedagogies that are conducive to scientific literacy (Rennie and Goodrum, 2007). Generally speaking, professional development events are stand-alone sessions which tend to focus on renewing teaching techniques or consideration of updated curriculum materials. For the results of professional development around the area of 'scientific literacy' to be effective, the following must occur:

- An investment in time, support and appropriate leadership must be provided at school level.
- A knowledgeable professional outside of the school environment that could offer support and guidance, perhaps someone akin to the old science advisors. Welsh universities could facilitate local professional research groups whose focus is on improving standards within different subject areas.
- Finally and most importantly, clearly defined objectives and outcomes need to be provided, so Science teachers are able to understand their intended progress.

Such intentional organisation of scientific literacy within Wales could ensure progression towards an education system where Welsh pupils develop high level scientific literacy skills, and can actively engage with the socio-scientific issues that currently abound by this increasingly developing world.

6.4 Further Research

My research has ultimately questioned the whole paradigm of science education within Wales. A succession of curriculum revisions, new initiatives and a perceived lack of teacher support have effectively prevented the improvement of pupil attainment within the country.

My research and the literature has repeatedly mentioned that science educators believe the science curriculum is particularly content-driven, thus meaning scientific literacy improvement activities cannot take place due to the examination pressures (Millar, 2006). As the new education system is implemented within Wales, an investigation of how Welsh Science teachers approach the new curriculum, including the new interpretations of scientific literacy within it could lead to a continuation of this study and the impact of the current educational reforms. In addition to this, future research could also include an investigation into how each of the Welsh Education Consortia implement improvement for scientific literacy and how they have approached the new science curriculum. Finally, although boys significantly outperform girls in Wales (Bradshaw et al., 2010, Wheater, 2013), no respondent mentioned gender issues within their classes. Research based on this gender-divide could be particularly interesting.

6.5 Final Words

Wales is at a particularly exciting time of its educational history. Having diverged further from England's system, it now has an ideal opportunity to independently become a forerunner of educational excellence. Careful collaboration between all stakeholders involved in educational could provide Wales with the potential to lead in the PISA tests. By involving teachers, universities, consortia and professional development bodies in the planning, implementation and reflection of any new initiative, Wales would move to a culture whereby research truly informs policy and practice. Donaldson recommended this in his review (Donaldson, 2015), but this situation needs to be made a reality.

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9 Appendices

9.1 Pilot Study Letter

PRIFYSGOL
BANGOR
UNIVERSITY

School of Education

Scientific Literacy in Wales: Pilot Study

Hello,

Many thanks for agreeing to participate in this pilot study. Your feedback is valuable for the completion of my EdD, as it will influence the final questionnaire.

All feedback is welcomed (good and bad!) so please be honest. The questionnaire is obviously paper based, but will also be available online for the final questionnaire.

Feedback may include, but is not limited to:

- How you feel about the layout of the questionnaire.
- Do the questions make sense? Are there any problems with understanding what is required of the question?
- Have I missed any options you feel are appropriate for the multiple-choice answers?
- Are boxes the correct size?
- As a Science teacher, are there any further questions that you feel would be useful?

Thanks again for your help. It is much appreciated!

Gemma Dale

edpb51@bangor.ac.uk

9.2 Participant Information Sheet

PRIFYSGOL
BANGOR
UNIVERSITY

School of Education

INFORMATION SHEET FOR PARTICIPANTS

Study title
What is the current status of Scientific Literacy in Wales?

Invitation
You are being invited to take part in a research study to explore the issues surrounding the current status of Scientific Literacy in Welsh secondary schools. This will include the current perceptions and attitudes towards the area of Scientific Literacy and the current methods used to measure it.

What is the purpose of the study?
For pupils to succeed within Science, they must become scientifically literate. However, this process is made increasingly difficult by the language specificity of Science itself. Becoming scientifically literate is a long and multi-faceted process that can be affected by many different factors but there is a lack of literature regarding successful literacy policies or practices within Science. This is despite Wales having significantly lower levels of pupils that are both literate and performing well within the subject compared to the rest of the UK. This study will consider the current perceptions and attitudes of teachers and other relevant education professionals towards scientific literacy. In addition, the study will gather evidence about the methods used to measure it and the factors that may potentially support or hinder the development of scientific literacy.

Why have you been chosen?
As a professional linked with the delivery of scientific education, you will have the knowledge, skills and experiences to share that will allow a greater understanding of the issues surrounding scientific literacy.

Do you have to take part?
No, participation is entirely voluntary and you can withdraw from the study at any point.

What will happen to me if I take part?
You will complete a questionnaire that seeks to discover the current perceptions and attitudes of education professionals towards scientific literacy in Wales. At the end of the questionnaire, you will have the option to become involved in further research by opting in to be considered for participation in an interview. At any point, you may contact me for further information or if you have any questions.

What are the possible disadvantages and risks of taking part?
You will be asked to give up your time to complete the questionnaire and if applicable, participate in the interview and focus group. Talking and reflecting upon certain issues may be difficult, although all efforts will be made to ensure you are a comfortable as possible. This includes undertaking any work at a time and place convenient to yourself.

8

What are the possible benefits of taking part?
You will be contributing to an important area of science education which may in turn inform your own practice in addition to a wider improvement of Science education in Wales. You will be entitled to receive a short summary of the research project.

Will my taking part in this study be kept confidential?
Yes. If you agree to participate, nobody will be informed and your participation is completely anonymous. If you participate in the interview and focus group session, then any recordings will not be shared with anyone else. Any transcriptions of the recording will have all names and identifying data removed by allocating you a numeric code. The data will be stored on my personal computer with password protected access and any printed material will be stored in a locked cabinet. Once the study has been reported, the data will be destroyed.

What will happen to the results of the research study?
The findings will form the basis of my research dissertation as part of my EdD (Doctorate in Education). Dependent upon the final findings, the study may be submitted to journals for publishing, in addition to being disseminated to relevant education bodies. All participants will be offered a one page summary of the key findings at the end of the study.

Who has reviewed the study?
The project has been reviewed by Bangor University Ethics Committee.

Who is funding the study?
The study is being funded by myself as part of my EdD. No external organisations are involved in the funding.

Contact for further Information
If you have any questions, then do not hesitate to contact me at edpb51@bangor.ac.uk for further information about this study.

Alternatively, you may contact my study supervisors, Drs. John Lewis and Susan Jones, at john.lewis@bangor.ac.uk or s.w.jones@bangor.ac.uk or by post at:

The School of Education
Bangor University
Normal Site
Bangor
Gwynedd
LL57 2PZ

Many thanks in advance for your help.

Gemma Dale

PRIFYSGOL
BANGOR
UNIVERSITY

School of Education

PARTICIPANT CONSENT FORM

Title of Project: What is the current status of Scientific Literacy in Wales?
Name of Researcher: Gemma Dale
If you have any questions, then do not hesitate to contact me at edpb51@bangor.ac.uk for further information about this study.

Please initial box

1.	I am 18 years or older and am competent to provide consent.	
2.	I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.	
3.	I agree that my data is used for research purposes and I have no objection that my data is published in educational publications in a way that does not reveal my identity.	
4.	I understand that I may stop electronic recordings at any time, and that I may at any time, even subsequent to my participation have such recordings destroyed.	
5.	I understand that, subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers/research team.	
6.	I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.	
7.	I understand that my participation is fully anonymous and that no personal details about me will be recorded.	
8.	I agree that this form that bears my name and signature may be seen by a designated auditor	
9.	I agree to take part in the above study.	

____________________ __________ ____________________
Name of participant Date Signature

____________________ __________ ____________________
Researcher Date Signature

One copy should be given to the participant and one copy should be retained by the researcher and kept as a record.

Participant Identification Number: ________________

9.3 Teacher Questionnaire (English)

'Scientific Literacy in Wales' Questionnaire

PRIFYSGOL BANGOR UNIVERSITY

Dear Headteacher, Head of Science or Science teacher/s,

I invite you to be involved in a Wales-wide research study to investigate the current status of scientific literacy in Welsh secondary schools. This research is being self-funded by myself as part of an EdD degree being undertaken at Bangor University.

This study specifically aims to determine the following:
1. What are the interpretations and perceptions of scientific literacy in Wales?
2. What methods are used for measuring scientific literacy in Wales?
3. What factors support or hinder the development of scientific literacy in Wales?

Enclosed you will find an anonymous questionnaire to be completed by a member of staff involved in the delivery of science education. This should take approximately ten to fifteen minutes to complete. A reply paid envelope has been provided for you to return the questionnaire.

All information provided will be anonymous, treated confidentially and used for research purposes only. No individuals or schools will be identified in any reports of the research. All data records will be stored securely and destroyed five years after the completion of the study. Please note that this project has the approval of the College of Business, Law, Education and Social Sciences Research Ethics Committee, Bangor University and meets the requirements for research in your school system.

I am happy to discuss any questions you may have about the questionnaire. Please direct questions regarding this research study to myself on edpb51@bangor.ac.uk. If you have any concerns about the project or would like to talk to the supervising staff, you may contact Drs. John Lewis and Susan Jones, at john.lewis@bangor.ac.uk or s.w.jones@bangor.ac.uk.

Thank you very much for participating in this research study. Your time is much appreciated.

Kind regards,

Gemma Dale

INFORMATION SHEET FOR PARTICIPANTS

Study title
What is the current status of Scientific Literacy in Wales?

Invitation
You are being invited to take part in a research study to explore the issues surrounding the current status of Scientific Literacy in Welsh secondary schools. This will include the current perceptions and attitudes towards the area of Scientific Literacy and the current methods used to measure it.

What is the purpose of the study?
For pupils to succeed within Science, they must become scientifically literate. However, this process is made increasingly difficult by the language specificity of Science itself. Becoming scientifically literate is a long and multi-faceted process that can be affected by many different factors but there is a lack of literature regarding successful literacy policies or practices within Science. Wales has significantly lower levels of pupils that are both literate and performing well within the subject, compared to the rest of the UK. This study will consider the current perceptions and attitudes of teachers and other relevant education professionals towards scientific literacy. In addition, the study will gather evidence about the methods used to measure it and the factors that may potentially support or hinder the development of scientific literacy.

Why have you been chosen?
As a professional linked with the delivery of scientific education, you will have the knowledge, skills and experiences to share that will allow a greater understanding of the issues surrounding scientific literacy.

Do you have to take part?
No, participation is entirely voluntary and you can withdraw (without prejudice) from the study at any point.

What will happen to me if I take part?
You will complete a questionnaire that seeks to discover the current perceptions and attitudes of education professionals towards scientific literacy in Wales. At the end of the questionnaire, you will have the option to become involved in further research by opting in to be considered for participation in an interview and focus group. At any point, you may contact me for further information or if you have any questions.

What are the possible disadvantages and risks of taking part?
You will be asked to give up your time to complete the questionnaire and if applicable, participate in the interview and focus group. Talking and reflecting upon certain issues may be difficult, although all efforts will be made to ensure you are a comfortable as possible. This includes undertaking any work at a time and place convenient to you. No detrimental effects are expected from this study. However, if this is the case, it is recommended that you speak to a professional regarding any issues that have arisen. This may include a trusted colleague, union representative or a group such as the Teacher Support Network (http://www.teachersupport.info/get-support).

What are the possible benefits of taking part?
You will be contributing to an important area of science education which may in turn inform your own practice in addition to a wider improvement of Science education in Wales. You will be entitled to receive a short summary of the research project.

Will my taking part in this study be kept confidential?
Yes. If you agree to participate, nobody will be informed and your participation is completely anonymous. If you participate in the interview and focus group session, then any recordings will not be shared with anyone else. Any transcriptions of the recording will have all names and identifying data removed by allocating you a numeric code. The data will be stored on Bangor University's encrypted computer system with password protected access. Any printed material will be stored in a locked cabinet. The data will be kept for a period of five years, after which it will be destroyed.

What will happen to the results of the research study?
The findings will form the basis of my research dissertation as part of my EdD (Doctorate in Education). Dependent upon the final findings, the study may be submitted to journals for publishing, in addition to being disseminated to relevant education bodies. All participants will be offered a one page summary of the key findings at the end of the study.

Who has reviewed the study?
The project has been reviewed by the College of Business, Law, Education and Social Sciences Research Ethics Committee, Bangor University.

Who is funding the study?
The study is being funded by me as part of my EdD. No external organisations are involved in the funding.

Contact for further information
If you have any questions, then do not hesitate to contact me at edpb51@bangor.ac.uk for further information about this study.

Alternatively, you may contact my study supervisors, Drs. John Lewis and Susan Jones, at john.lewis@bangor.ac.uk or s.w.jones@bangor.ac.uk or by post at:

The School of Education
Bangor University
Normal Site
Bangor
Gwynedd
LL57 2PZ

Many thanks in advance for your help.

Gemma Dale

This questionnaire is also available to complete at:
http://tinyurl.com/kxa4hhs

Participant Identification Code (for researcher use only)

We request your name and workplace details for monitoring purposes only. All information provided will be anonymous, treated confidentially and used for research purposes only. Your responses will contribute to my overall picture of scientific literacy in Wales.

Forename

Surname

What is the name of your workplace?

Please indicate whether you would be interested in participating in either a semi-structured interview or a focus group session regarding scientific literacy in Wales.
I am interested in participating in:

☐ Semi-structured interview: This involves speaking to a researcher about scientific literacy in Wales, at a time and place convenient to yourself. The researcher will have a pre-determined list of topics to talk about, but the interview will be open and informal, leading to flexibility in the discussion.

☐ Focus Group: This involves having a discussion with a small group of similar professionals about scientific literacy in Wales, at a time and place convenient to all participants.

☐ I am not interested in participating in further research

If you have indicated that you are interested in participating in further research, please provide your contact details below:
Email Address:

Telephone Number

This questionnaire is also available to complete at:
http://tinyurl.com/kxa4hhs

Participant Identification Code (for researcher use only)

---

1. Where is your workplace located?

- ○ Anglesey
- ○ Blaenau Gwent
- ○ Bridgend
- ○ Caerphilly
- ○ Cardiff
- ○ Carmarthenshire
- ○ Ceredigion
- ○ Conwy
- ○ Denbighshire
- ○ Flintshire
- ○ Gwynedd
- ○ Merthyr Tydfil
- ○ Monmouth
- ○ Neath
- ○ Newport
- ○ Port Talbot
- ○ Pembroke
- ○ Powys
- ○ Rhondda Cynon Taff
- ○ Swansea
- ○ Torfaen
- ○ Vale of Glamorgan
- ○ Wrexham

---

2. How would you describe your workplace?

- ○ School with attached sixth form
- ○ School with no sixth form
- ○ College
- ○ University
- ○ Pupil Referral Unit
- ○ Other (please state)

---

3. What is your job role?

- ○ Headteacher
- ○ Head of Science
- ○ Curriculum Leader of a scientific subject (e.g. Head of Biology)
- ○ Teacher of Science
- ○ PGCE Tutor
- ○ Education Training Facilitator
- ○ LEA Science Advisor
- ○ Other (please state)

---

4. What Key Stages do you teach? (tick all that are relevant)

☐ KS3 (11-14 years)
☐ KS4 (14-16 years)
☐ KS5 (16+ years)
☐ Not applicable (not involved in teaching science)

---

5. What is your subject specialism?

☐ Biology
☐ Chemistry
☐ Physics
☐ Not applicable (not involved in teaching science)
☐ Other (please state)

---

6. Are you required to teach GCSE lessons outside of your subject specialism?

○ Yes
○ No
○ Not applicable (not involved in teaching science)

---

7. How many years have you been involved in the delivery or organisation of scientific education?

○ 1-3
○ 4-7
○ 8-10
○ 10-15
○ 16+

---

8. Do you understand the term "scientific literacy"?

○ Yes
○ No
○ Unsure

---

9. In the box below, outline your interpretation of the term "scientific literacy".

10. Have you ever received any CPD (professional development) training regarding scientific literacy?

- ○ Yes
- ○ No
- ○ Unsure

11. If relevant, please give details regarding the scientific literacy CPD training (name of the training provider, length of session, main learning outcomes, etc).

12. Do you feel that you would benefit from scientific literacy training?

- ○ Yes
- ○ No
- ○ Unsure
- ○ Other

13. Every three years, the Organisation for Economic Co-operation and Development (OECD) undertakes the Programme for International Student Assessment (PISA). This is an international study which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students in the key subjects: reading, mathematics and science.

Prior to this questionnaire, were you aware of PISA testing?

- ○ Yes
- ○ No
- ○ Unsure

---

14. Place the following countries in order of who **you think** achieved the best PISA score for scientific literacy. No more than one tick should be placed in each column.

	1 (Best)	2	3	4 (Worst)
England	○	○	○	○
Ireland	○	○	○	○
Scotland	○	○	○	○
Wales	○	○	○	○

---

15. In 2009, 68 countries participated in PISA testing. In **your opinion**, what place do you think Wales came? Please only use numerical values (1-68).

---

16. In September 2013, the National Literacy and Numeracy Framework (LNF) will become statutory for all learners in Wales aged 5 to 14. Do you believe that the LNF will have a positive impact upon the scientific literacy levels of pupils?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The LNF will have a positive impact upon the scientific literacy levels of pupils.	○	○	○	○	○

---

17. In your opinion, what is the purpose of science education?

	Unimportant	Low Importance	Neutral	Important	Very Important
To acquire appropriate knowledge (facts, concepts, laws and theories).	O	O	O	O	O
Learn the process of scientific methodology.	O	O	O	O	O
Learn how to solve daily life problems.	O	O	O	O	O
Develop a positive attitude and interest in science.	O	O	O	O	O
Be able to make critical assessments regarding science in society (positive and negative aspects of scientific and technological development).	O	O	O	O	O

Other (please outline below)

---

18. Do you feel confident in improving the scientific literacy levels of pupils?

- O Yes
- O No
- O Unsure

19. Does your school have a specific policy regarding scientific literacy?

- ○ Yes
- ○ No
- ○ Unsure

20. Indicate how much you agree with the following statements:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The recent emphasis on scientific literacy in the new GCSE specifications has had a detrimental impact upon pupil performance.	○	○	○	○	○
Exam boards provide enough support to allow teachers to improve pupil literacy levels.	○	○	○	○	○
Other departments support the delivery of scientific literacy (e.g. English).	○	○	○	○	○

21. In your school, what methods are used to improve the scientific literacy levels of pupils?

	Never	Rarely	Occasionally	Frequently	Always
Word walls or mats	O	O	O	O	O
Vocabulary and definition games	O	O	O	O	O
Vocabulary and definition tests	O	O	O	O	O
Commercially available literacy worksheets	O	O	O	O	O
Shared reading (reading aloud)	O	O	O	O	O
Writing frames	O	O	O	O	O
Interactive whiteboard games specific to literacy	O	O	O	O	O
Extended writing activities	O	O	O	O	O
Other (outline below)	O	O	O	O	O

Other

---

22. In your school, do you specifically assess the scientific literacy levels of pupils?

- O Yes
- O No
- O Unsure

23. In your school, which methods are used to assess the scientific literacy of pupils?

	Never	Rarely	Occasionally	Frequently	Always
Commercially available standardised tests	O	O	O	O	O
Teacher developed tests	O	O	O	O	O
Teacher judgement	O	O	O	O	O
Commercially available literacy worksheets	O	O	O	O	O
Pupil portfolios	O	O	O	O	O
Other (outline below)	O	O	O	O	O

Other:

---

24. In your opinion, what factors support the development of scientific literacy in Wales?

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25. In your opinion, what factors hinder the development of scientific literacy in Wales?

26. If you have any further information that you feel may be relevant to this study, please outline below:

End of the questionnaire.

Many thanks for completing this questionnaire. Your time is much appreciated.

9.4 Teacher Questionnaire (Welsh)

Holiadur - "Llythrennedd Gwyddonol yng Nghymru"

PRIFYSGOL BANGOR UNIVERSITY

Annwyl Bennaeth, Bennaeth Gwyddoniaeth neu athro Gwyddoniaeth,

Rwy'n ysgrifennu atoch i'ch gwahodd i fod yn rhan o waith ymchwil Cymru gyfan i ymchwilio i statws cyfredol Llythrennedd Gwyddonol yng Nghymru, mewn ysgolion uwchradd. Dewiswyd chi i gymryd rhan gan eich bod yn trefnu, addysgu neu gyflwyno Llythrennedd Gwyddonol. Mae'r ymchwil yn cael ei hunan-ariannu fel rhan o'm gradd EdD ym Mhrifysgol Bangor.

Mae'r astudiaeth hon yn anelu yn benodol ar bennu'r canlynol:
1. Beth yw'r dehongliadau a chanfyddiadau Llythrennedd Gwyddonol yng Nghymru?
2. Pa ddulliau a ddefnyddiwyd i fesur Llythrennedd Gwyddonol yng Nghymru?
3. Pa ffactorau sy'n cefnogi neu amharu ar ddatblygiad Llythrennedd Gwyddonol yng Nghymru?

Yn amgaeedig mae holiadur anhysbys i'w gwblhau gan aelod o staff sydd â gwybodaeth o addysg Wyddoniaeth. Dylai cwblhau'r holiadur gymryd tua deg i bymtheg munud. Mae amlen i ddychwelyd yr holiadur yn amgaeedig.

Bydd y wybodaeth a roddir yn yr holiadur yn gwbl anhysbys a chyfrinachol, a chaiff ei ddefnyddio at ddibenion ymchwil yn unig. Ni enwir unrhyw ysgol nag unigolyn ac ni fydd modd adnabod unrhyw un yn yr adroddiadau ymchwil. Bydd pob cofnod data yn cael ei gadw yn ddiogel ac yna yn cael ei ddinistrio ar ôl pum mlynedd. Nodwch fod y prosiect hwn wedi'i gymeradwyo gan Y Pwyllgor Moeseg Ymchwil, Y Coleg Busnes, Addysg a Gwyddoniaeth Gymdeithasol, Prifysgol Bangor, a'i fod yn cyrraedd y gofynion ar gyfer ymchwil.

Byddaf yn falch o drafod unrhyw ofynion ynglŷn â'r holiadur hwn. Fe ddylid cyfeirio unrhyw gwestiwn neu bryder ynglŷn â'r astudiaeth i mi ar edpb51@bangor.ac.uk. Os oes gennych unrhyw bryderon am y prosiect neu os hoffech siarad gyda'r staff sy'n goruchwylio, gallwch gysylltu gyda Dr John Lewis (john.lewis@bangor.ac.uk) neu Dr Susan Wyn Jones (s.w.jones@bangor.ac.uk.)

Diolch am gymryd rhan yn yr ymchwil; rwy'n gwerthfawrogi eich amser a chefnogaeth.

Gyda diolch,

Gemma Dale

TAFLEN WYBODAETH I GYFRANOGWYR

Teitl yr ymchwil
Beth yw statws cyfredol Llythrennedd Gwyddonol yng Nghymru?

Gwahoddiad
Rydych yn cael eich gwahodd i gymryd rhan mewn ymchwil sydd yn ceisio darganfod beth yw statws cyfredol Llythrennedd Gwyddonol yng Nghymru yn y sector addysg uwchradd. Bydd hyn yn cynnwys canfyddiadau cyfredol ac agweddau tuag at Lythrennedd Gwyddonol a'r dulliau cyfredol a ddefnyddir i'w fesur.

Beth yw bwriad yr astudiaeth?
Er mwyn i ddisgyblion lwyddo mewn Gwyddoniaeth mae'n rhaid iddynt fod yn wyddonol llythrennog. Mae'r broses yn un anodd oherwydd y sialensiau ieithyddol o fewn Gwyddoniaeth ei hun. Mae deall a dod yn hyderus mewn llythrennedd gwyddonol yn gallu bod yn broses hir a chymhleth ac mae prinder o lenyddiaeth ymchwil ar gael am bolisïau ac ymarfer llwyddiannus o fewn Gwyddoniaeth. A chymharu â gweddill y Deyrnas Unedig mae'r nifer o ddisgyblion sy'n llythrennog ac yn perfformio'n dda yn is yng Nghymru. Bydd yr astudiaeth yn ystyried canfyddiadau cyfredol ac agweddau athrawon, ac eraill, o fewn addysg tuag at Lythrennedd Gwyddonol. Yn ogystal, bydd yr astudiaeth yn casglu tystiolaeth am y dulliau a ddefnyddir i fesur Llythrennedd Gwyddonol, a'r ffactorau sy'n hyrwyddo neu atal datblygiad Llythrennedd Gwyddonol.

Pam y cefais fy newis?
Fel gweithiwr proffesiynol sy'n gysylltiedig â chyflwyno addysg wyddoniaeth, bydd gennych wybodaeth, sgiliau a phrofiad perthnasol i'w rannu gyda mi ac i roi gwell dealltwriaeth o'r materion sy'n ymwneud â llythrennedd gwyddonol.

Oes rhaid i chi gymryd rhan?
Nag oes, mae eich cyfraniad yn gwbl wirfoddol a gallwch dynnu'n ôl o'r astudiaeth ar unrhyw adeg.

Beth fydd yn digwydd os yr wyf yn cymryd rhan?
Byddwch yn cwblhau holiadur sy'n ceisio darganfod beth yw'r canfyddiad cyfredol ac agweddau addysgwyr proffesiynol tuag at Lythrennedd Gwyddonol yng Nghymru. Ar ddiwedd yr holiadur bydd cyfle i chi fod yn rhan o gyfweliad a/neu grŵp ffocws. Gallwch gysylltu â mi unrhyw bryd am wybodaeth bellach neu i holi am unrhyw gwestiwn.

Beth yw'r anfanteision a pheryglon o gymryd rhan?
Bydd gofyn i chi roi amser i gwblhau'r holiadur, ac os yn berthnasol, bydd gwahoddiad i chi gymryd rhan mewn cyfweliad a/neu grŵp ffocws. Gall siarad a chysidro rhai materion fod yn anodd, ond bydd pob ymgais yn cael ei wneud i sicrhau y byddwch yn teimlo yn gyfforddus. Mae hyn yn cynnwys gwneud unrhyw waith casglu gwybodaeth mewn lleoliad ac ar amser sy'n gyfleus i chi. Ni ddisgwylir unrhyw ganlyniadau negyddol o'r astudiaeth. Serch hyn, petai hyn yn digwydd awgrymir y dylech siarad â pherson proffesiynol i drafod unrhyw faterion sy'n codi. Gall hyn gynnwys cydweithiwr agos, swyddog undeb neu grŵp fel y Teacher Support Network (http://www.teachersupport.info/get-support).

Beth yw manteision cymryd rhan?
Byddwch yn cyfrannu i ymchwil addysg wyddonol bwysig, fydd, mewn tro, yn hybu eich ymarfer yn ogystal â datblygu addysg Gwyddoniaeth yng Nghymru. Byddwch yn derbyn crynodeb o ganlyniadau'r ymchwil.

A fydd yr astudiaeth hon yn gyfrinachol?
Bydd. Os byddwch yn cytuno i gymryd rhan, ni fydd hyn yn cael eu datgelu i neb a bydd eich cyfraniad yn gwbl anhysbys. Os byddwch yn rhan o'r cyfweliadau neu grŵp ffocws ni fydd unrhyw recordiad yn cael ei rannu. Bydd unrhyw recordiad sydd yn cynnwys eich enw a lleoliad gwaith yn cael ei ddileu trwy ddefnyddio côd rhifol personol . Bydd y data yn cael ei storio ar system gyfrifiadurol wedi ei amgryptio gyda chyfrinair. Bydd unrhyw waith ysgrifenedig yn cael ei gadw dan glo. Bydd y data yn cael ei gadw am bum mlynedd ac wedyn yn cael ei ddileu.

Beth fydd yn digwydd i ganlyniadau'r astudiaeth ymchwil?
Bydd y canlyniadau yn cael eu defnyddio fel sylfaen ar gyfer fy ymchwil ar gyfer traethawd hir sydd yn rhan o fy ngradd EdD (Doethuriaeth mewn Addysg). Yn ddibynnol ar fy nghanfyddiadau terfynol mae'n bosib y bydd yr astudiaeth yn cael ei gyflwyno i gylchgronau i'w gyhoeddi yn ogystal â'i ddosbarthu i sefydliadau addysg. Cynigir crynodeb un tudalen i bob cyfrannwr ar ddiwedd yr astudiaeth.

Pwy sydd wedi adolygu'r astudiaeth?
Mae'r astudiaeth wedi ei adolygu gan Y Pwyllgor Moeseg Ymchwil, Y Coleg Busnes, Addysg a Gwyddoniaeth Gymdeithasol, Prifysgol Bangor.

Pwy sy'n noddi'r astudiaeth?
Mae'r astudiaeth yn cael ei ariannu gen i fel rhan o fy ngradd EdD. Nid oes unrhyw noddwr allanol yn cael ei gynnwys yn y cyllid.

Cyswllt pellach
Os oes unrhyw gwestiwn cysylltwch trwy e-bost: edpb51@bangor.ac.uk
Neu cysylltwch â fy arolygwyr Dr John Lewis a Dr Susan Wyn Jones, (john.lewis@bangor.ac.uk neu s.w.jones@bangor.ac.uk) neu drwy'r post ;

Ysgol Addysg
Prifysgol Bangor
Safle Normal
Bangor
Gwynedd
LL57 2PZ

Diolch am eich cymorth,

Gemma Dale

I gwblhau'r holiadur :
http://tinyurl.com/kk9o878

Côd Adnabod (at ddefnydd yr ymchwilydd yn unig)

Rydym yn gofyn am eich enw a lleoliad gwaith ar gyfer pwrpas monitro yn unig. Bydd pob gwybodaeth yn gyfrinachol ac at ddefnydd ymchwil yn unig. Bydd eich ymateb yn ychwanegu at y darlun cyfan o Lythrennedd Gwyddonol yng Nghymru.

Enw cyntaf

Cyfenw

Enw lleoliad gwaith?

Nodwch os oes gennych ddiddordeb mewn cymryd rhan mewn cyfweliad lled-strwythuredig neu grŵp ffocws bydd yn trafod llythrennedd gwyddonol yng Nghymru.
Mae gen i ddiddordeb mewn cymryd rhan yn:

☐ Cyfweliad lled-strwythuredig: Golyga siarad â'r ymchwilydd am lythrennedd gwyddonol yng Nghymru ar adeg ac mewn lleoliad sy'n gyfleus ichi. Bydd gan yr ymchwilydd restr ymlaen llaw o bynciau i'w trafod ond fe fydd y cyfweliad yn agored ac anffurfiol i roi cyfle i fod yn hyblyg.

☐ Grŵp Ffocws: Golyga hyn gael trafodaeth gyda grŵp bach o bobl broffesiynol tebyg, am lythrennedd gwyddonol yng Nghymru. Bydd hyn mewn lleoliad ac ar amser sy'n gyfleus i chi.

☐ Nid oes gennyf ddiddordeb mewn cymryd rhan ychwanegol yn yr ymchwil.

Os oes diddordeb gennych, nodwch eich manylion cyswllt isod:
Cyfeiriad ebost:

Rhif ffôn:

Gellir cwblhau y holiadur yma:
http://tinyurl.com/kk9o878

Côd Adnabod (at ddefnydd yr ymchwilydd yn unig)

1. Ble mae lleoliad eich gwaith?

- ○ Ynys Môn
- ○ Caerffili
- ○ Ceredigion
- ○ Sir y Fflint
- ○ Sir Fynwy
- ○ Port Talbot
- ○ Rhondda Cynon Tâf
- ○ Bro Morgannwg
- ○ Blaenau Gwent
- ○ Caerdydd
- ○ Conwy
- ○ Gwynedd
- ○ Castell-nedd Port Talbot
- ○ Sir Benfro
- ○ Abertawe
- ○ Wrecsam
- ○ Pen-y-bont ar Ogwr
- ○ Sir Gaerfyrddin
- ○ Sir Ddinbych
- ○ Merthyr Tudful
- ○ Casnewydd
- ○ Powys
- ○ Torfaen

2. Sut byddech yn disgrifio eich gweithle?

- ○ Ysgol â chweched dosbarth
- ○ Ysgol heb chweched dosbarth
- ○ Coleg
- ○ Prifysgol
- ○ Unedau Cyfeirio Disgyblion (UCD)
- ○ Arall (nodwch)

3. Beth yw eich swydd?

- ○ Pennaeth
- ○ Pennaeth Gwyddoniaeth
- ○ Arweinydd Cwricwlwm pwnc gwyddonol (ee Pennaeth Bioleg)
- ○ Athro/Athrawes Gwyddoniaeth
- ○ Tiwtor PGCE
- ○ Hwylusydd Hyfforddiant Addysg
- ○ Ymgynghorydd Gwyddoniaeth yr AALl
- ○ Arall (nodwch)

4. Pa gyfnodau Allweddol ydych yn ei ddysgu? (Ticiwch bob un perthnasol

☐ CA3 (11-14 oed)
☐ CA4 (14-16 oed)
☐ CA5 (16+ oed)
☐ Ddim yn berthnasol (ddim yn dysgu pwnc gwyddoniaeth))

5,. Beth yw eich arbenigedd pwnc?

☐ Bioleg
☐ Cemeg
☐ Ffiseg
☐ Ddim yn berthnasol (ddim yn dysgu pwnc gwyddoniaeth)
☐ Arall (nodwch)

---

6. A ydych yn dysgu gwersi TGAU y tu allan i'ch pwnc arbenigedd ?

○ Ydw
○ Nac ydw
○ Ddim yn berthnasol (ddim yn dysgu pwnc gwyddoniaeth)

---

7. Ers sawl blwyddyn ydych wedi bod yn gyfrifol am gyflwyno neu drefnu addysg wyddoniaeth?

○ 1-3
○ 4-7
○ 8-10
○ 10-15
○ 16+

---

8. A ydych yn deall y term "llythrennedd gwyddonol"?

○ Ydw
○ Nac ydw
○ Ansicr

---

9. Yn y blwch isod, amlinellwch eich dealltwriaeth o'r term "llythrennedd gwyddonol".

10. A ydych wedi derbyn unrhyw DPP (datblygiad proffesiynol) sy'n ymwneud a llythrennedd gwyddonol?

- Ydw
- Nac ydw
- Ansicr

11. Os yn briodol, rhowch fanylion am yr hyfforddiant DPP llythrennedd gwyddonol (enw'r darparwr hyfforddiant, hyd y sesiwn, y prif ganlyniadau dysgu, ac ati).

12. Ydych yn teimlo y byddech yn cael budd o gael hyfforddiant llythrennedd gwyddonol?

- Ydw
- Nac ydw
- Ansicr

13. Bob tair blynedd, mae'r Sefydliad ar gyfer Cydweithrediad a Datblygiad Economaidd (OECD) yn cynnal Rhaglen Ryngwladol ar gyfer Asesiad Myfyrwyr (PISA). Mae hon yn astudiaeth ryngwladol sy'n anelu at werthuso systemau addysg ledled y byd drwy brofi'r sgiliau a gwybodaeth mae myfyrwyr 15-mlwydd-oed wedi ei dderbyn yn y pynciau allweddol: darllen, mathemateg a gwyddoniaeth.

Cyn i chi gwblhau'r holiadur hwn, a oeddech yn ymwybodol o brofion PISA?

- ○ Oeddwn
- ○ Nac oeddwn
- ○ Ansicr

---

14. Trefnwch y gwledydd canlynol yn y drefn yr ydych yn credu sydd yn adlewyrchu'r canlyniad.

	1 (Gorau)	2	3	4 (Gwaethaf)
Lloegr	○	○	○	○
Iwerddon	○	○	○	○
Yr Alban	○	○	○	○
Cymru	○	○	○	○

---

15. Yn 2009, cymerodd 68 gwlad ran yn y profion PISA. Yn eich barn chi, ym mha safle oedd Cymru. Defnyddiwch rifolyn yn unig (1-68).

[ ]

---

16. O fis Medi 2013, bydd y Fframwaith Llythrennedd a Rhifedd Cenedlaethol (FfLlRh) yn statudol i bob dysgwr yng Nghymru o 5 i 14 oed. Ydych yn credu y bydd y FfLlRh yn cael effaith bositif ar lefelau llythrennedd gwyddonol y disgyblion?

	Anghytuno yn gryf	Anghytuno	Niwtrall	Cytuno	Cytuno yn gryf
Bydd yr FfLlRh yn cael effaith bositif ar lefelau llythrennedd gwyddonol y disgyblion.	○	○	○	○	○

---

17. Yn eich barn chi, beth yw pwrpas addysg gwyddoniaeth?

	Ddim yn bwysig	Pwysigrwydd isel	Niwtral	Pwysig	Pwysig iawn
I ddysgu gwybodaeth briodol (ffeithiau, cysyniadau, rheolau a damcaniaethau).	○	○	○	○	○
Dysgu'r broses o fethodoleg wyddonol	○	○	○	○	○
Dysgu sut i ddatrys problemau bob dydd.	○	○	○	○	○
Datblygu agwedd bositif a diddordeb mewn gwyddoniaeth.	○	○	○	○	○
Gallu gwerthuso datblygiadau technegol a gwyddonol.	○	○	○	○	○

Arall (rhowch amlinelliad isod):

---

18. A ydych yn teimlo'n hyderus wrth wella lefelau llythrennedd gwyddonol y disgyblion?

○ Ydw
○ Nac ydw
○ Ansicr

---

19. A oes gan eich ysgol bolisi penodol o ran llythrennedd gwyddonol?

○ Oes
○ Nac oes
○ Ansicr

---

20. Nodwch faint yr ydych yn cytuno gyda'r datganiadau isod:

	Anghytuno yn gryf	Anghytuno	Niwtral	Cytuno	Cytuno yn gryf
Mae'r pwyslais diweddar ar lythrennedd gwyddonol wedi cael effaith andwyol ar berfformiad TGAU'r disgyblion.	○	○	○	○	○
Mae byrddau arholi yn rhoi cefnogaeth ddigonol i athrawon i godi safonau llythrennedd gwyddonol.	○	○	○	○	○
Mae adrannau eraill yn cefnogi cyflwyno llythrennedd gwyddonol (ee Saesneg).	○	○	○	○	○

21. . Yn eich ysgol, pa ddulliau sydd yn cael eu defnyddio i wella lefelau llythrennedd gwyddonol y disgyblion?

	Byth	Yn brin	O bryd i'w gilydd	Yn aml	Yn gyson
Muriau neu fat geiriau	○	○	○	○	○
Gemau geirfa a diffiniad	○	○	○	○	○
Profion geirfa a diffiniad	○	○	○	○	○
Taflenni gwaith llythrennedd masnachol.	○	○	○	○	○
Darllen mewn pâr (darllen ar lafar)	○	○	○	○	○
Fframiau ysgrifennu	○	○	○	○	○
Gemau bwrdd gwyn rhyngweithiol yn benodol i lythrennedd	○	○	○	○	○
Tasgau ysgrifennu ymestynnol	○	○	○	○	○
Arall (nodwch isod)	○	○	○	○	○

Arall

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22. Yn eich ysgol chi, a ydych yn asesu lefelau llythrennedd gwyddonol penodol y disgyblion?

- ○ Ydym
- ○ Nac ydym
- ○ Ansicr

---

23. Yn eich ysgol chi, pa ddulliau sydd yn cael eu defnyddio i asesu llythrennedd gwyddonol y disgyblion?

	Byth	Yn brin	O bryd i'w gilydd	Yn aml	Yn gyson
Profion masnachol wedi eu safoni.	○	○	○	○	○
Profion a ddatblygwyd gan athro	○	○	○	○	○
Barn Athro	○	○	○	○	○
Taflenni gwaith llythrennedd ar gael yn fasnachol	○	○	○	○	○
Portffolios disgyblion	○	○	○	○	○
Arall (nodwch isod)	○	○	○	○	○

Arall:

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24. Yn eich barn chi, pa ffactorau sy'n cefnogi datblygiad llythrennedd gwyddonol yng Nghymru?

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25. Yn eich barn chi, pa ffactorau sy'n atal datblygiad llythrennedd gwyddonol yng Nghymru?

26. Nodwch unrhyw wybodaeth arall rydych yn teimlo gall fod yn berthnasol i'r astudiaeth hon:

Diwedd y holiadur.

Diolch am gwblhau'r holiadur. Rwy'n gwerthfawrogi eich cefnogaeth.

9.5 Professionals Questionnaire (English)

'Scientific Literacy in Wales' Questionnaire

PRIFYSGOL BANGOR UNIVERSITY

Dear Sir or Madam,

I invite you to be involved in a Wales-wide research study to investigate the current status of scientific literacy in Welsh secondary schools. You have been selected to participate as you are involved in the organisation or delivery of scientific literacy. This research is being self-funded by myself as part of an EdD degree being undertaken at Bangor University.

This study specifically aims to determine the following:
1. What are the interpretations and perceptions of scientific literacy in Wales?
2. What methods are used for measuring scientific literacy in Wales?
3. What factors support or hinder the development of scientific literacy in Wales?

Enclosed you will find an anonymous questionnaire to be completed by a member of staff that has some knowledge of science education. This should take approximately ten to fifteen minutes to complete. A reply paid envelope has been provided for you to return the questionnaire.

All information provided will be anonymous, treated confidentially and used for research purposes only. No individuals or workplaces will be identified in any reports of the research. All data records will be stored securely and destroyed five years after the completion of the study. Please note that this project has the approval of the College of Business, Law, Education and Social Sciences Research Ethics Committee, Bangor University and meets the requirements for research.

I am happy to discuss any questions you may have about the questionnaire. Please direct questions regarding this research study to myself on edpb51@bangor.ac.uk. If you have any concerns about the project or would like to talk to the supervising staff, you may contact Drs. John Lewis and Susan Jones, at john.lewis@bangor.ac.uk or s.w.jones@bangor.ac.uk.

Thank you very much for participating in this research study. Your time is much appreciated.

Kind regards,

Gemma Dale

INFORMATION SHEET FOR PARTICIPANTS

Study title

What is the current status of Scientific Literacy in Wales?

Invitation

You are being invited to take part in a research study to explore the issues surrounding the current status of Scientific Literacy in Welsh secondary schools. This will include the current perceptions and attitudes towards the area of Scientific Literacy and the current methods used to measure it.

What is the purpose of the study?

For pupils to succeed within Science, they must become scientifically literate. However, this process is made increasingly difficult by the language specificity of Science itself. Becoming scientifically literate is a long and multi-faceted process that can be affected by many different factors but there is a lack of literature regarding successful literacy policies or practices within Science. Wales has significantly lower levels of pupils that are both literate and performing well within the subject, compared to the rest of the UK. This study will consider the current perceptions and attitudes of teachers and other relevant education professionals towards scientific literacy. In addition, the study will gather evidence about the methods used to measure it and the factors that may potentially support or hinder the development of scientific literacy.

Why have you been chosen?

As a professional linked with the delivery of scientific education, you will have the knowledge, skills and experiences to share that will allow a greater understanding of the issues surrounding scientific literacy.

Do you have to take part?

No, participation is entirely voluntary and you can withdraw (without prejudice) from the study at any point.

What will happen to me if I take part?

You will complete a questionnaire that seeks to discover the current perceptions and attitudes of education professionals towards scientific literacy in Wales. At the end of the questionnaire, you will have the option to become involved in further research by opting in to be considered for participation in an interview and focus group. At any point, you may contact me for further information or if you have any questions.

What are the possible disadvantages and risks of taking part?

You will be asked to give up your time to complete the questionnaire and if applicable, participate in the interview and focus group. Talking and reflecting upon certain issues may be difficult, although all efforts will be made to ensure you are a comfortable as possible. This includes undertaking any work at a time and place convenient to you. No detrimental effects are expected from this study. However, if this is the case, it is recommended that you speak to a professional regarding any issues that have arisen. This may include a trusted colleague, union representative or a group such as the Teacher Support Network (http://www.teachersupport.info/get-support).

What are the possible benefits of taking part?
You will be contributing to an important area of science education which may in turn inform your own practice in addition to a wider improvement of Science education in Wales. You will be entitled to receive a short summary of the research project.

Will my taking part in this study be kept confidential?
Yes. If you agree to participate, nobody will be informed and your participation is completely anonymous. If you participate in the interview and focus group session, then any recordings will not be shared with anyone else. Any transcriptions of the recording will have all names and identifying data removed by allocating you a numeric code. The data will be stored on Bangor University's encrypted computer system with password protected access. Any printed material will be stored in a locked cabinet. The data will be kept for a period of five years, after which it will be destroyed.

What will happen to the results of the research study?
The findings will form the basis of my research dissertation as part of my EdD (Doctorate in Education). Dependent upon the final findings, the study may be submitted to journals for publishing, in addition to being disseminated to relevant education bodies. All participants will be offered a one page summary of the key findings at the end of the study.

Who has reviewed the study?
The project has been reviewed by the College of Business, Law, Education and Social Sciences Research Ethics Committee, Bangor University.

Who is funding the study?
The study is being funded by me as part of my EdD. No external organisations are involved in the funding.

Contact for further information
If you have any questions, then do not hesitate to contact me at edpb51@bangor.ac.uk for further information about this study.

Alternatively, you may contact my study supervisors, Drs. John Lewis and Susan Jones, at john.lewis@bangor.ac.uk or s.w.jones@bangor.ac.uk or by post at:

The School of Education
Bangor University
Normal Site
Bangor
Gwynedd
LL57 2PZ

Many thanks in advance for your help.

Gemma Dale

This questionnaire is also available to complete at:
http://tinyurl.com/lrpa2jo

Participant Identification Code (for researcher use only)

We request your name and workplace details for monitoring purposes only. All information provided will be anonymous, treated confidentially and used for research purposes only. Your responses will contribute to our overall picture of scientific literacy in Wales.

Forename

Surname

What is the name of your workplace?

Please indicate whether you would be interested in participating in either a semi-structured interview or a focus group session regarding scientific literacy in Wales.
I am interested in participating in:

- ☐ Semi-structured interview: This involves speaking to a researcher about scientific literacy in Wales, at a time and place convenient to yourself. The researcher will have a pre-determined list of topics to talk about, but the interview will be open and informal, leading to flexibility in the discussion.
- ☐ Focus Group: This involves having a discussion with a small group of similar professionals about scientific literacy in Wales, at a time and place convenient to all participants.
- ☐ I am not interested in participating in further research

If you have indicated that you are interested in participating in further research, please provide your contact details below:
Email Address:

Telephone Number

This questionnaire is also available to complete at:
http://tinyurl.com/lrpa2jo

Participant Identification Code (for researcher use only)

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1. Where is your workplace located?

- ○ Anglesey
- ○ Blaenau Gwent
- ○ Bridgend
- ○ Caerphilly
- ○ Cardiff
- ○ Carmarthenshire
- ○ Ceredigion
- ○ Conwy
- ○ Denbighshire
- ○ Flintshire
- ○ Gwynedd
- ○ Merthyr Tydfil
- ○ Monmouth
- ○ Neath
- ○ Newport
- ○ Port Talbot
- ○ Pembroke
- ○ Powys
- ○ Rhondda Cynon Taff
- ○ Swansea
- ○ Torfaen
- ○ Vale of Glamorgan
- ○ Wrexham

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2. What is your job role?

- ○ LEA Science Advisor
- ○ Education Training Facilitator (delivers CPD courses to teachers)
- ○ Welsh Government employee
- ○ Other (please state)

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3. How many years have you been involved in the delivery or organisation of scientific education?

- ○ 1-3
- ○ 4-7
- ○ 8-10
- ○ 10-15
- ○ 16+

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4. Do you understand the term "scientific literacy"?

- ○ Yes
- ○ No
- ○ Unsure

---

5. In the box below, outline your interpretation of the term "scientific literacy".

---

6. Have you ever received any CPD (professional development) training regarding scientific literacy?

- ○ Yes
- ○ No
- ○ Unsure

---

7. If relevant, please give details regarding the scientific literacy CPD training (name of the training provider, length of session, main learning outcomes, etc).

---

8. Do you feel that you would benefit from scientific literacy training?

- ○ Yes
- ○ No
- ○ Unsure
- ○ Other

---

9. Every three years, the Organisation for Economic Co-operation and Development (OECD) undertakes the Programme for International Student Assessment (PISA). This is an international study which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students in the key subjects: reading, mathematics and science.

Prior to this questionnaire, were you aware of PISA testing?

- ○ Yes
- ○ No
- ○ Unsure

10. Place the following countries in order of who **you think** achieved the best PISA score for scientific literacy. No more than one tick should be placed in each column.

	1 (Best)	2	3	4 (Worst)
England	○	○	○	○
Ireland	○	○	○	○
Scotland	○	○	○	○
Wales	○	○	○	○

11. In 2009, 68 countries participated in PISA testing. In **your opinion**, what place do you think Wales came? Please only use numerical values (1-68).

12. In September 2013, the National Literacy and Numeracy Framework (LNF) will become statutory for all learners in Wales aged 5 to 14. Do you believe that the LNF will have a positive impact upon the scientific literacy levels of pupils?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The LNF will have a positive impact upon the scientific literacy levels of pupils.	○	○	○	○	○

13. In your opinion, what is the purpose of science education?

	Unimportant	Low Importance	Neutral	Important	Very Important
To acquire appropriate knowledge (facts, concepts, laws and theories).	○	○	○	○	○
Learn the process of scientific methodology.	○	○	○	○	○
Learn how to solve daily life problems.	○	○	○	○	○
Develop a positive attitude and interest in science.	○	○	○	○	○
Be able to make critical assessments regarding science in society (positive and negative aspects of scientific and technological development).	○	○	○	○	○

Other (please outline below)

14. Indicate how much you agree with the following statements:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The recent emphasis on scientific literacy in the new GCSE specifications has had a detrimental impact upon pupil performance.	O	O	O	O	O
Exam boards provide enough support to allow teachers to improve pupil literacy levels.	O	O	O	O	O

15. In your opinion, what methods should be used to improve the scientific literacy levels of school pupils?

	Never	Rarely	Occasionally	Frequently	Always
Word walls or mats	O	O	O	O	O
Vocabulary and definition games	O	O	O	O	O
Vocabulary and definition tests	O	O	O	O	O
Commercially available literacy worksheets	O	O	O	O	O
Shared reading (reading aloud)	O	O	O	O	O
Writing frames	O	O	O	O	O
Interactive whiteboard games specific to literacy	O	O	O	O	O
Extended writing activities	O	O	O	O	O
Other (outline below)	O	O	O	O	O

Other

16. In your opinion, which methods should be used to assess the scientific literacy of school pupils?

	Never	Rarely	Occasionally	Frequently	Always
Commercially available standardised tests	O	O	O	O	O
Teacher developed tests	O	O	O	O	O
Teacher judgement	O	O	O	O	O
Commercially available literacy worksheets	O	O	O	O	O
Pupil portfolios	O	O	O	O	O
Other (outline below)	O	O	O	O	O

Other:

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17. In your opinion, what factors support the development of scientific literacy in Wales?

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18. In your opinion, what factors hinder the development of scientific literacy in Wales?

19. If you have any further information that you feel may be relevant to this study, please outline below:

End of the questionnaire.

Many thanks for completing this questionnaire. Your time is much appreciated.

9.6 Professionals Questionnaire (Welsh)

Holiadur - "Llythrennedd Gwyddonol yng Nghymru"

PRIFYSGOL BANGOR UNIVERSITY

Annwyl Syr neu Fadam,

Rwy'n ysgrifennu atoch i'ch gwahodd i fod yn rhan o waith ymchwil Cymru gyfan i ymchwilio i statws cyfredol Llythrennedd Gwyddonol yng Nghymru, mewn ysgolion uwchradd. Dewiswyd chi i gymryd rhan gan eich bod yn trefnu neu gyflwyno Llythrennedd Gwyddonol. Mae'r ymchwil yn cael ei hunan-ariannu fel rhan o'm gradd EdD ym Mhrifysgol Bangor.

Mae'r astudiaeth hon yn anelu yn benodol ar bennu'r canlynol:
1. Beth yw'r dehongliadau a chanfyddiadau Llythrennedd Gwyddonol yng Nghymru?
2. Pa ddulliau a ddefnyddiwyd i fesur Llythrennedd Gwyddonol yng Nghymru?
3. Pa ffactorau sy'n cefnogi neu amharu ar ddatblygiad Llythrennedd Gwyddonol yng Nghymru?

Yn amgaeedig mae holiadur anhysbys i'w gwblhau gan aelod o staff sydd â gwybodaeth o addysg Wyddoniaeth. Dylai cwblhau'r holiadur gymryd tua deg i bymtheg munud. Mae amlen i ddychwelyd yr holiadur yn amgaeedig.

Bydd y wybodaeth a roddir yn yr holiadur yn gwbl anhysbys a chyfrinachol, a chaiff ei ddefnyddio at ddibenion ymchwil yn unig. Ni enwir unrhyw ysgol nag unigolyn ac ni fydd modd adnabod unrhyw un yn yr adroddiadau ymchwil. Bydd pob cofnod data yn cael ei gadw yn ddiogel ac yna yn cael ei ddinistrio ar ôl pum mlynedd. Nodwch fod y prosiect hwn wedi'i gymeradwyo gan Y Pwyllgor Moeseg Ymchwil, Y Coleg Busnes, Addysg a Gwyddoniaeth Gymdeithasol, Prifysgol Bangor, a'i fod yn cyrraedd y gofynion ar gyfer ymchwil.

Byddaf yn falch o drafod unrhyw ofynion ynglŷn â'r holiadur hwn. Fe ddylid cyfeirio unrhyw gwestiwn neu bryder ynglŷn â'r astudiaeth i mi ar edpb51@bangor.ac.uk. Os oes gennych unrhyw bryderon am y prosiect neu os hoffech siarad gyda'r staff sy'n goruchwylio, gallwch gysylltu gyda Dr John Lewis (john.lewis@bangor.ac.uk) neu Dr Susan Wyn Jones (s.w.jones@bangor.ac.uk.)

Diolch am gymryd rhan yn yr ymchwil; rwy'n gwerthfawrogi eich amser a chefnogaeth.

Gyda diolch,

Gemma Dale

TAFLEN WYBODAETH I GYFRANOGWYR

Teitl yr ymchwil
Beth yw statws cyfredol Llythrennedd Gwyddonol yng Nghymru?

Gwahoddiad
Rydych yn cael eich gwahodd i gymryd rhan mewn ymchwil sydd yn ceisio darganfod beth yw statws cyfredol Llythrennedd Gwyddonol yng Nghymru, yn y sector addysg uwchradd. Bydd hyn yn cynnwys canfyddiadau cyfredol ac agweddau tuag at Lythrennedd Gwyddonol a'r dulliau cyfredol a ddefnyddir i'w fesur.

Beth yw bwriad yr astudiaeth?
Er mwyn i ddisgyblion lwyddo mewn Gwyddoniaeth mae'n rhaid iddynt fod yn wyddonol llythrennog. Mae'r broses yn un anodd oherwydd y sialensiau ieithyddol o fewn Gwyddoniaeth ei hun. Mae deall a dod yn hyderus mewn llythrennedd gwyddonol yn gallu bod yn broses hir a chymhleth ac mae prinder o lenyddiaeth ymchwil ar gael am bolisïau ac ymarfer llwyddiannus o fewn Gwyddoniaeth. A chymharu â gweddill y Deyrnas Unedig mae'r nifer o ddisgyblion sy'n llythrennog ac yn perfformio'n dda yn is yng Nghymru. Bydd yr astudiaeth yn ystyried canfyddiadau cyfredol ac agweddau athrawon, ac eraill, o fewn addysg tuag at Lythrennedd Gwyddonol. Yn ogystal, bydd yr astudiaeth yn casglu tystiolaeth am y dulliau a ddefnyddir i fesur Llythrennedd Gwyddonol, a'r ffactorau sy'n hyrwyddo neu atal datblygiad Llythrennedd Gwyddonol.

Pam y cefais fy newis?
Fel gweithiwr proffesiynol sy'n gysylltiedig â chyflwyno addysg wyddoniaeth, bydd gennych wybodaeth, sgiliau a phrofiad perthnasol i'w rannu gyda mi ac i roi gwell dealltwriaeth o'r materion sy'n ymwneud â llythrennedd gwyddonol.

Oes rhaid i chi gymryd rhan?
Nag oes, mae eich cyfraniad yn gwbl wirfoddol a gallwch dynnu'n ôl o'r astudiaeth ar unrhyw adeg.

Beth fydd yn digwydd os yr wyf yn cymryd rhan?
Byddwch yn cwblhau holiadur sy'n ceisio darganfod beth yw'r canfyddiad cyfredol ac agweddau addysgwyr proffesiynol tuag at Lythrennedd Gwyddonol yng Nghymru. Ar ddiwedd yr holiadur bydd cyfle i chi fod yn rhan o gyfweliad a/neu grŵp ffocws. Gallwch gysylltu â mi unrhyw bryd am wybodaeth bellach neu i holi am unrhyw gwestiwn.

Beth yw'r anfanteision a pheryglon o gymryd rhan?
Bydd gofyn i chi roi amser i gwblhau'r holiadur, ac os yn berthnasol, bydd gwahoddiad i chi gymryd rhan mewn cyfweliad a/neu grŵp ffocws. Gall siarad a chysidro rhai materion fod yn anodd, ond bydd pob ymgais yn cael ei wneud i sicrhau y byddwch yn teimlo yn gyfforddus. Mae hyn yn cynnwys gwneud unrhyw waith casglu gwybodaeth mewn lleoliad ac ar amser sy'n gyfleus i chi. Ni ddisgwylir unrhyw ganlyniadau negyddol o'r astudiaeth. Serch hyn, petai hyn yn digwydd awgrymir y dylech siarad â pherson proffesiynol i drafod unrhyw faterion sy'n codi. Gall hyn gynnwys cydweithiwr agos, swyddog undeb neu grŵp fel y Teacher Support Network (http://www.teachersupport.info/get-support).

Beth yw manteision cymryd rhan?
Byddwch yn cyfrannu i ymchwil addysg wyddonol bwysig, gall, mewn amser , yn hybu eich ymarfer yn ogystal â datblygu addysg Gwyddoniaeth yng Nghymru. Byddwch yn derbyn crynodeb o ganlyniadau'r ymchwil.

A fydd yr astudiaeth hon yn gyfrinachol?
Bydd. Os byddwch yn cytuno i gymryd rhan, ni fydd hyn yn cael eu datgelu i neb a bydd eich cyfraniad yn gwbl anhysbys. Os byddwch yn rhan o'r cyfweliadau neu grŵp ffocws ni fydd unrhyw recordiad yn cael ei rannu. Bydd unrhyw recordiad sydd yn cynnwys eich enw a lleoliad gwaith yn cael ei ddileu trwy ddefnyddio côd rhifol personol . Bydd y data yn cael ei storio ar system gyfrifiadurol wedi ei amgryptio gyda chyfrinair. Bydd unrhyw waith ysgrifenedig yn cael ei gadw dan glo. Bydd y data yn cael ei gadw am bum mlynedd ac wedyn yn cael ei ddileu.

Beth fydd yn digwydd i ganlyniadau'r astudiaeth ymchwil?
Bydd y canlyniadau yn cael eu defnyddio fel sylfaen ar gyfer fy ymchwil ar gyfer traethawd hir sydd yn rhan o fy ngradd EdD (Doethuriaeth mewn Addysg). Yn ddibynnol ar fy nghanfyddiadau terfynol mae'n bosib y bydd yr astudiaeth yn cael ei gyflwyno i gylchgronau i'w gyhoeddi yn ogystal â'i ddosbarthu i sefydliadau addysg. Cynigir crynodeb un tudalen i bob cyfrannwr ar ddiwedd yr astudiaeth.

Pwy sydd wedi adolygu'r astudiaeth?
Mae'r astudiaeth wedi ei adolygu gan Y Pwyllgor Moeseg Ymchwil, Y Coleg Busnes, Addysg a Gwyddoniaeth Gymdeithasol, Prifysgol Bangor.

Pwy sy'n noddi'r astudiaeth?
Mae'r astudiaeth yn cael ei ariannu gen i fel rhan o fy ngradd EdD. Nid oes unrhyw noddwr allanol yn cael ei gynnwys yn y cyllid.

Cyswllt pellach
Os oes unrhyw gwestiwn cysylltwch trwy e-bost: edpb51@bangor.ac.uk
Neu cysylltwch â fy arolygwyr Dr John Lewis a Dr Susan Wyn Jones, (john.lewis@bangor.ac.uk neu s.w.jones@bangor.ac.uk) neu drwy'r post ;

Ysgol Addysg
Prifysgol Bangor
Safle Normal
Bangor
Gwynedd
LL57 2PZ

Diolch am eich cymorth,

Gemma Dale

I gwblhau'r holiadur:
http://tinyurl.com/lkdgo8q

Côd Adnabod (at ddefnydd yr ymchwilydd yn unig)

Rydym yn gofyn am eich enw a lleoliad gwaith ar gyfer pwrpas monitro yn unig. Bydd pob gwybodaeth yn gyfrinachol ac at ddefnydd ymchwil yn unig. Bydd eich ymateb yn ychwanegu at y darlun cyfan o Lythrennedd Gwyddonol yng Nghymru.

Enw cyntaf

Cyfenw

Enw lleoliad gwaith?

Nodwch os oes gennych ddiddordeb mewn cymryd rhan mewn cyfweliad lled-strwythuredig neu grŵp ffocws bydd yn trafod llythrennedd gwyddonol yng Nghymru.
Mae gen i ddiddordeb mewn cymryd rhan yn:

- ☐ Cyfweliad lled-strwythuredig: Golyga siarad â'r ymchwilydd am lythrennedd gwyddonol yng Nghymru ar adeg ac mewn lleoliad sy'n gyfleus ichi. Bydd gan yr ymchwilydd restr ymlaen llaw o bynciau i'w trafod ond fe fydd y cyfweliad yn agored ac anffurfiol i roi cyfle i fod yn hyblyg.
- ☐ Grŵp Ffocws: Golyga hyn gael trafodaeth gyda grŵp bach o bobl broffesiynol tebyg, am lythrennedd gwyddonol yng Nghymru. Bydd hyn mewn lleoliad ac ar amser sy'n gyfleus i chi.
- ☐ Nid oes gennyf ddiddordeb mewn cymryd rhan ychwanegol yn yr ymchwil.

Os oes diddordeb gennych, nodwch eich manylion cyswllt isod:
Cyfeiriad e-bost:

Rhif ffôn:

I gwblhau'r holiadur:
http://tinyurl.com/lkdgo8q

Côd Adnabod (at ddefnydd yr ymchwilydd yn unig)

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1. Beth yw swyddogaeth eich gwaith?

- ○ Ynys Môn
- ○ Caerffili
- ○ Ceredigion
- ○ Sir y Fflint
- ○ Sir Fynwy
- ○ Port Talbot
- ○ Rhondda Cynon Tâf
- ○ Bro Morgannwg
- ○ Blaenau Gwent
- ○ Caerdydd
- ○ Conwy
- ○ Gwynedd
- ○ Castell-nedd Port Talbot
- ○ Sir Benfro
- ○ Abertawe
- ○ Wrecsam
- ○ Pen-y-bont ar Ogwr
- ○ Sir Gaerfyrddin
- ○ Sir Ddinbych
- ○ Merthyr Tudful
- ○ Casnewydd
- ○ Powys
- ○ Torfaen

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2. Beth yw swyddogaeth eich gwaith?

- ○ Ymgynghorydd Gwyddoniaeth AALl
- ○ Hwylusydd Hyfforddiant Addysg (darparu cyrsiau DPP i athrawon)
- ○ Cyflogedig gan Llywodraeth Cymru
- ○ Arall (nodwch)

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3. Ers sawl blwyddyn ydych wedi bod yn rhan o ddarparu neu drefnu addysg gwyddonol?

- ○ 1-3
- ○ 4-7
- ○ 8-10
- ○ 10-15
- ○ 16+

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4. Ydych yn deall y term "llythrennedd gwyddonol"?

- ○ Ydw
- ○ Nac ydw
- ○ Ansicr

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5. Yn y blwch isod, amlinellwch eich dealltwriaeth o'r term "llythrennedd gwyddonol".

6. A ydych wedi derbyn unrhyw DPP (datblygiad proffesiynol) ynglŷn â llythrennedd gwyddonol?

- Ydw
- Nac ydw
- Ansicr

7. Os yn briodol, nodwch fanylion am yr hyfforddiant DPP llythrennedd gwyddonol (enw'r darparwr hyfforddiant, hyd y sesiwn, y prif ganlyniadau dysgu, ac ati).

8. Ydych yn teimlo y byddech yn cael budd o hyfforddiant llythrennedd gwyddonol?

- Ydw
- Nac ydw
- Ansicr
- Arall

9. Bob tair blynedd, mae'r Sefydliad ar gyfer Cydweithrediad a Datblygiad Economaidd (OECD) yn cynnal Rhaglen Ryngwladol ar gyfer Asesiad Myfyrwyr (PISA). Mae hon yn astudiaeth ryngwladol sy'n anelu at werthuso systemau addysg ledled y byd drwy brofi'r sgiliau a gwybodaeth mae myfyrwyr 15-mlwydd-oed wedi ei dderbyn yn y pynciau allweddol: darllen, mathemateg a gwyddoniaeth.

Cyn yr holiadur hwn, a oeddech chi'n ymwybodol o brofion PISA?

- Oeddwn
- Nac oeddwn
- Ansicr

10. Trefnwch y gwledydd canlynol yn y drefn yr ydych yn credu sydd yn adlewyrchu'r canlyniad PISA gorau am lythrennedd gwyddonol. Ni ddylai mwy nag un tic gael ei roi ym mhob colofn.

	1 (Gorau)	2	3	4 (Gwaethaf)
Lloegr	○	○	○	○
Iwerddon	○	○	○	○
Yr Alban	○	○	○	○
Cymru	○	○	○	○

11. Yn 2009, cymerodd 68 gwlad ran yn y profion PISA. Yn eich barn chi ym mha safle oedd Cymru. Defnyddiwch rifolyn yn unig (1-68).

12. O fis Medi 2013, bydd y Fframwaith Llythrennedd a Rhifedd Cenedlaethol (FfLlRh) yn statudol i bob dysgwr yng Nghymru o 5 i 14 oed. Ydych yn credu y bydd y FfLlRh yn cael effaith bositif ar lefelau llythrennedd gwyddonol y disgyblion?

	Anghytuno yn gryf	Anghytuno	Niwtral	Cytuno	Cytuno yn gryf
Bydd yr FfLlRh yn cael effaith bositif ar lefelau llythrennedd gwyddonol y disgyblion.	○	○	○	○	○

13. Yn eich barn chi, beth yw pwrpas addysg gwyddoniaeth?

	Ddim yn bwysig	Pwysigrwydd isel	Niwtral	Pwysig	Pwysig iawn
I ddysgu gwybodaeth briodol (ffeithiau, cysyniadau, rheolau a damcaniaethau).	O	O	O	O	O
Dysgu'r broses o fethodoleg wyddonol	O	O	O	O	O
Dysgu sut i ddatrys problemau bob dydd.	O	O	O	O	O
Datblygu agwedd bositif a diddordeb mewn gwyddoniaeth.	O	O	O	O	O
Gallu gwerthuso datblygiadau technegol a gwyddonol.	O	O	O	O	O

Arall (rhowch amlinelliad isod):

14. Nodwch faint ydych yn cytuno gyda'r datganiadau isod:

	Anghytuno yn gryf	Anghytuno	Niwtral	Cytuno	Strongly Agree
Mae'r pwyslais diweddar ar lythrennedd gwyddonol wedi cael effaith andwyol ar berfformiad TGAU'r disgyblion.	○	○	○	○	○
Mae byrddau arholi yn rhoi cefnogaeth ddigonol i athrawon i godi safonau llythrennedd gwyddonol.	○	○	○	○	○

15. Yn eich barn chi pa ddulliau sydd yn cael eu defnyddio i wella lefelau llythrennedd gwyddonol y disgyblion?

	Byth	Yn brin	O bryd i'w gilydd	Yn aml	Yn gyson
Muriau neu fat geiriau	O	O	O	O	O
Gemau geirfa a diffiniad	O	O	O	O	O
Profion geirfa a diffiniad	O	O	O	O	O
Taflenni gwaith llythrennedd masnachol.	O	O	O	O	O
Darllen mewn pâr (darllen ar lafar)	O	O	O	O	O
Fframiau ysgrifennu	O	O	O	O	O
Gemau bwrdd gwyn rhyngweithiol yn benodol i lythrennedd	O	O	O	O	O
Tasgau ysgrifennu ymestynnol	O	O	O	O	O
Arall (nodwch isod)	O	O	O	O	O

Arall

16. Yn eich barn chi pa ddulliau ddylai gael eu defnyddio i asesu llythrennedd gwyddonol disgyblion yn yr ysgol?

	Byth	Yn brin	O bryd i'w gilydd	Yn aml	Yn gyson
Profion masnachol wedi eu safoni.	○	○	○	○	○
Profion a ddatblygwyd gan athro	○	○	○	○	○
Barn Athro	○	○	○	○	○
Taflenni gwaith llythrennedd ar gael yn fasnachol	○	○	○	○	○
Portffolios disgyblion	○	○	○	○	○
Arall (nodwch isod)	○	○	○	○	○

Arall:

17. Yn eich barn chi, pa ffactorau sy'n cefnogi datblygiad llythrennedd gwyddonol yng Nghymru?

18. Yn eich barn chi, pa ffactorau sy'n atal datblygiad llythrennedd gwyddonol yng Nghymru?

19. Nodwch unrhyw wybodaeth arall rydych yn teimlo gall fod yn berthnasol i'r astudiaeth hon:

Diwedd y holiadur.

Diolch am gwblhau'r holiadur. Rwy'n gwerthfawrogi eich cefnogaeth.

9.7 Semi-Structured Interview Questions

Introduction

I'm going to ask you a series of questions regarding scientific literacy in Wales. You do not have to take part or answer any questions you don't want to and there are no right or wrong answers; I am merely interested in your opinions. You can stop the interview process at any point you wish.

To ensure that I have an accurate record of our conversation, I'd like to record it. Do you give permission for this conversation to be recorded?

<table>
<tr><th>Main Questions</th><th>Additional Questions</th><th>Clarifying Questions</th></tr>
<tr><td>Introductions:
School/subject/job role, etc
General rapport building</td><td></td><td rowspan="6">Can you expand a little on this?</td></tr>
<tr><td>What do you think are the most important skills science develops in pupils?</td><td>What advantages does science offer to pupils?</td></tr>
<tr><td>How would you define scientific literacy?</td><td></td></tr>
<tr><td>Do you know about the National Literacy and Numeracy Framework?</td><td>In what ways do you think NLF will affect you and your pupils?</td></tr>
<tr><td>What do you know about PISA testing?</td><td></td></tr>
<tr><td>Wales came 30th (out of 68) in the 2009 PISA tests. This was much lower than the other UK countries. Why do you think this is?</td><td></td></tr>
</table>

What do you think about the following statement? “Every teacher is a teacher of literacy and has a responsibility in improving pupil literacy levels.”	Is there much cross-curricular support within your school?	Can you tell me anything else? Can you give me some examples?
Do your pupils encounter many problems while they are processing scientific texts?	How do you help students when they have difficulties when reading and understanding scientific texts? Do you feel that gender has an impact upon pupils’ ability?	
How much support has your exam board offered in terms of the new literacy focus? (extended answer questions)		
What strategies are used by you and your department to develop Scientific Literacy?		
How is scientific literacy measured in your school?		
What factors do you feel support the development of scientific literacy in Wales?		
What factors do you feel hinder the development of scientific literacy in Wales?		
What do you feel would improve the scientific literacy of pupils in your school?		

Do you have any other thoughts about the issues surrounding scientific literacy in Wales?		
Would you like to ask me anything in relation to the research I'm doing?		

Closing remarks, thanking them for their time, etc.

9.9 Case Study Information Sheet

Background to the study

For pupils to succeed within Science, they must become scientifically literate. However, this process is made increasingly difficult by the language specificity of Science itself. Becoming scientifically literate is a long and multi-faceted process that can be affected by many different factors but there is a lack of literature regarding successful literacy policies or practices within Science.

According to PISA, pupil performance in Science is lower in Wales than the rest of the U.K. The most recent PISA report, published in 2013, found that pupil performance in Science is not significantly different between England, Scotland and Northern Ireland, but is significantly lower in Wales. Wales was ranked at number 36 out of the 68 countries that participated in the testing. This performance was six places lower than the 2009 PISA results, and far lower than the other individual UK countries.

Purpose of the study

My study will consider the current perceptions and attitudes of teachers and other relevant education professionals towards scientific literacy. In addition, my study will gather evidence about the methods used to measure it and the factors that may potentially support or hinder the development of scientific literacy.

Role of the case study

I have already gathered information via questionnaires and interviews. However, triangulation is very important in any form of research. A case study will allow me to check and establish validity in my study by analysing my research question from multiple perspectives.

I would like to interview four staff members in the same school: a member of senior management involved in literacy, the Head of Science, a general Science teacher and a literacy coordinator (or equivalent role). This will allow me an insight into the different understandings, perceptions, attitudes and difficulties faced by staff in one school. The study is not intended to be negative, critical or derogatory in any way, just an alternative method of trying to answer my research question. I believe that this method will be particularly fascinating, considering how specific literacy roles are a relatively new initiative in many schools.

My choice of High School

It would be unethical for me to complete my research in my own school. I therefore needed a secondary school that was relatively nearby to my workplace. Your school has always been at the forefront of new initiatives, and I felt that the school could offer me the most in terms of how you're implementing the new National Literacy and Numeracy Framework.

What are the possible benefits of taking part?

You will be contributing to an important area of science education which may in turn inform Science teaching within your school, in addition to a wider improvement of Science education in Wales. This is especially important when considering the recent drive on improving standards. The school will be entitled to receive a short summary of the research project.

Will any information be kept confidential?

Yes. If the school agrees to participate, nobody will be informed and your participation is completely anonymous. Any transcriptions of the recording will have all names and identifying data removed by allocating the interviewees a numeric code. The data will be stored on Bangor University's encrypted computer system with password protected access. Any printed material will be stored in a locked cabinet. The data will be kept for a period of five years, after which it will be destroyed.

What will happen to the results of my research study?

The findings will form the basis of my research dissertation as part of my EdD (Doctorate in Education). Dependent upon the final findings, the study may be submitted to journals for publishing, in addition to being disseminated to relevant education bodies. All participants will be offered a one page summary of the key findings at the end of the study.

Who has reviewed the study?

The project has been reviewed by the College of Business, Law, Education and Social Sciences Research Ethics Committee, Bangor University.

Who is funding the study?

The study is being funded by me as part of my EdD. No external organisations are involved in the funding.

Contact for further information

If you have any questions, then do not hesitate to contact me at edpb51@bangor.ac.uk for further information about this study.

Alternatively, you may contact my study supervisors, Drs. John Lewis and Susan Jones, at john.lewis@bangor.ac.uk or s.w.jones@bangor.ac.uk or by post at: The School of Education, Bangor University, Normal Site, Bangor, Gwynedd, LL57 2PZ